Smart Stadium Tools

An explorative case study of the Johan Cruijff ArenA: identification and optimization of smart tools

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Integrating Smart Tools within Stadiums

An explorative case study of the Johan Cruijff ArenA: identification and optimization of smart tools

by
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Preface

In the context of my Master of Science in Management in the Built Environment (MBE) at the Faculty of Architecture and the Built Environment at the Delft University of Technology, I conducted this research as my final graduation project. The research focused on improving the integration of smart tools in stadiums, which fits in the department of real estate management. This research is the results of almost nine months of work. In September 2018 I started with the preparations of this research. This research project has enabled me to combine my interests in real estate management, stadiums, and technology. My personal interests in real estate management resulted from attending the course Real Estate Management from my master's program. At the same time, I was working as an assistant consultant. In that period, I received a proposal to write a real estate strategy for an agricultural company. I really liked this experience and I was triggered to learn more about this research field, especially in combination with new technologies and innovations. Besides this, I was always interested in large scale building projects, such as stadiums. A stadium is such a special kind of real estate, whereby it unites different classes of society and it let them experience a wide range of emotions during events.

Throughout the research process, I could rely on the help of my supervisors. I would like to take the opportunity to sincerely thank everybody that contributed to the process of writing this research. Firstly, I would like to thank Bart Valks. The whole idea for this research topic started in a conversation with Bart in September 2018. He was always available and gave me always clear and constructive feedback that helped me a lot. His expertise with researching smart tools was very valuable for me and clearly benefitting the quality of this research. Secondly, I would like to thank Alexandra den Heijer for their extensive knowledge of real estate management research and asking critical questions to keep me motivated to improve certain aspects. This input was very valuable to make my research more understandable and to get a better picture of the visitors' experience. This was very useful to understand what was needed to further improve to research, which kept me motivated.

Another person that I would like to thank is Phillip Koppels, who was my second mentor during the research process. Philip gave always a lot of advice and tips for improvements. This was especially very valuable for my literature study and setting up a proper research methodology. I experienced Philip as very helpful and reliable, thanks for the articles you have send and the time you took for the meetings.

Next to my graduation committee, I would like to express my gratitude to Wilco Leenslag, who was my company's supervisor at KPMG Innovation Advisory. I really appreciated your enthusiasm and expertise about this research topic which I have experienced during our supervision meetings and working sessions in the Johan Cruijff ArenA and in Amstelveen. Besides this, I have met a lot of interesting persons in the world of stadiums and innovation. I am Wilco very grateful for his mentorship and the opportunity to graduate at KPMG. Last but not least, I would like to thanks everyone who participated in my research. It was not possible to come to this report without them.

So, I look back on a period where a learned a lot about smart tools, stadiums, and real estate management, which has led to this report. This was not possible without the positive collaboration that I experienced with all my supervisors. It has led to the final product of my student career and we will see how the next chapter will look like!

Enjoy reading!

Simon van Heck
Rotterdam, June 2019

Abstract

Today's stadiums face increasing competition from home-viewing options, powered by better camera angles and multiplatform, multimedia experiences. Concurrent with these trends is the increase in computing power and near ubiquity of the smartphone. These technological developments create new opportunities to measure real-time space use. The service or product that can measure (real-time) space use is called a 'smart tool'. There are some studies about smart tools, but these are not focussing on the integration in stadiums. This resulted in the following research question that will be addressed in this research: *which smart tools can be identified in stadiums, and how can the use of these smart tools be optimized*? Due to this nascent character of the research topic qualitative research is conducted, whereby literature is reviewed in combination with an exploratory case study. The case that is studied is the Johan Cruijff Arena in Amsterdam, the stadium has the ambition to be the most innovative stadium by 2020. Based on the case study, nine different smart tools are identified, whereby the main goals of the tools are to reduce costs and to support user activities. Based on the outcomes of this research it can be concluded that the integration of smart tools in stadiums are in their 'infancy'. From these nine smart tool projects, only five were in use at the moment of the research, the other four were still under development. As a result, concrete numbers of the effects of integrating of smart tools are missing. However, the current experience of integrating smart tools in stadiums did generate some valuable insights on how the use of the tools can be optimized by linking the findings to innovations from practice. Recommendations are provided to guide stadium managers in the effective management of smart tools. Lastly, the research stresses out the importance of future research on this topic

Key words – Smart tools, Smart stadium, Innovation, Internet of things, Smart buildings, Real Estate Management

Executive Summary

Introduction

Today's stadiums face increasing competition from home-viewing options, powered by better camera angles and multiplatform, multimedia experiences (Giorgio, Deweese, Reichheld, & Ebb, 2018, p. 3). While at the same time, the monetary costs to operate and maintain a stadium are remaining the same. Concurrent with these trends is the increase in computing power and near ubiquity of the smartphone which gives even the most remote user access to the benefits of this technology. Today's smartphone owner carries a device with processing power that would have required a computer the size of a stadium fifty years ago (Campbell & Giorgio, 2018, p. 2). One of the benefits of this technology is that it has the potential to measure real-time the use of the stadium. This can be done by so-called smart tools, whereby this definition originally derived from campus research. A smart tool is a *"service or product which collects real-time information on space use to improve the space use on the current campus on the one hand, whilst supporting decision making on the future space use on the other hand"* (Valks, Arkesteijn, Den Heijer, 2018, p. 23). The implementation of smart tools in the built environment has the potential to align real estate portfolios more frequently in time and on a higher level of detail in space to the needs of their users, due to the provision of real-time information.

Problem Statement

Smart tools can have a lot of potential to solve issues which typically occur in stadiums: in a short period of time, a lot of people are gathered, which create challenges. Providing (real-time) information to the users of the stadium has the potentials to improve certain processes in stadiums, such as safety and security, the satisfaction and experience of the fan, sustainability, energy reduction, efficiency, and longevity (Buckman, Mayfield & Beck, 2014; D'Orazio and Guaragnella, 2014; Dong, 2015; Panchanathan et al., 2017; O'Brolcháin, Colle & Gordijn, 2018). In addition to this, the information required from the smart tools can be used for the long term, by using the information to develop long-term plans, real estate strategies, which can improve the decision-making processes of managers (Valks Arkesteijn, Den Heijer & VandePutte, 2016, p. 104). This information that is generated is affecting the decision-making of managing a stadium, thus the real estate management of a stadium. In real estate management, the focus is in general on the match between demand and supply with can result in a 'competitive advantage', which in the end can lead to different 'added values' for an organization (Den Heijer, 2011). This is also the case for stadiums, whereby the potential technology can affect the 'competitive advantage' of a stadium (Sartori & Nienhoff, 2013).

However, the integration of smart tools in stadiums is a new development which is in their first infancy. Not a lot is known about the effects of smart tools and the scientific body of knowledge of 'smart stadiums' is limited. Better understanding the effects and possibilities of smart tools in stadiums can contribute to a successful integration, whereby the benefits are optimized. Visiting a stadium is all about offering visitors the best experience (Campbell & Giorgio, 2016, p. 127). The physical environment of the stadium has a significant effect on the extent to which spectators will desire to stay and return to the stadium (Wakefield, Blodgett & Sloan, 1996, p. 15). Stadiums are an important part of our society; the first known stadium was built in the ancient Greeks in the 8th century BC. Besides the impact it has on the stadium and their environment, the use of a smart stadium as a living laboratory to more easily deploy and evaluate technologies within the smart city concept. Due to the size and heterogeneity of the stadium environment that is small enough to practically trial but large and complex enough to evaluate effectiveness and scalability (Panchanathan et al., 2017, p. 2). This can be seen as a strong justification in favour of the development of 'smart stadiums.

Research objectives and questions

Thus, based on the problem statement it can be said that there is a lack of knowledge in science and practice about: (1) which specific smart tools there can be integrated to solve challenges related to stadiums, and (2) what the effects are of integrating smart tools within stadiums.

Based on the research objectives, the following research question is addressed in this research:

"Which **smart tools** can be identified in **stadiums**, and how can the use of these smart tools be **optimized**?"

To provide an answer to the main question, it is divided into three different themes whereby the following sub-questions are formulated:

1. Smart tools

- What are smart tools?
- How is the integration of smart tools related to real estate management theories?
- What are the characteristics of smart stadiums?

2. Stadium

- What are the characteristics of a stadium and how is this related to the need for smart tools?
- What is a 'smart stadium'?
- Which smart tools are integrated within stadiums and what are the objectives for integrating them?

3. Optimization:

- What is the progress since the integration of the smart tools and how can this be improved?
- What interventions can be recommended to improve the use of smart tools?

Research methodology

Smart tools and the integration of them in stadiums are a recent development. It can be stated that the research subject is in a 'nascent phase'. A qualitative research method is more suitable for subjects that are more in a nascent phase (Edmondson & McManus, 2007). That is why a qualitative research method is conducted.

The research consisted of three different phases: (1) literature review (2) empirical research, and (3) the synthesis. The data collected in the literature study yielded standardised information about smart tools, the relation of smart tools to real estate management theories, and the specifications and characteristics of (smart) stadiums. To do this effectively, a narrative literature review was conducted.

In the empirical part, which is the second phase of the research, an exploratory case study is conducted. The case study is used to assess the different smart tools in the stadium and to identify the effect of the smart tools. The case that is studied, is the Johan Cruijff ArenA, which is a stadium located in Amsterdam. The goal of the stadium management is that by 2020 the Johan Cruijff ArenA must be the most innovative stadium in the world (Johan Cruijff ArenA, 2017) and by this create the first 'smart' stadium. The integration of smart tools and other innovations in the Johan Cruijff ArenA are among the precursors, which is the main selection argument for selecting this case. The used sources of evidence in the case study are: semi-structured interviews, participant observations and documentation review. The interview protocol to assess the smart tools is based on the research of Valks et al. (2018). The smart tools that are assessed in the case study are analysed based on the frameworks and perspectives derived from the literature review.

Based on the analysis of the smart tools, different findings were formulated how the use of smart tools could be optimized. To come to concrete possible interventions on how the use of smart tools can be optimized, another smart system, which is the 'smart' Edge Olympic office, is studied. In addition to this, smart solutions are explored based on an innovation challenge for stadiums. This is done in the last phase of this research, which is the synthesis.

Results from the Literature study

In the literature study, four different sub-questions are answered by reviewing literature. The results are summarized in this part:

What are smart tools?

A smart tool is part of the smart environment of real estate, whereby it provides the user with real-time information about space use in the real estate asset. There come to useful information about space use, different data sources can be used.

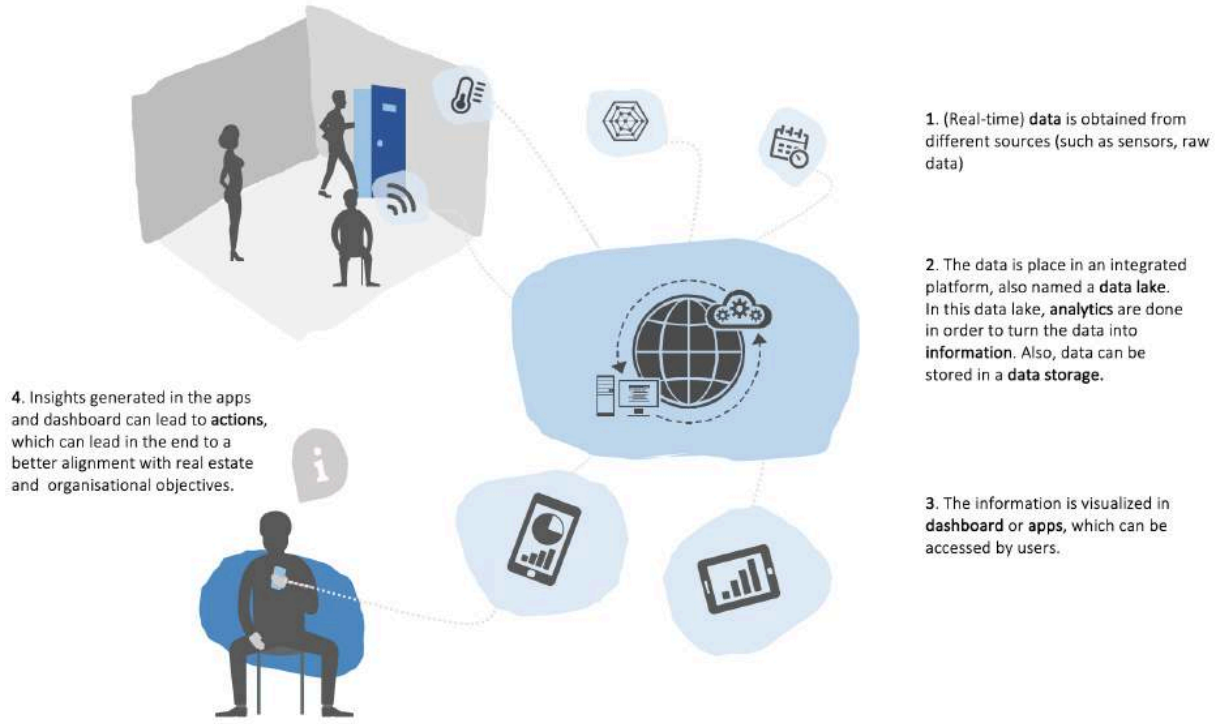

Figure a. Visualization of the smart tool principle (own illustration)

How is the integration of smart tools related to real estate management theories?

Smart tools have the potential to align real estate portfolios more frequently in time and on a higher level of detail in space to the needs of their users, due to the provision of real-time information. The integration of smart tools is related to real estate management theories, which can be divided into Corporate and Public Real Estate Management. For stadiums, which are more and more privately owned, theories on Corporate Real Estate Management (CREM) are applicable. CREM theories focus on attuning real estate to the organisational objectives. This can lead to thirteen added values for the organisation, and in the end a competitive advantage and cost reductions. So, Smart tools have the potential to contribute to the different added values, and thus the competitive advantage of a stadium.

What are the characteristics of a stadium and how is this related to the need for smart tools?

The stadium is studied based on five perspectives (economic, physical, strategic, functional, and financial). Mainly the need for smart tools in stadiums can be explained by the following findings derived from the literature study.

Table a: Characteristics of the stadium from five perspectives

Economic perspective	Stadium developments can have an economic impact on the (local) area, however, this is on a lower scale than policymakers often claim. It is used as justifications for investing with public money. Stadium development can be used as a driver for new area developments. The smart tool can contribute to improve the image of a stadium for policymakers and to utilize the potential for 'smart-city concepts'.
Physical perspective	Stadiums contain more and more different functions (office space, leisure), which can affect the type of tools needed. Stadiums are located in or around city centers, in urban areas, which means that events have a high impact on the infrastructural network and stakeholders. This can affect the need for smart tools: a lot of visitors and employees during a short period of time means an intense space use (both inside and outside the stadium).
Strategic perspective	Stadiums are typically a combination of a partnership with sports clubs, municipalities, and other investors. their interests are reflected in the stadium policy. Need for smart tools is strongly connected to the objectives of these 'partners. These have to be considered in smart tool investments and ambitions.
Functional perspective	The most important user is the spectator as a visitor: visiting a stadium is all about offering visitors the best experience that requires extensive preparations. The visitors' experience is made understandable by constructing a 'customer journey'. The customer journey reflects the different critical touch points of a visitor, that can be solved by integrating smart tools. For the critical touch points in the customer journey, smart tools could contribute to adding value to these situations. Examples are visualized in this research. Besides the visitor, smart tools can contribute to the activities of the stadium management. Which is mainly the operational part of the stadium.
Financial perspective	Integrating tools seem to affect the different income and expenditures of a stadium, which shows that it has the potential to optimize a stadiums' business case. The most important income for the stadium organization is hiring out the stadium for events. Integrating smart tools can lead to a reduction in costs or extra revenues, which can impact the financial situation of stadiums. Also, by creating extra value for the visitors by tools, it can lead to better competitive advantage to the stadiums.

What are the characteristics of 'smart stadiums'?

Smart is a trendy but vague definition. As seen from current scientific research it can be stated that integration of new technologies in stadiums have five potential to enhance entertainment, commercial opportunities and improved customer service, enhanced safety and security, sustainability, reduced environmental impacts and energy costs, and improved athletic performance.

Results from the Case Study

The objectives of the case study of the Johan Cruijff ArenA are to (1) assess the different smart tools that are integrated into a stadium (2) understand the objectives of integrating smart tools, and (3) to find out how the potential of smart tools can be optimized and improved. In the case study, two sub-research questions are answered.

Which smart tools are integrated into a stadium and what are the objectives for integrating them?

In total 9 smart tools are distinguished, which are in alphabetical order: cash registers, cleaning, crowd control, energy consumption and battery, mobility portal, smart turf monitoring system, staffing, technical maintenance, and ticketing check-in. Only five of these tools were operational at the time of the interviews, the other four were under still under development. These four are planned to become operational before January 2020. The tools clearly express two objectives that seem to be the most important: reducing costs and supporting user activities.

What is the progress since the integration of the smart tools and what can be improved?

It is hard to figure out the effects of integrating the smart tools within a stadium, due to the recent integration of the tools. There has been some progress for some of the tools that are integrated, however specific numbers of the progress since integrating the tools are not available. An important finding was the importance of a well-functioning technical layer is required for smart tools. In all the interviews the importance of the technical layer

was emphasized. This technical layer is still under development, but a lot of progress is already made. That is why a lot of tools are currently developed and integrated on the technical layer.

As seen from the different tools that were integrated, the following points were mentioned during the interview that needs improvement in order to make more progress: In order to improve the current use of smart tools the following points of improvements were identified:

1. Improve the use of historical data to predict different processes,
2. A better real-time response to the visitors based on the information from the smart tools
3. ambition to link the tools with other systems (or tools).

Points that require special attention are (1) privacy issues and threats of the smart tools, (2) the collaboration with partners and the (3) accuracy and reliability of the measurement methods, and the importance of (4) technological infrastructure.

Results from the Synthesis

In the previous chapter points of improvements were identified to optimize the use of smart tools. Based on the Edge Olympic and the 'Change the Game' Innovation Challenge, different interventions are recommended, which will contribute to the optimization of the smart tools and their objectives.

What interventions can be recommended to optimize the use of the tools?

As compared with the Edge Olympic, the following recommendations for possible interventions are:

1. The smart system is similar to the one of the Johan Cruijff ArenA. This means that it will be easy to link the different tools with each other.
2. In the Edge Olympic, the information obtained from the tools were compared to performance goals. This made it possible to automate different processes.
3. Preferences, as selected by the user through a mobile application, are used for input in the data lake.

Other future applications that can be used to improve the current benefits of the tools were discussed. These applications can be used to improve the current tools, measure space use, and/or control the visitor more.

1. Mobile ordering platform.
2. Pro-active and visual communication to steer visitors more on real-time information.
3. Guide users throughout a venue by using innovative features.
4. Smart map solutions.
5. Facial recognition technique for ticketing and staffing check-in.

Conclusions

The answers on the sub-questions lead to the answer on the main question; which smart tools can be identified in stadiums, and how can the use of these smart tools be optimized?

Based on an extensive analysis of the Johan Cruijff ArenA, nine different smart tools can be identified. These results demonstrate the potential of these technologies for smart stadium solutions and the usefulness of investigating technologies within stadiums. These nine different smart tools are analysed from different theories as found in the literature. It shows that the nine smart tools focus on different touch points: payments (cash registers), cleaning activities, crowd control, energy consumption, mobility, turf quality, staffing, maintenance, and ticketing. Input for the tools is based on different frameworks that are obtained in the literature study. The focus of the smart tools is mainly on reducing costs (financial) and supporting user activities and increase users' satisfaction (functional). However, not all nine smart tools are already integrated and part of daily operations. Four out of the

nine smart tools are still under development. It can be stated that the integration of smart tools implemented is stadiums are in their infancy.

The first advice how use of the smart tools can be optimized is to make a profile for different type of events, based on the historical data collected by the different smart tools. The second advice is that the advantages of smart tools can be used more when the stadiums' visitors are steered based on real-time information. There are various ways to do, such as pro-active and visual communication, guide visitors by innovative features, and smart map solutions. Moreover, technologies such as facial recognition and mobile ordering platforms can be used to improve the efficiency of the current tools. Lastly, the tools can be linked between each other or linked to performance goals, in order to create new valuable insights and to stimulate automation.

Discussion

Some limitations to the theory are observed due to the fact that the 'added value's' from theory did not match the objectives of 'safety' and 'increasing revenues', which were discussed several times. Usually, these added values are mainly linked to offices or other types of real estate, but not to the stadium. Next, the information from the smart tool can only be accessed and used by the stadium management, despite the mobility portal. As compared to the stakeholder groups as described in theory, the focus is of the tools is mainly of 'employees' and suppliers. Other implications are the limited available theoretical knowledge of 'smart stadiums', the lack of a well-known definition of 'smart tools', and the diachronic (temporal) elements of the case study.

Limitations

The main limitation of this research is that only one case is investigated. As such, this type of methodology can harm the external validity of this research. An important remark to this statement is that stadiums are a ubiquitous 'industry', which operates similarly worldwide, increasing the likelihood that this study will also be applicable in other cases. Operating stadiums is prevalent. Other limitations of the research are the timing of the research, the niche of the research, the heterogeneity of the data collection.

Recommendations for practice

Based on the findings in this research, the following recommendations are presented in this research:

1. State clear objectives and goals that have to be achieved by the smart tools: what adds value to the stadium
2. Assess clearly which data is needed to achieve the objectives and goals
3. Monitor the progress of the smart tools
4. Integrating smart tools require new capabilities: be aware of a partner ecosystem
5. Potential to connect to the smart city
6. Basic technology infrastructure takes a lot of time and effort to be implemented
7. Be aware of privacy and security risks
8. Visitors are focussing on a live experience; smart tools can disrupt this experience.

Recommendations for further research

New research into this research field can easily add value to the current scientific body of knowledge, whereby further research is recommended to focus on:

1. Conduct research with multiple case studies
2. Conduct the same research in a few years (when all the tools are integrated)
3. Conduct quantitative research to the effects of the smart tools
4. Research into the 'value' of smart tools in stadiums
5. Broaden the research scope of stadiums to other types of real estate (cross-case analysis)

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Readers' Guide

The first part of the report presents an introduction of the research topic and the concepts of the research which consists out of two chapters. In the first chapter the problem statement is described and explained. Thereafter, the different research questions are stated. In the next chapter, chapter 2, the methodology of the research is explained. The research methodology consists of the following four parts: the research strategy; the methods to be used; the type of data collection; and the data analysis. This chapter ends with the ethical considerations of the methodology.

In the second part of the research, the theoretical foundation of the research is described. This part contains of three different chapters, wherein the conducted literature study is explained. In chapter 3 the role of smart tools in relation to (corporate) real estate management theories is discussed. In chapter 4 the characteristics of a stadium are described based on four different perspectives. In the fifth chapter, the phenomenon of integrating smart tools within a stadium is discussed.

The findings from the literature study are served as the input for the next part, which are the practices. In the practices a case study of the Johan Cruijff ArenA is conducted. Different findings from the Johan Cruijff ArenA are discussed and confronted with the literature study.

In the fourth part, which contains the synthesis of the research, the findings from the case study are linked to possible solutions that are available in practice. This is done in chapter 7. In the next chapter 8, the main research question and the sub-questions are answered, which forms the conclusions of this research. These conclusions are discussed in the second part of chapter 8. Based on the conclusions, recommendations are given for practices and future research. The research ends with a reflection on the whole research process.

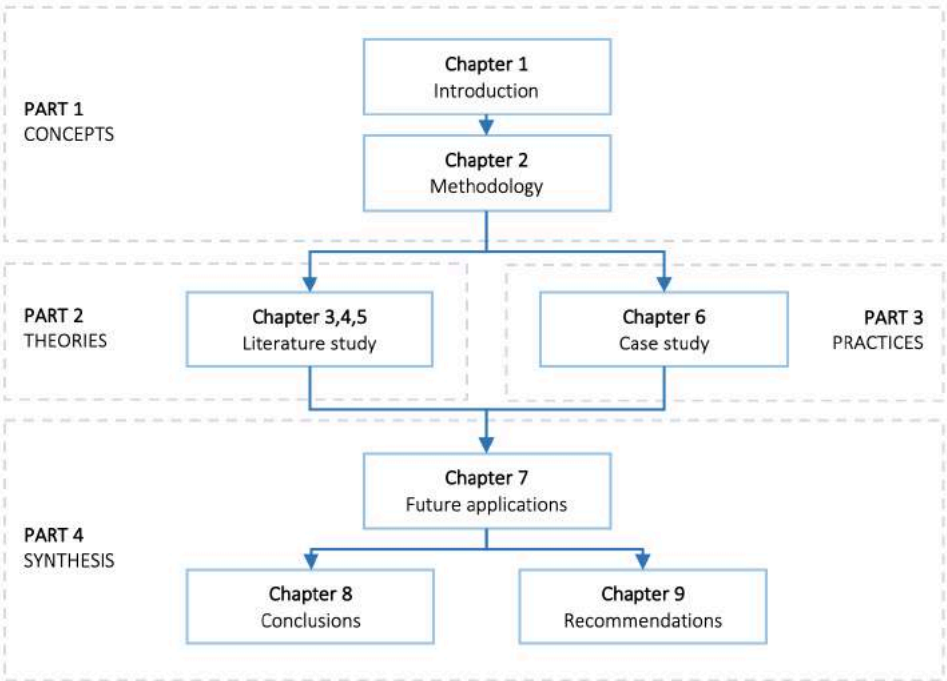

Figure 1: Overview of the report (own illustration)

PART 1

CONCEPTS

1. Introduction

1.1 Problem statement

Today's stadiums face increasing competition from home-viewing options, powered by better camera angles and multiplatform, multimedia experiences (Giorgio, Deweese, Reichheld, & Ebb, 2018, p. 3). While at the same time, the monetary costs to operate and maintain a stadium are remaining the same. Another development, according to Sartori and Nienhoff (2013) is the fact that in the current landscape of Europe and further afield, most of the stadiums were built more than 35 years ago. As a result of these outdated venues, the stadiums are unable to fulfil the expectations of today's fans (Sartori & Nienhoff, 2013, p. 3). These trends are harming the financial viability of the key stakeholders of the stadiums and it shows that many stadiums do not realise their business case opportunities.

Concurrent with these trends is the increase in computing power and the and near ubiquity of the smartphone which gives even the most remote user access to the benefits of this technology. Today's smartphone owner carries a device with processing power that would have required a computer the size of a stadium fifty years ago (Campbell & Giorgio, 2018, p. 2). These technological developments have the potential to measure real-time the use of the stadium. This information that is generated is affecting decision-making of managing a stadium, thus the real estate management of a stadium. In real estate management, the focus is in general on the match between demand and supply with can result in a 'competitive advantage', which in the end can lead to different 'added values' for an organization (Den Heijer, 2011). In order to keep attracting the fans to the stadium, it is important that the demand and supply are in line with each other. By measuring the real-time use of stadiums due to technological developments, it has the potential to match demand and supply more efficiently. This can be done by the so-called technology of 'smart tools', whereby this definition derived from campus research. A smart tools can be defined as: *"service or product which collects real-time information on space use to improve the space use on the current campus on the one hand, whilst supporting decision making on the future space use on the other hand"* (Valks, Arkesteijn & Den Heijer, 2018, p. 23). The implementation of smart tools in the built environment has the potential to align real estate portfolios more frequently in time and on a higher level of detail in space to the needs of their users, due to the provision of real time information. According to Buckman, Mayfield and Beck (2014) the reason for providing this information will lead to improving certain aspects, which can be grouped in the following categories: energy and efficiency, longevity, and comfort and satisfaction (Buckman, Mayfield & Beck, 2014, p. 104).

Within the context of stadiums, a lot of data can be made available due to the implementation of smart tools. Due to the fact that stadiums gather a lot of people for a specific, short period of time create challenges. As shown in different studies (D'Orazio and Guaragnella, 2014; Dong, 2015; of Panchanathan et al., 2017; O'Brolcháin, Colle & Gordijn, 2018), integrating smart tools can improve specific touch points of stadiums, such as safety, fan experience, sustainability, and energy reduction. These touch points are affecting the competitive advantage of a stadium (Sartori & Nienhoff, 2013). This means that the stadium can differentiate from other stadiums and reduce operational costs (Den Heijer, 2011).

However, the integration of smart tools in stadiums is a new development which is in their first infancy. Integrating smart tools in the built environment is difficult as shown in the research of Cisco (2017). The research shows that only 26% of the projects which involve smart tools are considered a success and 60% of these projects are not continued. To gain more knowledge in this field, it will help stadium stakeholders to make more informed decisions

and well-structured choices for integrating smart tools in stadiums successfully. This can result in a better alignment between the demands and needs of all stadium stakeholders in the short term.

In addition, information required from the smart tools can be used for the long term, by using the information to develop long-term plans, real estate strategies, and for the decision-making process of stadiums (Valks et al., 2018). In figure 2, the hypothesis of the effects of smart tools for both short term and long term are shown.

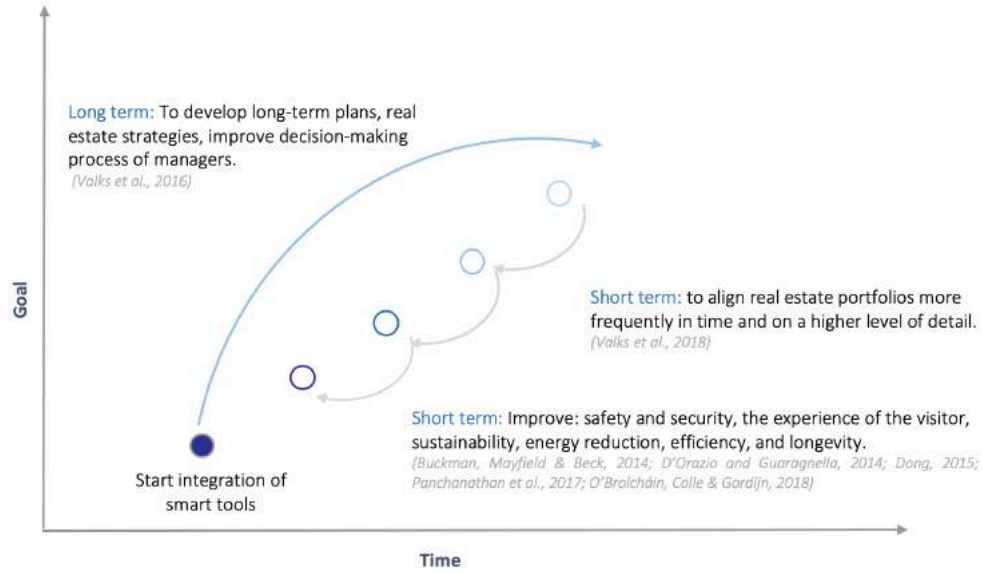

Figure 2: Hypothesis of integrating smart tools in real estate (own illustration)

Thus, based on the problem statement it can be said that there is a lack of knowledge in science and practice about:

- Which specific smart tools there can be integrated to solve challenges related to stadiums.
- What the effects are of integrating smart tools within stadiums.

1.2 Research Questions

Based on the problem statement it can be said that there is a lack of knowledge in science and practice regarding which smart tools there can be integrated in stadiums to solve challenges and what the effects are of integrating smart tools. In this research the following research question is addressed:

> Which smart tools can be identified in stadiums, and how can the use of these smart tools be optimized?

1.3.1 Sub questions

In answering the main research question different sub questions need to be answered. The main research question can be divided into different subjects, which are:

> Which smart tools (1) can be identified in stadiums (2), and how can the use of these smart tools be optimized (3)?

In order to answer the main research question, the research addresses the following sub questions:

To provide an answer to the main question, it is divided into three different themes whereby the following sub-questions are formulated:

4. Smart tools
- What are smart tools?
- How is the integration of smart tools related to real estate management theories?
- What are the characteristics of smart stadiums?

5. Stadium
- What are the characteristics of a stadium and how is this related to the need for smart tools?
- What is a 'smart stadium'?
- Which smart tools are integrated within stadiums and what are the objectives for integrating them?

6. Optimization:
- What is the progress since the integration of the smart tools and how can this be improved?
- What interventions can be recommended to improve the use of smart tools?

To give an answer to these different questions a suitable research method is selected. This selected research method is discussed in the next chapter.

2. Methodology

This paragraph describes the used research method in order to gather the data which is needed to provide an answer to the proposed research question. This paragraph consists of the following five parts: the research strategy; the methods to be used; the type of data collection; the data analysis, and the ethical considerations.

2.1 Research Strategy

The research focusses on a topic (the integration of smart tools in stadium) that is not yet fully researched. It can be stated that the study of smart tools, especially focussing on the integration in stadiums, is in a nascent phase. According to the methodological fit for management field research as introduced by Edmondson and McManus a qualitative research method is more suitable for subjects that are more in a nascent phase (Edmondson & McManus, 2007). The research focus is on a new phenomenon whereby there are not a lot of theories available yet. Quantitative research methods can be relevant for supporting qualitative theories that already exist, which is not the case for this topic. So, a qualitative research method is more suitable for answering the research question. The qualitative research is done by conducting literature reviews and empirical research, which are in the end combined in the synthesis.

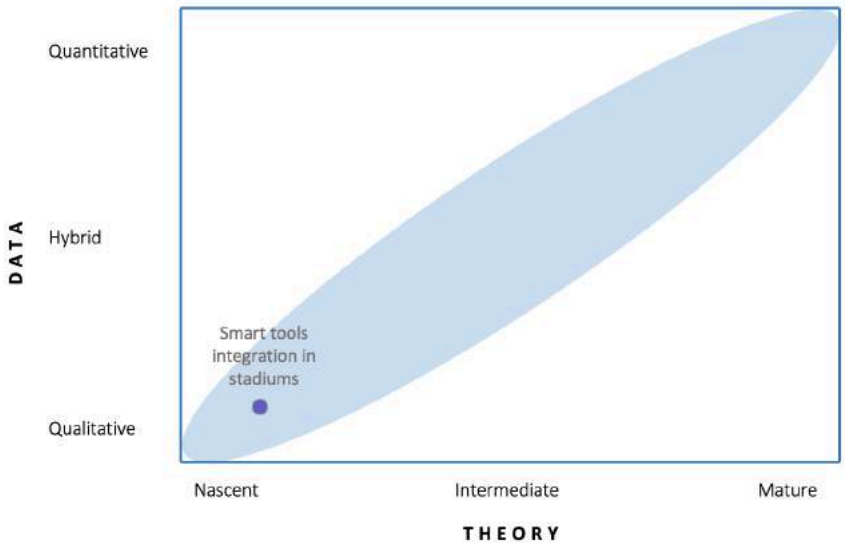

Figure 3: Methodological fit of this research (own illustration, based on Edmondson & McManus (2007))

The main objective of the literature review is to understand the phenomenon of stadiums, understand the different (smart) real estate management theories, and to find out which theories there are already available for the integration of smart tools in stadiums. The data is collected by reviewing (scientific) literature. The literature review will be explained more in-depth in the next sections.

The empirical research is used to provide information which smart tools there are integrated in a stadium and what the effects are since implementing the smart tools. To acquire this information, empirical research is suitable, due to the fact that empirical research focusses on observation of experiences. According to Bryman (2012, p. 23) the empirical principle focusses on gaining knowledge based on experience (Bryman, 2012, p. 23). Thus, empirical evidence is based on observations or experience and can be recognized due to the descriptive character. To analyse the observations, both qualitative methods can be used. According to Barendse, Binnekamp, De Graaf,

Van Gunsteren and Van Loon (2012) empirical research deals with knowledge-related problems and by this knowledge is produced and explanations are formulated based on practices. A suitable method is the use of case studies allowing the researcher to retain holistic characteristics of real-life event. Due to the innovative character of smart tools, which is a recent technological development, the case study is suitable to investigate this contemporary phenomenon more broadly. As mentioned by Yin, case studies are an empirical inquiry which 'investigates a contemporary phenomenon within its real-life context: when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used (Yin, 2014, p. 23).

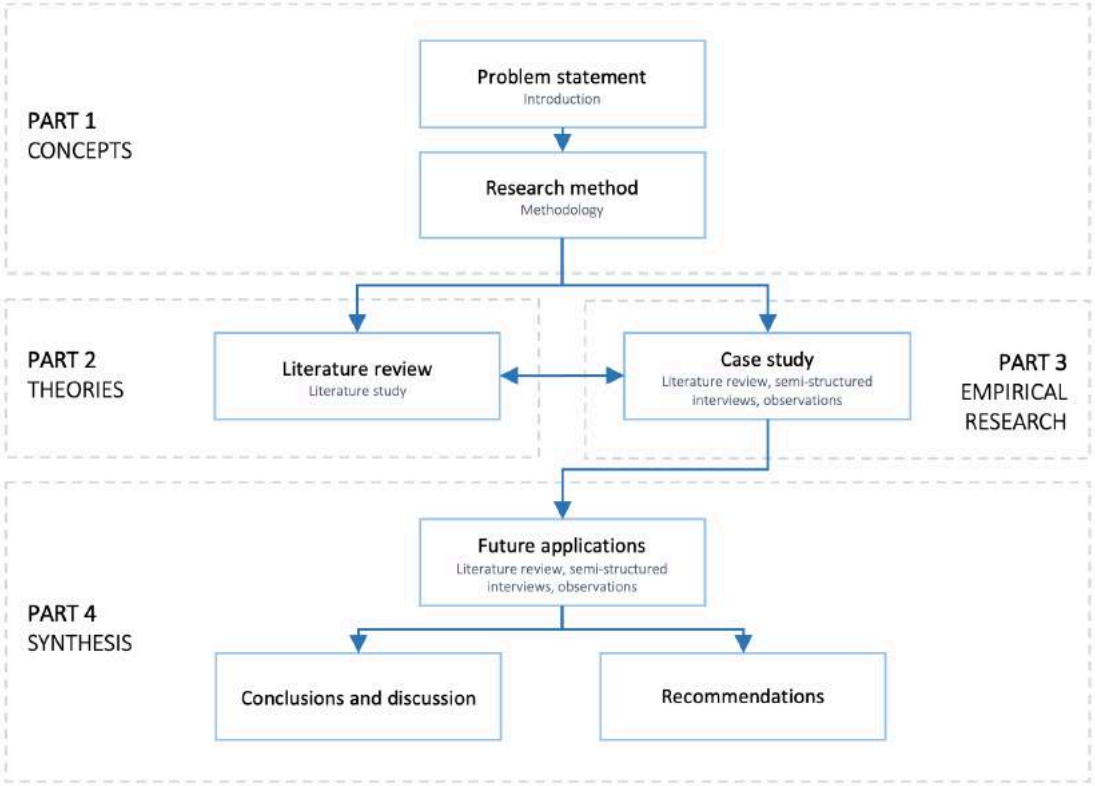

Figure 4: Research Framework (own illustration)

2.2 Research Phases: Methods and techniques to be used

In order to execute the research strategy, the research is set up into different research phases. The research consisted of three different phases: (1) literature review (2) empirical research, and (3) the synthesis.

2.2.1 Phase 1: Literature review

In the first phase a literature review is conducted. The data collected in the literature study yielded standardised information about smart tools, the relation of smart tools to real estate management theories, and the specifications and characteristics of (smart) stadiums. To do this effectively, a narrative literature review was conducted. This literature review is explained in the next section.

Literature study

The literature study will be done in order to gain in-depth knowledge about smart tools and their relation to real estate management theories. Secondly, the specifications of stadiums are researched. These topics are also linked to the different sub-research questions. The sequence of the literature study with the related research questions are:

1. Step 1: (Smart) real estate management
   What are smart tools?
   How is the integration of smart tools related to real estate management theories?

2. Step 2: Specifications of (smart) stadiums
   What are the characteristics of a stadium and how is this related to the need for smart tools?
   What are the characteristics of 'smart stadium'?

The data collection in the literature study yielding standardised information on smart tools and the relation to real estate management theories and specifications of stadiums. The literature review resulted in a better understanding of the different topics. As a result, a 'narrative review' of the literature is more suitable than a systematic review for this type of research (Bryman, 2016, p. 110). That is why a narrative literature review was conducted in this research. By this, a large amount of useful information is found in a short period of time. However, the main flaw of this research method is that narrative reviews tend to be less focused and more wide-ranging in scope than systematic reviews (Bryman, 2016, p. 110). The literature study will be conducted by using Google Scholar, Scopus, and various internet sources. The selection of the literature will be based on the quality of the source, the number of citations and the relevance of the research.

2.2.2 Phase 2: Empirical research

Phase 2 of the research is based on the input from the literature study. In the empirical research phase, a case study is conducted, whereby the data from the case study is used to assess the smart tools in practice and to identify how the use of the smart tools can be optimized.

Case Study: Johan Cruijff Arena

The case that is selected is the Johan Cruijff ArenA, which is a stadium located in Amsterdam. The goal of the stadium management is that by 2020 the Johan Cruijff ArenA must be the most innovative stadium in the world (Johan Cruijff ArenA, 2017) and by this create the first 'smart' stadium. The integration of smart tools and other innovations in the Johan Cruijff ArenA are among the precursors. The focus will be on the following 6 themes: the fan experience, customer journey, safety & security, sustainability & circular economy, facility management, and digital connectivity (Amsterdam Smart City, 2018). Due to the fact that the stadium management has the ambition to become the first 'smart' and 'innovative' stadium, the technologies and innovations that are integrated are among the frontrunners, which makes it interesting to research and likely to identify different smart tools.

The data extracted from the project are case specific and unique which can harm the external validity. However, findings can be used generally for other stadium projects. This issue is explained in more detail in the discussion of this research. According to Yin (2014) suitable sources of evidence for conducting case study research is the use of semi-structured interviews, participant observations and documentation review. These methods for data collection are also used, whereby the main data collection technique used is the semi-structured interviews.

Semi-structured Interviews

The reason to conduct these semi-structured interviews is to assess the different smart tools that are integrated into the Johan Cruijff ArenA. The advantage of choosing for semi-structured interviews is that as an interviewer there is more latitude to ask further questions in response to what is seen as significant replies (Bryman, 2012, p. 212). Also, the interviewer has a series of questions that are in general protocol but is able to vary the sequence of the questions.

The interviews are held with market specialists and stadium operators who are involved in the Johan Cruijff ArenA project. The interview protocol can be found in appendix A. The interview protocol is adapted from the interview

protocol as used in the 'smart campus tools' research of Valks et al. (2016). Only some small adaptations have been made. The interviews will be recorded, a transcript is made and analysed by the use of coding.

2.2.3 Phase 3: Synthesis

Based on the analysis of the smart tools, different findings were formulated how the use of smart tools could be optimized. To come to concrete possible interventions on how the use of smart tools can be optimized, another smart system, which is the 'smart' Edge Olympic office, is studied. In addition to this, smart solutions are explored based on an innovation challenge for stadiums. This is done in the last phase of this research, which is the synthesis. In the end, the conclusions, discussions and recommendations are presented based on the findings of the different research phases. The research closes off with a reflection on the research process and the research findings.

2.3 Data collection

The table below shows the way the data will be collected in relation to the research question and the different methods for collecting data.

Table 1: Research questions with methods and type of data collection

Phase	Type	Main and sub research questions	Research methods	Data collection
1	Literature study	What are smart tools? How is the integration of smart tools related to real estate management theories? What are the characteristics of a stadium and how is this related to the need for smart tools? What is a 'smart stadium'?	Narrative literature review	Scopus, Google Scholar, Library, Internet
2	Empirical	Which smart tools are integrated within stadiums and what are the objectives for integrating them?	Case-study: Johan Cruijff Arena.	Semi-structured interviews, participant observations and documentation review
3	Synthesis	What is the progress since the integration of the smart tools and how can this be improved? What interventions can be recommended to improve the use of smart tools?	Market analysis smart system and innovation challenge	Input phase 1 and 2 Semi-structured interviews, participant observations and documentation review

2.4 Data analysis & plan

A data plan describes how raw and processed data are collected and used in this research project, how it is stored and who is responsible for the data. The literature is mainly collected from the internet, while the interviews ware recorded and transcribed. All the data is stored on the authors' laptop, which is secured. For the data collection the FAIR guiding principles are respected in order to enhance the reusability of data holdings (Wilkinson et al., 2016). According to these principles, data have to be: (1) findable, (2) accessible, (3) interoperable, and (4) reusable. To meet these principles in general, the research will be published on a free access website (repository TU Delft), written in English, and according to the APA 2012 guidelines.

2.5 Ethical considerations

Innovations may be designed with good intentions but can have unintended negative consequences on people involved. In this paragraph, the ethical considerations of this research proposal will be discussed. The ethical considerations will focus on two dimensions of the research. The first dimension is the research method will be ethically considered. Secondly, the research subject is discussed from an ethical perspective.

2.5.1 Research Method

Discussions about ethical principles in research have been usefully broken down by the researchers Diener and Crandall (1978) into four different areas. These four areas will function as guide in this paragraph for explaining the ethical considerations of the research method. The areas as described by Diener and Crandall (1978) are:

1. whether there is harm to participants;
2. whether there is a lack of informed consents;
3. whether there is an invasion of privacy;
4. whether deception is involved.

Harm to participants

In the research semi-structured interviews are conducted. In order to protect participants, their identities and recordings are maintained as confidential. This also means that if the research is published, care needs to be taken. This is done by asking for permission to publish their names and interviews. The interview protocol can be found in the Appendix.

Lack of informed consents

To minimize the risk of a lack of informed consents for the participants of the research, all the interviews started with an information sheet, which explains the research goal, how the data will be processed and contact details. In addition, a consent form is added, which can be signed by the participant. As stated in the book of Bryman (2016), the advantage of such information sheets and consent form is that it gives the participants the opportunity to be totally informed of the nature of the research and the implications of their participation (Bryman, 2016, p. 140).

Invasion of privacy

There is some overlap with the first area, but in order to make sure that the privacy of participants is not harmed, their privacy and anonymity are respected by keeping the personal information of the participants protected. The protection of data will be done according to the Data Protection Act 2018, information must be used (1) fairly, lawfully, and transparency, (2) used for explicit, specified purposes, (3) used in a way that is adequate, relevant and limited to only what is necessary, (4) accurate and, where necessary, kept up to date, (5) kept for no longer than is necessary, (6) handled in a way that ensures appropriate security, and (7) including protection against unlawful or unauthorised processing, access, loss, destruction or damage (Government Digital Service, 2018).

Deception is involved

Deception is caused when researchers represent their work as something other than what it is (Bryman, 2012, p. 143). To prevent this, it is important that interviews need to be recorded. For the literature study, it is important that assumptions made are critically reflected and underpinned by reliable sources. This was taken into account during the execution of this research.

2.5.2 Ethics of a smart stadium

The integration of smart tools and the emerging of Internet of Things (IoT) technologies do affect the visitors to the stadium. In the research of O'Brolcháin et al. (2018), a case study is conducted for examining the ethics of a smart stadium, which is in their case Dublin's Croke Park stadium. Based on this case, different ethical challenges were encountered and distinguished as critical. The following ethical challenges are described as critical:

1. Risk of violation of privacy: The challenge is that fans want to attend an event at a stadium, but may not wish to consent to have information gathered about them. Yet, in a smart stadium scenario, information will be gathered for sure.
2. Risk of infringement of autonomy: This refers to the ability of people to make up their own minds regarding how they act. The IoT will influence people in the smart stadium for two reasons. First, it will be pervasive because it is constant in people's lives. Secondly, based on the gathered data, messages can be nudged, which affect the autonomy of people. IoT as surveillance technology can be "detrimental to the social, cultural, and civic importance of these places" (Patton, 2000).
3. Gathering information without informed consent: in smart stadiums where many people are unaware that they are producing data. There is a lot of unclarity whether they will have given their consent to provide their data to others.
4. Risk of violation of data ownership rights: after the massive amounts of data is collected, the data can be very useful to whoever can access it or control it. As stated in the report of Deloitte (2018) data is the new gold. The data, when spread, can be very revealing about individuals or groups (O'Brolcháin et al., 2018, p. 23).

These four challenges can lead to the following negative consequences as stated in the research: (1) misuse sensitive data, (2) complex responsibility allocation, (3) potential surveillance and safety issues (O'Brolcháin et al., 2018).

To conclude, the integration of innovations in stadiums raises some ethical questions. During the research, these ethical considerations are incorporated into the development of the research. These ethical considerations should also be considered in further research.

PART 2

THEORIES


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3. Real estate management theories

In this chapter, the different real estate management theories introduced. After this, the relation to the potential of smart tools is explained. The focus of the chapter is to provide an answer to the sub-question how the implementation of smart tools is related to the field of real estate management theories and what exactly a smart tool is. To answer this question, a literature review is conducted.

3.1 Real Estate Management theory

Organisations and their people need real estate to conduct and execute their activities in a pleasurable environment. It can be stated that from a particular point of view, real estate and developing real estate is not an objective, but a mean to perform better. Broadly speaking, this is the principle of Real Estate Management (REM) (De Jonge, Arkesteijn, Den Heijer, Vande Putte, De Vries, & Van der Zwart, 2009, p. 3). In general, Den Heijer (2011) stated that theories on REM have the focus on the match on hand the demand of space, and on the other hand the supply of space (Den Heijer, 2011). However, REM according to De Jonge (1994) has the objective to achieve a return on investment in real estate (De Jonge, 1994, p. 15). REM is seen as a financial instrument with the objective to achieve a return on investment in real estate instead of a factor of production. Often, practitioners use the definition of commercial real estate: in commercial real estate, the business is the real estate. In corporate real estate, the real estate supports the (business) organizational function (CoreNet Global, 2015, p. 11).

3.1.1 Corporate Real Estate Management (CREM) – Public Real Estate Management (PREM)

Corporate Real Estate (CRE) refers to the real estate properties that house the business activities of an organization that owns or leases and, consequently, manages real estate incidental to its primary business objectives, which are not real estate. De Jonge et al (2009) stated that Corporate Real Estate Management (CREM) is a form of real estate management that is steered by private organisations or businesses (De Jonge et al., 2009). This makes it very easy to distinguish the type of real estate management because it is directly linked to the type of the involved organisation. But what if the organisation has both private and public interests? In the case of stadiums, most of the stadiums in Europe are owned publicly, however in the recent years more and more clubs are shifting towards more a private ownership (Sartori & Nienhoff, 2013, p. 7). Moreover, there are also stadiums owned with a consortium, whereby both public and private organizations are involved. So, based on the definition as stated in De Jonge et al (2009), the business owned stadiums would be in line with CREM practices, while public owned stadiums not. This issue is exactly why this assumption causes some critic amongst scholars, which is discussed in the book of Heywood (2018). According to Heywood it is difficult to make a distinction between 'corporate' and 'public' real estate, because that would suggest different management imperatives which is difficult to do.

As seen in commonly used definition for describing CREM, which is *"the management of a corporation's real estate portfolio by aligning the portfolio and services to the needs of the core business, in order to maximize the added value for the business and to optimally contribute to the overall performance of the corporation"* (Dewulf, Krumm & De Jonge, 2000). In this definition, the focus is on creating added value for the business itself based on the organizational objectives, also referred to as the needs of the core business. In other words, it can be said that the main objective of corporate real estate management is to optimally attune corporate accommodation to organisational performance (Valks et al., 2018).

This is also in line with the findings of Heywood (2018), which stated that CRE has to be managed to meet the strategic objectives of the occupier. Whereby it does not matter if the organization is public or private. Also, CREM

is linked to organisation where real estate is incidental and not the core business of the organisation. Moreover, this means that objectives do not only contain information on the goals of the organizations, as the organizations strategy also can be seen as part of their identity. In 1993, this issue was already noticed by Nourse and Roulac, who stated that real estate decisions are effective if such decisions support the organisations overall business objectives. This result can be achieved only by the explicit consideration of how real estate strategy supports the business strategy and the sub-strategies (Nourse & Roulac, 1993).

To summarize, CREM focusses on aligning the real estate to the needs of the organization in order to create and maximize the added value for the organization and by this improve the performance. These theories are based on privately-owned organisations (corporations), but how does this differ for public organisations?

If real estate is managed by a public organization, we speak about Public Real Estate Management (PREM). The objective of PREM is in general the same as for CREM, namely: to optimally align real estate with the organizational objectives in order to add value and increase performance. The main difference is the kind of objectives and concerns of public organizations in comparison with privately-owned organisations. At large, objectives of public organizations are not financial. As stated in the article of Simons (1993) the most important driver for public real estate activity has been to stimulate economic development in the community. An important justification for the involvement of the government is the public capital hypothesis, where investment in public lands and infrastructure is believed to be linked with the job and income growth in the private sector (Simons, 1993, p. 639). In the definition of PREM as described in the assentation of Van der Schaaf (2002) two important characteristics are added, which is the role of the financial policy set by the Treasury and the political goals that the government wants to achieve. An often-seen political value is the equal treatment of citizens (Van der Schaaf, 2002, p. 6). So, the main difference is that organizational goals of PREM are not mainly financial as compared to CREM, but rather economical, societal and/or political.

Stadium management objectives

Based on the findings in the previous paragraph, it can be stated that the management of stadiums is connected with the organisational objectives of the stadium management. It depends on the case; the stadium organization can be more public or more corporate. This is because of the goal of CREM that to attune accommodation to the organizational objectives and thus the performance.

The specific objectives related to the owner of a stadium will be discussed later in the research. However, what is seen from previous researches is that it is important that every organisation focuses on the incorporation of appreciating the role of real estate. Weatherhead (1997) researched the company IBM UK Ltd, who made significant real estate savings which were the result of their more intense real estate management approach. Besides the conclusions that the real estate provision should meet the business needs, other transferable, important lessons learned from the IBM UK case are: the importance of senior management appreciating the role of real estate, and the incorporation of real estate into the main business strategy (Weatherhead, 1997, p. 203). In more recent studies, the role of incorporating and appreciating the role of real estate management in the organization strategy is mentioned. As concluded by Haynes, Nunnington & Eccles (2017), the perception of real estate has moved unequivocally from being merely an operating necessity to a strategic resource integral to business strategy and board-level decision making. In other words, organizations have to prioritize their CRE department in order to optimally attune the real estate with the objectives. This development is recognized more frequently by both practitioners and scholars, because organizations see more and more that real estate management theories influence the performance of the organisation. In literature, this is indicated as creating ‘added values’ for the organisation. The different added values as found in literature, are manifested in the consecutive paragraph.

3.1.2 Added values of real estate

Around 30 years ago, the image of CREM was considered as an item of expense for the organizations, which had to be minimised as much as possible (Krumm, 1999, p. 4). However, this image shifted the last couple of years: CREM is not only a method to reduce costs but also a way to add value to an organization. As stated by Den Heijer, the basis of managing real estate is the presumed added value of the real estate on performance, either negatively or positively. If the real estate had no impact on performance, no one would spend resources on it (Den Heijer, 2011, p. 91). Moreover, real estate is one of the resources that organisations can use to attain organisational goals and by this way add value to the organisation (Van der Zwart, 2011). Nowadays, the importance of corporate real estate management and the purpose of creating advantage and added value for organizations is widely recognized among scientist. They acknowledge that real estate can contribute to the organisational performance, which is the concept of 'adding value by real estate'. The principle of adding value by real estate is visualized in figure 5, based on the article of Lindholm and Leväinen (2011). The concept is based on the hypotheses that a better alignment of demand and supply can lead to added values. But what exactly are these 'added values' for organizations?

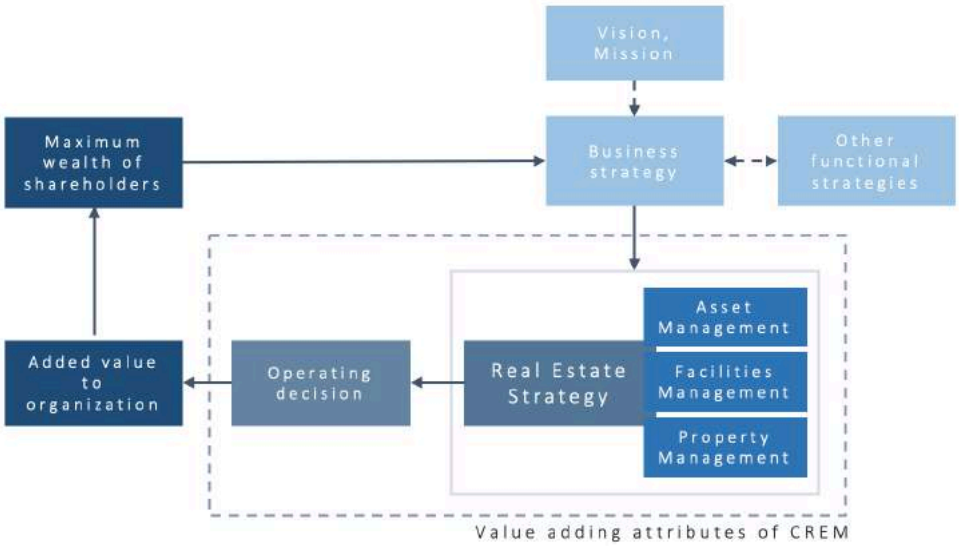


Figure 5: Principle of 'adding value by real estate': deciding on real estate in order to create a positive added value to performance (Adapted from Lindholm and Leväinen, 2006).

According to Van der Zwart (2011), the added value principle of real estate is a multi-dimensional concept with multiple stakeholders involved. This shows that the added value is really dependent on the perspective a stakeholder involved in the process.

The first research that really focused on the added value principle of real estate in relation to the performance of an organisation can be found in 1993 by Nourse and Roulac. In their research, titled as *"Linking real estate decisions to corporate strategy",* they discovered seven different added values of real estate, which are: (1) minimize costs; (2) facilitate and control of production, operations and service delivery; (3) promote human resource objectives; (4) facilitate of managerial process and knowledge work; (5) promote marketing message; (6) improve flexibility; (7) capture real estate value creation (Nourse & Roulac, 1993).

These seven added values functioned as a starting point for a stream of scientific research, a lot of additions were made to this list of added values. Firstly, De Jonge (1996) added marketing, whereby real estate can be used to improve the branding of your organization. In addition, the added value of risk management was added. Ten years later, Lindholm and Leväinen (2006) distinguished another added value: innovation. Whereby real estate can be designed in such a way that it allows innovative processes. Subsequent reports of Scheffer (2006) and De Vries (2008) mainly supported these added values, only some small differences can be found in the chosen definitions.

Which were, according to Van der Zwart the following nine categories of added values: (1) reducing costs; (2) improving productivity; (3) increasing user satisfaction; (4) improving flexibility; (5) supporting image; (6) increasing innovation; (7) improving culture; (8) controlling risks and (9) improving the financial position (Van der Zwart, 2011, p. 53). Den Heijer (2011) discovered a new added value: reducing the ecological footprint. At that time, sustainability became more and more important within society.

In the most recent publication of Valks, Arkesteijn, and Den Heijer (2018), thirteen added values were listed based on the previous research of Den Heijer. The added value of "reducing ecological footprint" was divided into ecological footprint per square meter and ecological footprint as CO2 emissions. This list of added values contains all the different added values as proved from the previous scientific research. In addition, it is the most complete list. That is why in this research these added values will be used. The different added values as found in the scientific literature can be found in table 2. Interesting from these different studies is the development over time. Due to the fact that the studies are done over a period of almost 17 years, some developments are reflected. The role of innovation has grown and the growing awareness of sustainability is also reflected in this list. As mentioned by Braun from the Oxford University, the baseline standard to deliver an asset now includes a commitment to sustainability (Baum, 2017, p. 32). Lastly, different definitions are used over time for marketing and public relations (PR).

Table 2: Added value of real estate based on different literature (adapted from Van der Zwart (2011), based on (De Jonge, 1996; de Vries et al., 2008; Den Heijer, 2011; Lindholm & Leväinen, 2006; Nourse & Roulac, 1993; Scheffer et al., 2006))

Nourse & Roulac	De Jonge	Lindholm & Leväinen	Scheffer et al.	De Vries	Den Heijer	Van der Zwart	Valks, Den Heijer, Arkesteijn
1993	1996	2006	2006	2008	2011	2011	2018
Occupancy cost minimalization	Reduce costs	Reduce costs	Cost reduction	Reducing costs	Decreasing costs	Reducing costs	Decreasing costs
Facilitate and control production, operations and service delivery	Improve productivity	Increase productivity	Increasing productivity	Increase productivity	Support user activities	Improving productivity	Support user activities
Promote human resource objectives	Improve culture	Increase employee satisfaction	Changing the culture	Increasing satisfaction	Increasing (user) satisfaction	Increasing user satisfaction	Increasing (user) satisfaction
					Improving quality of place		Improving quality of place
Facilitate managerial process and knowledge work	Marketing	Promote marketing and sale	PR and marketing	Supporting image	Supporting culture	Supporting image	Supporting culture
					Stimulating collaboration		Stimulating collaboration
Promote marketing message		Increase Innovation		Stimulating innovation	Stimulating innovation	Increasing innovation	Stimulating innovation
Flexibility	Increase flexibility	Increase flexibility	Increase of flexibility	Enhancing flexibility	Increase flexibility	Improving flexibility	Increase flexibility
Capture real estate value creation	Improve availability of finance (increase of value)	Increase value of assets	Increase of value	Expanding funding possibilities	Increase real estate value	Improving the financial position	Increase real estate value
	Risk management		Risk control	Controlling risks	Controlling risk	Controlling risks	Controlling risk
				Improving culture	Supporting image	Improving culture	Supporting image
					Reducing ecological footprint		Reducing footprint (m2)
							Reducing footprint (CO2)

The thirteen added values as derived from the research of Vaks, Arkesteijn and Den Heijer (2018) and Den Heijer (2011, p. 97 - 98) are explained shortly:

1. Decreasing costs – Not just the real estate costs, but all the cost for an organization. Different real estate concepts can lead to higher production or decrease of absence. The most well-known strategy is reducing floor space.
2. Support user activities – The former definition of this added value is 'increasing production' in the research of De Vries (2008). Real estate interventions can lead to an increase of production of an organisation, but it can also be used to satisfy users and make the more dedicated for an organisation. In stadiums, the visitors are one of the most important users in stadiums.
3. Increasing (user) satisfaction – This type of interventions has the goal to increase the satisfaction of the user. This can be done by quicker response to changing demand or the right location decision making. Also for this added value, the visitor is an important user that need to be satisfied.
4. Improving quality of place – The kind of interventions that will lead to a higher quality level of space. This will lead to an extension of the guaranteed lifespan of a real estate asset.
5. Supporting culture – Internal interaction within the real estate asset. The building community and the values for interaction between different user groups.
6. Stimulating collaboration – The real estate interventions that stimulates encounters between different type of users and organizations that are involved in a real estate asset.
7. Stimulating innovation – Innovation can be achieved by stimulating the culture and collaboration. By this the culture of an organization can emphasize the importance of integrating and stimulating innovative ideas.
8. Increase flexibility – This concerns the flexible use of facilities and thus financial flexibility. This can be done by real estate interventions that implement more standardized space more multi-user concepts without exclusive use.
9. Increase real estate value – The real estate interventions that will lead to a higher market value of land and buildings.
10. Controlling risk – Consists of financial, technical and functional risks. Controlling financial risks can be done by being able to easily adjust real estate portfolio. Controlling technical and functional risks can be done by monitoring the condition of the real estate to make sure that primary processes are not hindered.
11. Supporting image – The way that real estate contributes to the image of the organization. The image can support the organizational goals and is seen by current users or external parties. Interventions are usually linked to the terms of "practice what you preach" from an organisational point of view (Den Heijer, 2011, p. 97).
12. Reducing footprint (m2) – The way that real estate interventions lead to a reduction of m2 or optimal use of m2.
13. Reducing footprint (CO2) – Sustainable interventions in real estate in order to reduce CO2 emissions. More and more important for organisations, due to the Climate Agreement of Paris.

The thirteen different added values in relation to the organisational performance can be divided into four different CREM variables; physical, strategic, financial, and functional. If the input in the CREM is in line with the organizational objectives it can lead to productivity, sustainable development, and that can lead ultimately to the output of a competitive advantage and higher profitability. With competitive advantage is meant that an organization can due to its real estate assets outperform their competitors. It is often a challenge for organisations to build and maintain such competitive advantage (O'mara, 1999, p. 3). The principle of the relation between the added value and organisational performance can be found in figure 6, which is based on the scheme as represented in the dissemination of Den Heijer (2011).

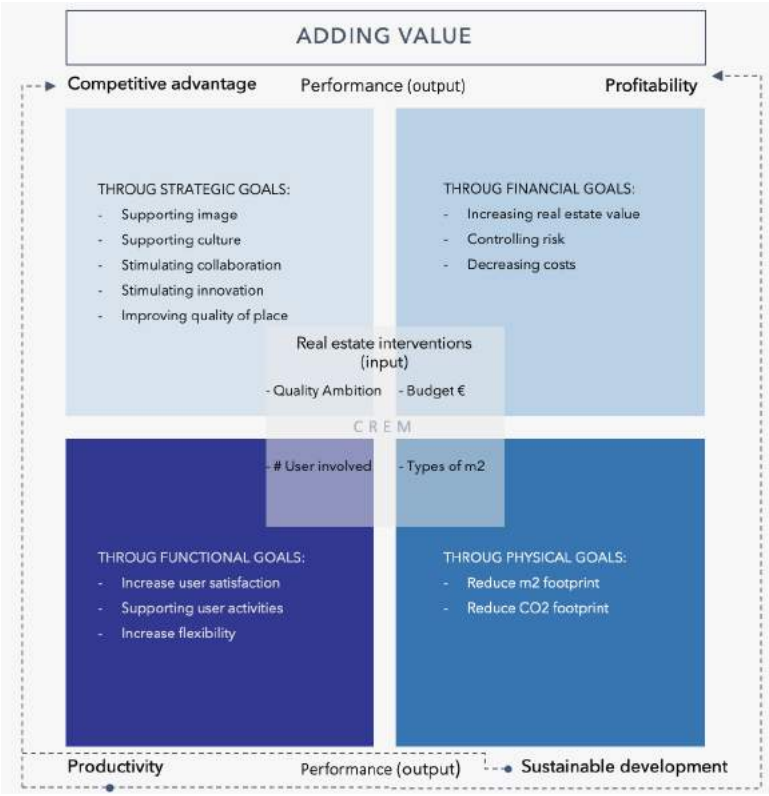


Figure 6: Relation between added value and organisational performance (adapted from Den Heijer, (2011))

In recent years, developments such as Internet of Things (IoT) and big data are playing a more prominent role into real estate. The expectation is that these technological developments will have a 'positive' impact on the real estate sector, and thus also on CREM practices. The next paragraph will explain this digital shift and the potential impact it has on CREM and the different added values.

3.2 Digital change

As mentioned in the previous paragraph, a lot of technological developments around our daily lives are implemented and changing the way we live, and also the way we will use real estate. This digital change is also described as the Fourth Industrial Revolution, or Industry 4.0. Which can be seen as a new step based on the past three industrial revolutions from the last two decades.

3.2.1 The Fourth Industrial Revolution

Organizations must decide how and where to invest in these new technologies and identify which ones would meet their objectives the best. Without a full understanding of the changes and opportunities Industry 4.0 brings, companies risk losing ground (Cotteleer & Sniderman, 2017). The Industry 4.0 terminology comes from the field of manufacturing industries. But it goes far away from that, it also impacts other types of industries. The principle of the Industry 4.0 is the closer integration of both digital and physical worlds, as visualized in figure 7. This integration can lead to different advantages such as smarter decisions, better-designed products, service and systems, potentially more efficient use of resources, and a greater ability to predict future needs (Cotteleer & Sniderman, 2017). In addition to this, it can lead to cost reduction, improvement in performance and also offering improved products and services, considering the preferences and behavior of consumers time (Ślusarczyk, 2018, p. 233).

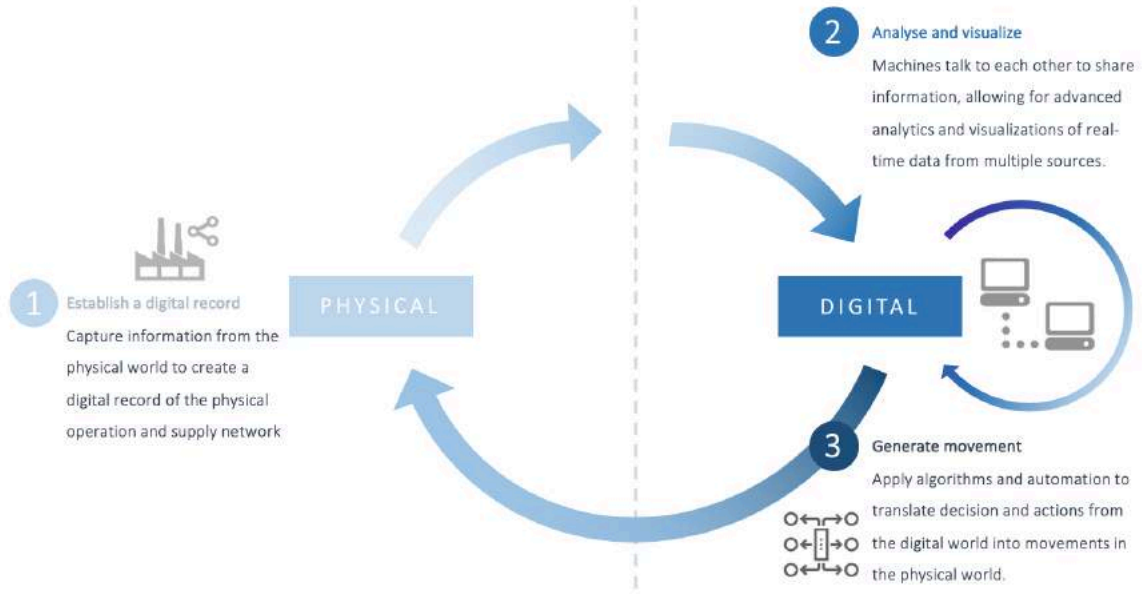


Figure 7: The physical-to-digital-to-physical loop (own illustration: based on (Cotteleer & Sniderman, 2017))

3.2.2 Internet of Things

The concept of the Industry 4.0 is based on the use and exchange of data in real time (Ślusarczyk, 2018, p. 233). The role of the development of big data and Internet of Things (IoT) are related this. IoT is a novel paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. As discussed in the research of Trappey, Trappey, Govindarajan, Chuang and Sun (2017), one of the key enablers for the formation of Industry 4.0, is the rise of IoT. IoT can be described at the fundamental level as a means of connecting physical objects to cloud services as a ubiquitous network that enables objects to collect and exchange information (Trappey et al., 2017, p. 208).

The basic idea of the IoT concept is the pervasive presence around us of a variety of things or objects, such as Radio – Frequency IDentification (RFID) tags, sensors, actuators, mobile phones, and so on. Due to unique addressing schemes, they are able to interact with each other and cooperate with their "neighbors" to reach common goals (Atzori, Iera & Morabito, 2010). This is the case for various components of our environment. In the research of Porter and Heppelman (2014) this is called the connectivity components of a smart, connected product. Despite the connectivity components, smart, connected products have two other core elements: physical components and "smart" components. Physical components comprise the mechanical components while the "smart components" comprise for example sensors (Porter & Heppelman, 2014, p. 67).

Porter and Heppelman (2014) distinguish four different areas of functions and capabilities of smart connected products, which are: monitoring, control, optimization, and autonomy. As stated in the research a smart product can potentially incorporate all four. Each capability is valuable in its own right and also sets the stage for the next level (Porter & Heppelman, 2014, p. 69).

So the first area is monitoring. IoT devices have the capability to monitor their condition, operation, usage, and the external environment. By monitoring data, the management can adapt their decision making. Based on monitoring the data, intelligent devices have the ability to control themselves, which is the second stage. This is mostly done by algorithms built into the device. The advantage is that the device can automatically respond to changes in the environment. The third stage is optimization of the operation and by this optimize performance and predict services and repair. Lastly, by combining the first three stages, devices can coordinate themselves autonomous with other systems without any human interventions (Bäumer, Von Oelffen & Keil, 2017). These four

stages are visualized in figure 8, as based on the figure of Porter and Heppelmann (2014). The four stages can be used to express the maturity of a 'smart' or 'connected' products

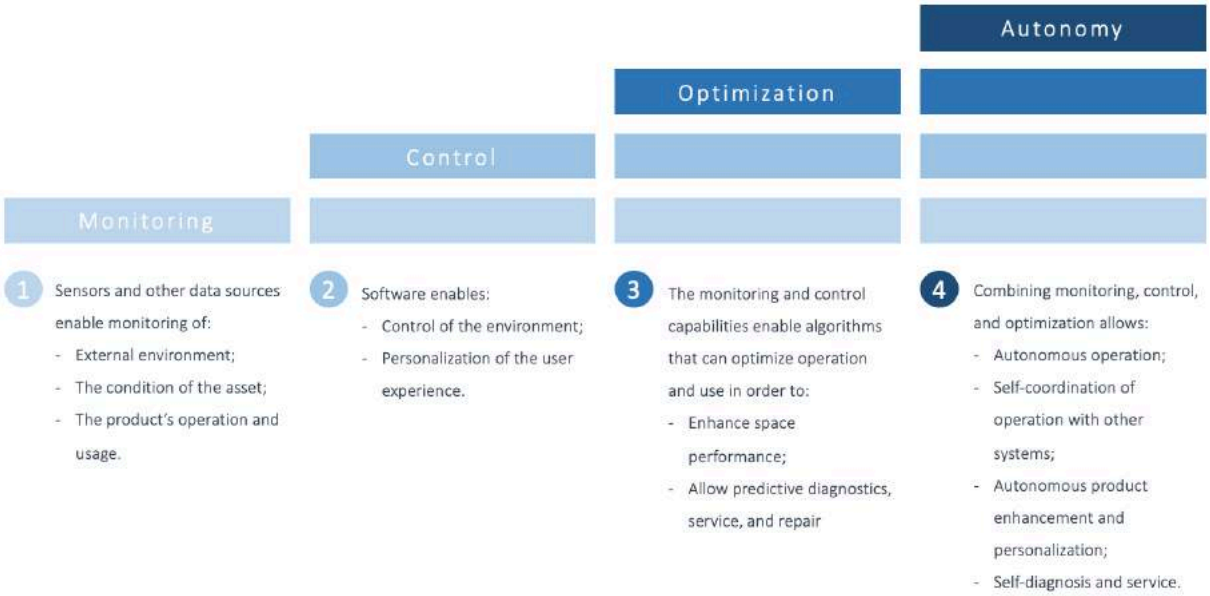


Figure 8: The capabilities of smart, connected products can be grouped into four areas (Porter & Heppelman, 2014, p. 70).

According to Bélissent (2010) a smart environment is an environment that uses the information and communications technologies to make the critical infrastructure components and services such as education, healthcare, public safety, real estate, transportation and utilities more aware, interactive and efficient (Bélissent, 2010, p. 3). IoT developments do affect and change the real estate industry, whereby often the terminology of smart real estate is often used.

3.2.3 Smart Real Estate

An array of innovations across the technology landscape in the real estate industry have converged to make smart products technically and economically feasible. As a result of this development, there is an emerging growth of information generated from buildings. It can be said that there is happening a digital change in the real estate industry. According to Arup (2017) the most important forces that cause this digital shift are the demand for a digital society for digitally enabled spaces, the falling price of technology, open information protocols and new environmental regulations that enable new forms of integration and control, and the sharing economy is disrupting the economics of ownership and usage (Arup, 2017, p. 11 - 12). The research of Aholt and Von Ditfurth (2018) explains the digital shift by the fact that sensor technologies have grown rapidly. They've become widely available, with prices about half compared with five years ago (Aholt & Von Ditfurth, 2018, p. 7). Due to the digital change, the role of real estate is changing and thus a new definition is born. In line with the changing role of real estate, due to the generation of all the data, it seems that companies specializing in big data processing will enter the real estate services market, which enjoys competitive advantages (Aholt & Von Ditfurth, 2018).

The digital enabled real estate, as caused by the abovementioned developments, is often described in the real estate sector with the terminology of "smart" (Buckman & Mayfield, 2014). In the research of Buckman and Mayfield, the development of real estate towards smart real estate is described. The first generation of buildings did not contain any elements of controlling the building, while due to technological developments buildings can be controlled and optimised, which is known as the smart building. This is in line with the expectations of Cook and Das (2007), who stated that real estate is shifting to "a subset of smart environments" where smart environments are "able to acquire and apply knowledge about the environment and its inhabitants in order to improve their experience in that environment" (Cook & Das, 2007).

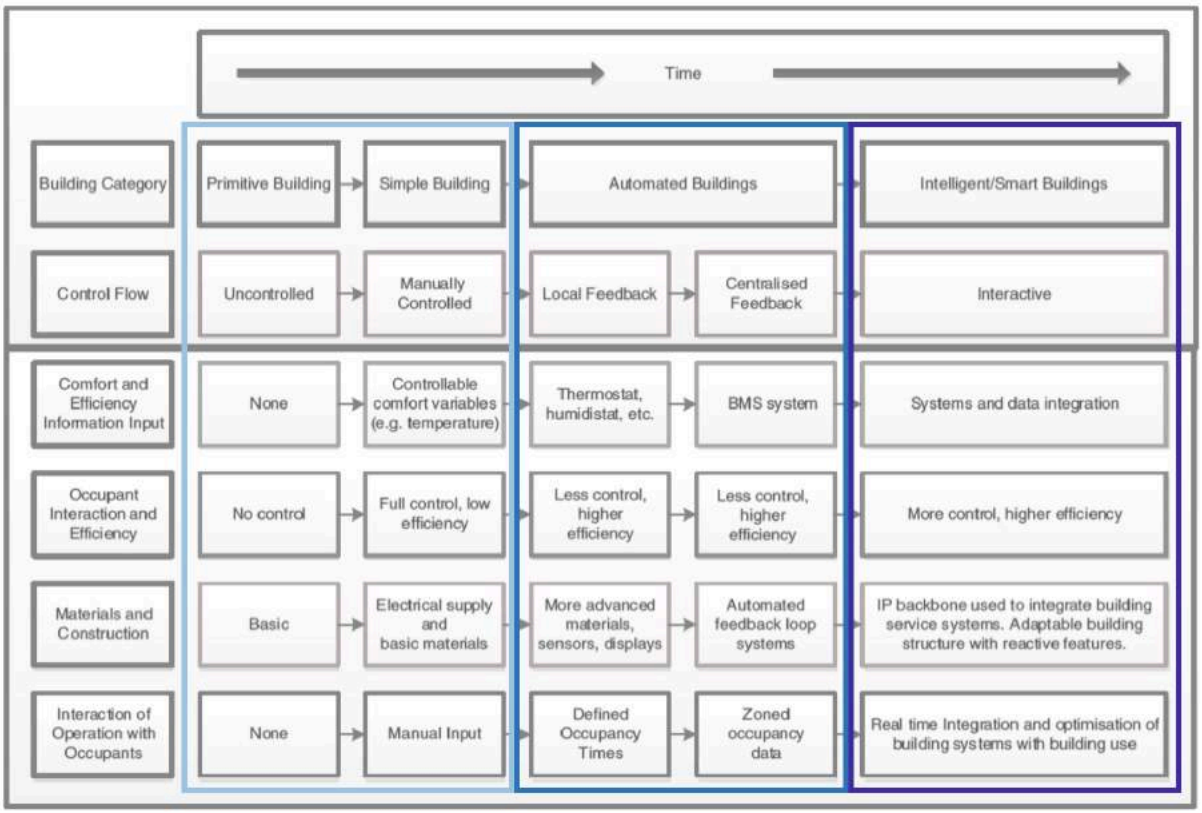


Figure 9: Development of smart buildings (Buckman & Mayfield, 2014, p. 95)

3.2.4 Smart Tools

As seen in the definition of Cook and Das (2007), smart buildings can be characterized by the ability to acquire knowledge or data from their environment. However, this explanation and covers the whole data process of a building. In general, a smart building contains of three different elements. Firstly, (real-time) data is obtained from sensors or other data sources. Secondly, the (real-time) data will be transferred to (real-time) information, which is often done in an integrated (open cloud) platform. Lastly, the information is made visible for the user of real estate, which can decide to adapt the decision making based on the real time information. The service or product that provides the real-time information to the user is described in literature as a "smart tool", as found in the research of Valks et al. (2018), where they use the definition of the 'smart tool' linked to the use on campuses. *"A smart tool is a service or product which collects (real-time) information on space use to improve the space use on the current campus on the one hand, whilst supporting decision making on the future space use on the other hand"* (Valks, Arkesteijn, Den Heijer & Vande Putte, 2018, p. 8). By collecting the real-time information, the use of the space can be managed more effectively and efficient. By collecting the real-time information from the building and presents this to the user, it can influence the use of the real estate asset. The smart tool principle is visualized in the figure below.

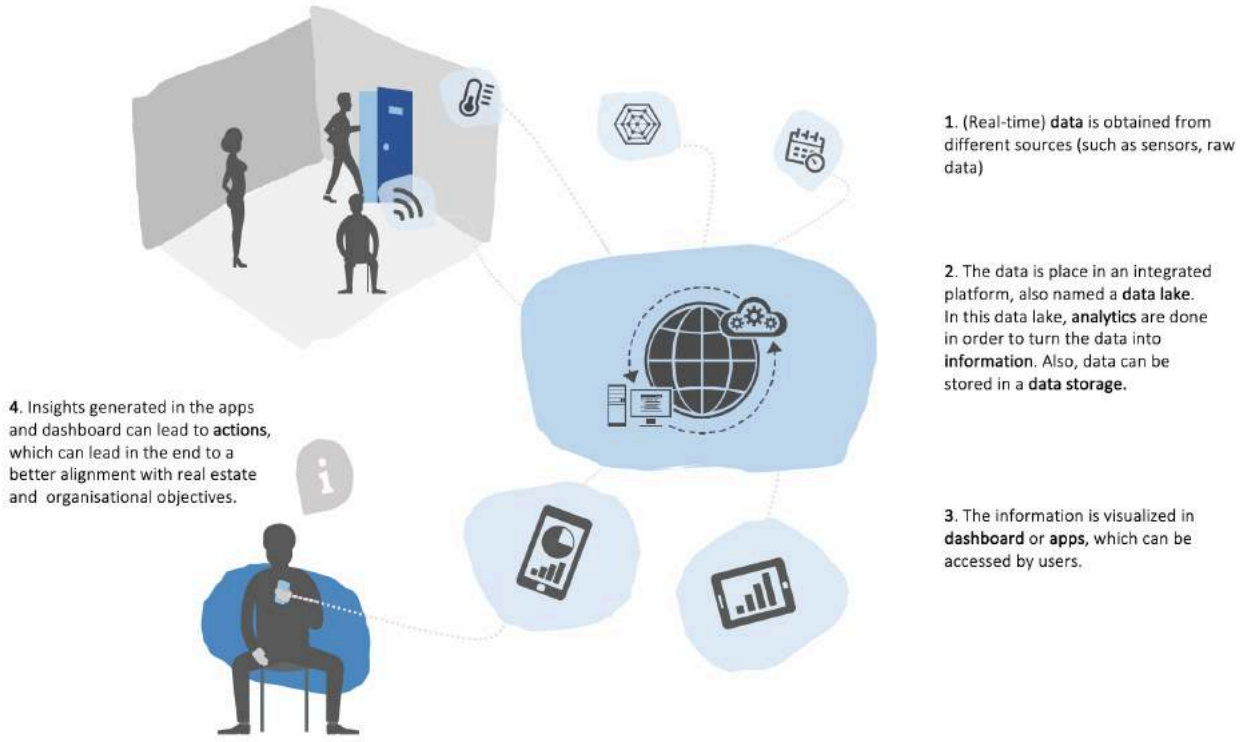


Figure 10: The principle of a smart tool: insight in real-time information to improve the use of real estate (own illustration)

In order to collect the (real-time) information, different types of sensors in real estate can collect the data. Products have been progressively provided with those capabilities thanks to new enabling technologies to enable technologies enabling things to acquire contextual information (Friess & Vermesan, 2013, p. 10). Based on the research of utilisation collection technologies (Serraview, 2015), a survey on indoor positioning methods (Mautz, 2012), and an international comparison of the use of smart tools on campuses (Valks et al., 2018), a list of sensors that collects data can be found in table 3. The application of the sensors can be used for different purposes. Sensors are used to measure space use; however, the sensors can also be used for optimising comfort, improve performance and health and find colleagues (Valks et al., 2018, p. 212). Setting up the list with sensors is based on these different sources. It might be the case that certain type sensors that collect real-time information in real estate are absent and in that way are not presented in table 3.

Table 3: List of sensors that collect real-time information in real estate (Adapted from Valks et al., 2018)

Space Use	
Wi-Fi	The Wi-Fi network can be used as a sensor to give an estimation of the number of people who are in the real estate asset. This can be done based on two different methods. The first one is to collect data based on the number of devices connected to the Wi-Fi access point. The second method is based on the attempts that devices make to connect to all the Wi-Fi access points.
RFID (Radio Frequency Identification)	The RFID is a system that consists of two elements; a chip that contains information and a reading device. The measurement of the amount of people is based on the system of granting access to the building. By measuring the amount of check ins, a clear estimation of the space use can be given.
Cameras	Cameras can measure space use, whereby two main methods are distinguished which are video cameras and infrared cameras. Infrared cameras register an estimation based on the heat radiation of objects. Video cameras are used on occasions where there is sufficient light. For both methods, the type of software plays an important role in measuring.
UWB (Ultra-wideband)	UWB enables wireless transmission of data between devices over large distance, while not hindered by doors and walls. In practice, this technology is not used a lot.
Infrared	The application of infrared (IR) can be divided in two different types; Active (AIR) and Passive (PIR). Different methods can be distinguished. The first method is using AIR to measure passages at the entrance. The second method is the use of integrated PIR methods in lighting systems, whereby the PIR sensor activates the lighting. However, this method is very limited because it measures frequency. The most-common used method is to place PIR sensors in a space, to measure the presence of people.
Bluetooth	Bluetooth is based on the same principle as Wi-Fi: transmit data over a short distance. A method to measure the presence of people is to place small devices in spaces which connects with Bluetooth devices of visitors. The devices are named as iBeacons.
CO2 sensors	Measuring the CO2 concentration gives an estimation of the number of users in a particular area. However, there are a lot of variables that will influence the accuracy, which makes it difficult to estimate occupancy.
Device use	The amount of people that is using a device gives an estimation of the amount of people represent. For example, computers, but also payments.
Energy	The energy consumption could also give an indication of the number of people in the room. However, this method is not very reliable.

3.2.5 Relation to the added value

The changing context due to converge of innovations across the technology landscape in the real estate industry have created opportunities for the stadium management but also new risks. Important in managing technology resources in relationship with Corporate Real Estate Management (CREM) is that it should add value to the organisation just like all real estate interceptions. To do this successfully and efficiently, it requires an accommodation strategy that is aligned with the organisational strategy.

Key is the relationship of 'smart' real estate and the added value for the organization. As stated in the research of Baum, smart real estate, smart cities and smart buildings are terms in common use which describe technology-based platforms which facilitate the operation of real estate assets. Platforms may simply provide information about building performance, or they may directly facilitate or control building services (Baum, 2017). Buckman and Mayfield (2014) stress out the relation of smart buildings and the potential added value. As stated in his definition, the buildings smart system will lead to improving the drivers for building progression, which is: energy and efficiency, longevity, and comfort and satisfaction. Due to the increased amount of information available from this wider range of sources will allow these systems to become adaptable. This academic view is supported by Wang et al. (2012), who suggested that smart real estate addresses issues by utilising computer and intelligent technologies. This result in the potential of adding value to an organisation.

It can be stated that due to different developments, the role of data within buildings will play an important role in the future real estate industry. The growing role of this so-called 'smart real estate' can be explained by the technological developments and the linked advantages. The process of optimally attuning the real estate supply with the changing demands can lead to different added values. In order to optimize and utilise the potential of smart real estate at the best, it is important that the right knowledge is available and criteria what is important needs to be identified.

3.3 Conclusions

Objective:	Define the principle of a smart tool Understanding the principle of real estate management theories and the role of smart tools related to real estate management.
Question:	What are 'smart tools'? How is the implementation of smart tools related to real estate management?
Method:	Literature study

The goal of this chapter wat to understand what a smart tool is, how the development of smart tools is related to the topic of real estate management theories and how these theories are related to the integration of smart tools. Based on the findings in the first chapter, the following conclusions can be drawn:

What is a smart tool?

- A smart tool is part of the smart environment of real estate, whereby it provides the user with (real-time) information about the space use in the real estate asset.
- In order to integrate a smart tool a technology infrastructure is required, which contains physical, connectivity and smart components.
- The information received from the smart tool can change the decision-making of the user on the short term and on the long-term. The hypothesis is that it can balance the demand and supply of real estate in more detail, thus contribute to the thirteen added values of real estate.

Real Estate Management theories:

- Real Estate Management differs from Corporate and Public Real Estate Management.
- The real estate decisions of stadiums are based on public and corporate objectives. Theories on Corporate Real Estate Management (CREM) are applicable.
- Based on these theories, a better alignment of demand and supply through real estate can lead to added values for the organization, which in the end can lead to a competitive advantage and costs reductions.
- In total, thirteen different added values can be distinguished from the most recent literature.

Relation technological developments and CREM:

- Currently, it can be stated that the world is in the fourth industrial revolution, which is impacting the real estate industry. This digital change in the real estate sector is often referred to as smart real estate.
- An array of innovations across the technology landscape in the real estate industry have converged to make smart products technically and economically feasible, which cause a growth of integration.
- Smart real estate is about using technological developments for building progression to attune the real estate supply with changing demands, which can lead to different added values for the organization as described in different CREM theories.
- Four different areas of functions and capabilities of smart connected products are distinguished: monitoring, control, optimization, and autonomy.

4. Five perspectives of a stadium

The focus of this research is on stadiums, which is a specific type of real estate asset with their own characteristics. To give a clear overview of the stadium characteristics five different perspectives are used to describe and analyze the stadium and the stadium environment. Four of the five different perspectives are based on the research of Den Heijer and De Jonge (2012), which is used in their research to describe CREM. These four perspectives on real estate can be classified into: strategic, functional, financial, and physical. Van der Zwart and Van der Voordt (2013) presented the four perspectives in a framework, as shown in figure 11.

These four different perspectives are relevant to give a complete overview in describing the characteristics of a stadium. This will help also to understand the stadium environment better, because in-depth knowledge will be acquired from the stakeholders, variables, and perspectives. The four perspectives can be described as:

1. Physical perspective: location characteristics, the condition and type of spaces within stadiums.
2. Strategic perspective: the organizational structure and the relation to the organizational objectives.
3. Functional perspective: type of users of a stadium and their characteristics.
4. Financial perspective: the financial perspective can be divided into costs, revenues and financial structure of stadiums.

Various researches claim that due to the unique character and the size stadiums it can lead to economic impacts in the area. That is why a fifth perspective is added: the economical perspective.

5. Economical perspective: the direct, indirect and induced economic effects of stadium developments.

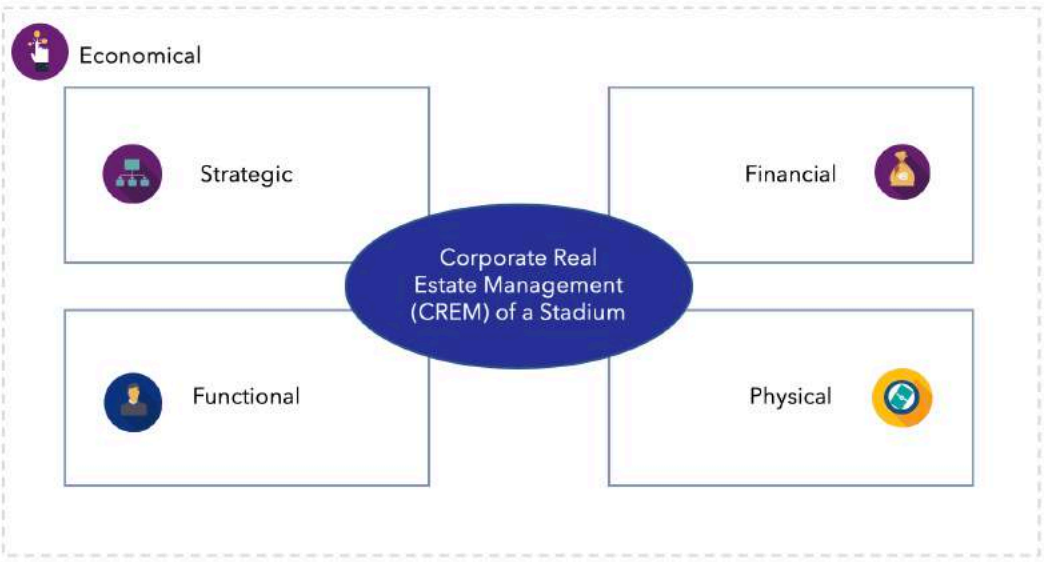


Figure 11: Perspectives of a stadium (own illustration; based on Den Heijer (2011))

4.1 Stadiums: an introduction

In terms of CREM, the real estate asset of organizations are mainly offices. Conversely, stadiums have totally different characteristics. In this paragraph 4.1, the stadium will be introduced and characterized by providing background information about the 'position' in the real estate industry, an estimation of the market size, and a historical overview.

4.1.1 Position of the stadium within the real estate industry

In general, real estate can be divided into two different categories: commercial real estate and residential real estate (DiPasquale & Wheaton, 1992). Residential real estate revolves the wants and needs for individual use, most often to provide housing. While commercial real estate focusses on supporting businesses, examples are offices, industry, retail and leisure. According to Davies (2006), stadiums can be seen from a commercial property perspective and categorized as leisure property.

According to the Oxford Dictionary (2019), a stadium can be defined as "*an athletic or sports ground surrounded with a structure designed for spectators to sit or stand*". This definition contains two important elements, on one hand, the characteristics of the tiers with seats, and on the other hand the athletic or sports ground. However, the last characteristic is not totally true in practice. As seen in the last years, more and more stadiums are used for not only sports events. But as a result of structural developments, there is the ability to host different types of events. Which can lead to an increase in the mixed usage of stadiums like sports, music, and other live events. This type of stadium is called in the context of sports stadiums a "domed stadium". Stadiums which are typically designed for outdoor sports, such as soccer, rugby and baseball can be distinguished as a traditional stadium. While originally those who are designed for indoor sports are often called "arena's". However, the terms sports venue and sports stadium are often used by each other. However, there is a clear difference between the two definitions. A stadium is a building where a filed or stage is partly or completely surrounded by a tiered structure, while a sports venue is a place where a sporting competition is held. For example, a motor circuit is a sports venue. So, in some cases, sports stadiums can include a venue or a stadium (Gammon, 2004).

4.1.2 Market analysis

A market analysis of notable soccer stadiums gives an idea of the size of the stadium market. The market analysis is based on the database of Wikipedia and the focus was on football stadiums (Wikipedia, 2019). In total, 1526 stadiums are listed in 82 countries, whereby Europe has the most stadiums. In general, the capacity does not vary very much per continent. If the focus is more on stadiums with a capacity of at least 20.000, there are in total 698 stadiums. Important remarks for the market analysis are that the capacity includes both seating and permanent standing areas, but excludes any temporary accommodation. In general, soccer stadiums represent quite good the total stadium market. An important remark for this is that in the United States this is not primarily the case. Results may vary a bit; however, the goal of this market analysis is to give a rough idea of the market size of stadiums with a capacity of at least 20.000.

Table 4: Football stadiums per continent

Continent	Football stadiums per continent	Average capacity * 1000 per continent	Football stadiums with minimum capacity of 20.000	Average capacity * 1000 with minimum capacity of 20.000
1 - Europe	831	21	297	36
2 - Asia	337	27	190	38
3 - South America	157	29	100	40
4 - Africa	82	29	51	41
5 - Central America	61	23	32	32
6 - North America	41	13	14	23
7 - Australia	17	24	14	43
Total / Average	*1526*	*24**	*698*	*37**

**Average*

As we zoom in on the European Market, a list is made with the top ten countries who have the most football stadiums with a capacity of at least 20.000 located in Europe. Based on this list, it can be stated that the stadiums with a capacity of more than 20.000 cover more than 50% in the top 4 countries. Which is quite logic, because England, Italy, Germany and Spain have the best and richest football competitions in Europe. To give a better idea how the seats are related to the population of a country, the seats per citizen are calculated for each country.

Table 5: Football stadiums with a minimal capacity of 20.000 per country

Continent	Football stadiums with minimal capacity of 20.000	Average stadium capacity * 1000	Population	Seats per citizen
1 - England	54	36	65,808,573	0,030
2 - Italy	37	34	60,589,445	0,021
3 - Germany	33	43	82,521,653	0,017
4 - Spain	31	38	46,528,966	0,025
5 - Ukraine	16	32	48,457,874	0,010
6 - France	14	47	66,989,083	0,010
7 - Portugal	13	35	10,309,573	0,044
8 - Romania	10	31	19,644,350	0,016
9 - The Netherlands	8	33	17,081,507	0,015
10 - Bulgaria	6	27	7,101,859	0,027
Average	*23*	*36*	*43,423,883*	*0,022*

On average, the top ten European countries with the most stadium have an average seat per citizen of 0,022. This means roughly that for every stadium seat there are 45 citizens. Between the different countries we see some differences. Ukraine and France have relatively high number of seats per citizen, while in Portugal there are the less seats per citizen. The high number of seats per citizen for Ukraine and France can be declared by the fact that both countries organized the last two editions of the European Championship. In 2012 Ukraine, in collaboration with Poland, organized this tournament, while in 2016 it took place in France. As declared by Barclay (2009) the countries and cities that host these kinds of events must commit a significant investment into sports stadia and other miscellaneous infrastructure. They see it as an opportunity to construct new sports stadiums and upgrade current stadiums (Barclay, 2009, p. 62). Consequently, this result in a higher number of seats per citizen as shown in the table 5.

4.1.3 History: The evolution of stadiums

Another definition as given by the Oxford Dictionary (2019) of the word stadium is *"an ancient Greek unit of measurement of length, about 185 meters"*. The 185 meters is the original length of a stadium. It is not strange that this definition was used these times, because the earliest known stadiums originated in the ancient Greece. Really giving stadiums a monumental shift, which was done by Romans in the first few centuries before Christ. The Colosseum in Rome, built in 70 AD, is seen as the first real founding father of stadiums. Up to six centuries, stadiums had a dominant role in society, while after this period the building of stadiums lacked intrigue for almost 1.000 years. In the late 1800's, simultaneous with the rising popularity of different sports, there was a rise in wooden stadium constructions, especially in the United Kingdom. But the real start of modern stadiums as we have today started at the beginning of 1900.

Dunning & Sheard (2005) identified five generations of stadiums after 1896. These generations mark the evolution of stadium design over the last century, in which stadiums have evolved immensely. The following subsequent developments of modern stadiums are identified:

The Analog Stadium (1900's)

The first stadiums were built with the sole purpose of showcasing sports games and offering standing and/or seating capacity for the spectators. It was all based on the analog experience. Due to the rising popularity of sports, especially fed by the growth of soccer in the United Kingdom, more and more stadiums were developed.

The Equipped Stadium (1950's)

The development of the equipped stadium was in line with the upcoming TV coverage of the big sporting events. People could follow the live events at home instead of watching the live event in the stadium. The stadiums had to compete with the comfort of watching a live event at home. Stadium operators renovated the stadiums in order to meet the visitors demands by improving the comfort (Bale, 1993). In line with these developments, more and more large stadiums, with more than 50.000 seats, were developed in Europe.

The Commercial Stadium (1980's)

With the growth of sports and spectator numbers, the development of new stadiums moved away from city centers to accommodate the required increase of seats and supportive facilities. Another development was also happening, namely the increase in mixed usage. Over time more and more stadiums were built with the purpose of not just housing and facilitating live events, but instead providing the abilities of multi-purpose options like sports, music, and other events.

The Flexible Stadium (1990's)

As the commercial stadium proved to be a success, the concept of organizing various types of events got more and more attention. Due to constructional developments which give the possibility to close the roof, both in and outdoor events could be organized. Also, commercialization of the stadium plays a bigger role due to the growth of television spectators.

The Urban Icon (2000's)

In line with the growing commercialization of sports, the potential role of urban regeneration increased (Gratton, Shibli & Coleman, 2005). Newly built stadiums seem to indicate a move back to central locations or arena districts, which become part of a city resulting in urban regenerations projects. This kind of trends requires a more specific business rationale to avoid uncontrolled investments not in line with modern expectations. Stadiums became more and more an icon for cities, with high architectural quality. This development was also remarked by Van Dam, who stated that *"to an increasing degree it is recognized that a football stadium can have more functions than were traditionally ascribed to it, from a business-economic perspective as well as from a less tangible symbolic and prestige perspective, the stadium as an urban landmark, the club as a source of local or regional civic pride*" (Van Dam, 2000, p. 142). As stated in the research of Sklair (2010) a stadium is a perfect symbol for a region or nation that most touches the hearts of minds of the common man. Whereby the stadium provides a focus on the community consciousness, social bonding and a place representing urban pride (Sklair, 2010, p. 146). This can also declare the new consumerist phenomenon of 'stadium tourism'. For example, there are more tourists in Barcelona visiting Nou Camp than the Picasso Museum.

New era: Smart / Connected / Cloud-enabled Stadiums

As seen in the latest years there is an increase in the usage of connectivity and smart product in stadiums. In the article of Dunning and Sheard, this was not stated. That is why an extra generation is added, which is named the 'smart stadium'. The first developments started roughly around 2015. Nowadays, with the rise of the Industry 4.0, IoT, connectivity, and other cloud and mobile technologies that are widely available, stadiums and their networks are keen to find new business models to increase fan experience, security and probability and more. These techniques provide options to interact on different levels and with various parties. This resulted in the growth of smart stadium platforms: infrastructure, resources, surrounding organization and activities that work together to

enable stadium operators and teams to create new experiences for all visitors, regardless of the event. Stadiums are more connected than ever before. Some scholars are speaking about stadiums as a platform (Campbell & Giorgio, 2016). Other synonyms (cloud-enabled stadiums / connected stadiums) are also used for this type of stadiums. In theory and practice, the terminology of a smart stadium is used the most. For a more elaborate explanation of the smart stadium, please read chapter 5. In this chapter, the specific characteristics of a smart stadium are explained and discussed.

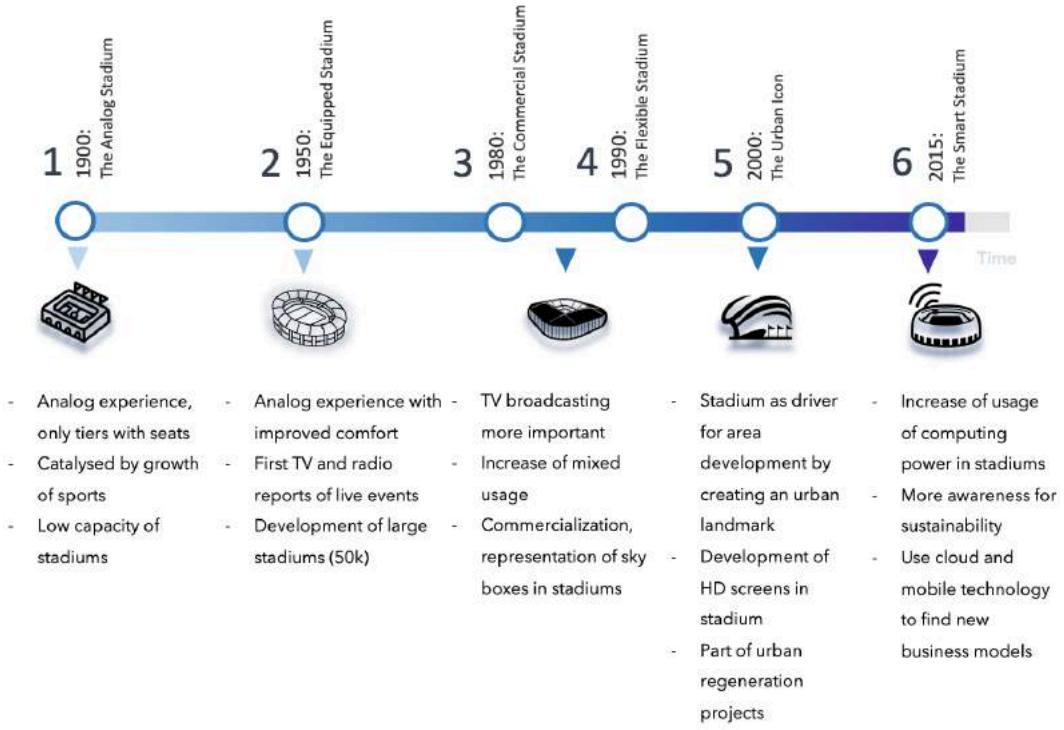


Figure 12: Evolution of stadiums (own illustration)

4.2 Economical perspective

A lot of research has been done on the economic impact of stadium developments. Policymakers often claim positive effects due to stadium developments. As stated by Holt and Shailer (2003), stadium developments help to stimulate economic growth and activity, and increase the demand for services in a city. In addition, policymakers are claiming that the presence of sports and stadiums will lead to economic prosperity (Baade & Dye, 1988).

However, a growing body of evidence shows that sports stadiums, and the franchises they are home to, may not be engines of economic growth in urban neighbourhoods (Coates & Humprheys, 2003). Often little or no evidence has been found that stadium developments result in significant economic benefits (Ahlfeldt & Maennig, 2010; Chapin, 2004; Coates & Humphreys, 2003; Siegfried & Zimbalist, 2000). According to Chapin (2004) investments in stadiums are not reflected in the expected economic growth within the area. More negatively, some say that in fact stadium developments may actually generate a negative impact on real income per capita (Coates & Humphreys, 2008). This emphasizes the importance of understanding the effects of stadium developments that are financed by public investments. Positive externalities are the legitimisation for public investments (Johnson & Whitehead, 2000).

So why would a municipality put public funding into new stadium developments? Well, there are assumptions 'spillover' effects' which are the consequence of stadium developments. There is some evidence that stadium developments result in an increase on surrounding real estate values (Ahlfeldt & Maennig, 2009). Secondly, stadium can add extra facilities to an area, which would result in more employment opportunities and tax incomes (Jones, 2001). It can be stated that the economic impact is on a smaller scale than expected. As illustrated in the research Santo (2005) stadiums have the ability to impact its local economy, but the size of the impact is lower as claimed by policymakers. So, research results do show a positive economic impact, however, the impact is tied to the local context.

This is line with the conclusions as drawn from the research of Crompton (1995) whereby the economic impact of large-scale developments is be divided into three elements that can contribute to the total impact of a given initial injection of expenditures for stadium developments (Crompton, 1995, p. 20). These three elements are: direct impact, indirect impact, and induced impact. Direct impact is the first round of visitor spending on the local economy. Indirect impacts are the additional round of recirculating the initial visitors' expenditures. Induced impact is further ripple effects caused by employees of impacted businesses in the broader area or city (Crompton, 1995, p. 20). As based on the conducted economic impact analysis the results showed that sports facilities do have a higher direct impact and that induced and indirect impacts are significantly lower. Which supports the conclusions as stated in the reports of Jones (2001), Santo (2005) and Ahlfeldt and Maennig (2009).

However, there are also arguments found that relates to the indirect and induced impact of stadium developments. These kinds of justifications for financing stadium developments with public funds can be found in the research of Chapin (2004). Stadium developments are a catalysator for larger area (re)developments. Chapin (2004) stated that this kind of evidence indicates that sports facilities offer opportunities to catalyse redevelopment, defined as the development of vacant land, the reuse of underutilized buildings, and the establishment of a new district image, but that district redevelopment is by no means guaranteed by these investments. Robertson (1995) agreed upon stadium development as a driver for district (re)development. He outlined that stadium developments can generate new construction in the district; and rejuvenate a blighted area (Robertson, 1995).

Besides that, the construction of a stadium can be used as a driver for further area developments, the stadium can also impact communities and social cohesion. As argued by Percy (2001) sports stadia can affect people's perception of the neighbourhood they are living in. Based on two stadium developments in Manchester and

Cardiff, research participants felt that there were more pride and confidence within the local community, due to new stadium developments. Moreover, the stadia enhanced the image of the city or the district they are located. The exposure of cities and districts improve by hosting major sports events and the media attention it generates, which can also be part of the city branding strategy (Davies, 2005). These findings are in line with the theory of Corwin (2011), who stated that a stadium will have an impact, besides economic and physical, on social and cultural domains.

Concluding, a lot of researches reflected that there is some evidence that stadium developments will lead to economic growth as stated by policy makers. It seems that stadium developments cause positive direct economic impacts tied to the local area. Besides this, there are some justifications found in the literature that stadium developments also have a positive indirect and induced impact on the area. Namely, as a driver for new area (re)development, to improve pride and confidence within local communities, and to enhance the image of cities and districts. These arguments can function as a justification for municipalities to invest public funds in stadium developments. That will declare the role of spending public money to finance stadium developments.

4.3 Physical perspective

In this paragraph, the stadium is analyzed based on the physical perspective. The physical perspective consists of different elements, such as the location characteristics, the different types of mixed-use, and the life span of a stadium.

4.3.1 Location

In the research of Newsome and Comer (2000, p. 108) three different configurations of stadium locations were distinguished, which are:

I. "Downtown" locations: defined as being in the central business district or within easy reach;
II. "Central city" locations: defined as those outside the central business districts, but still an inner-city development;
III. "Suburban" locations: defined as closely outside of a city, but not necessarily outside of the city. Often used as part or driver of urban regeneration.

The location of a stadium has a direct relationship with the density of an area. Usually, central locations within cities have a relation with the density. The higher the density, the more stakeholders there are affected, which also means the higher the risk of overcrowded areas. As stated by Wheaton (1998) there is a clear link between the density of an area and congestion problems, because driving and location are equivalent, is the same as regulating density. The research showed that internalizing the congestion externality always requires upward adjustments to market density, which is the greatest in urban centres (Wheaton, 1998, p. 258). As a result of a highly dense area, infrastructure that can deal with high capacity is more needed. The demand for technologies that would influence this may be higher in urban centres.

Figure 13: Location of stadiums (own illustration)

4.3.2 Mixed-use

As seen in the evolution of stadiums, stadium developments can be used as urban regeneration projects to benefit the wider area. While a stadium remains empty on non-match days, mixed-use developments within the stadium can shape to a successful place which is social, economic and environmentally important. To realize this, mixed use developments can contribute to that. As mentioned by Adams and Tiesdell (2012) a characteristic of a successful place is that it contains mixed use with a varied density and with distinctive places. By combining both the place where people live and work (places of existence) and the place with the capability to attract people from a distance (place of encounter) area development tend to be more successful (Adams & Tiesdell, 2012).

According to Sartori and Nienhoff (2013), typical mixed-use functions in relationship with stadium developments are: retail parks, restaurants, hotels, sports centers, offices, conferencing facilities, residential real estate, and museums. Besides the regeneration advantage of creating a more successful place, there are also other advantages related to mixed-use developments. Stadiums alone are maybe not the most attractive investment for

both private or public sponsors. Higher investment returns of commercial, residential, or other land use, can be more attractive for investors. Secondly, due to the more secure and predictable revenues of these kinds of functions, risks of stadium developments can be compensated and seems to be lower. Bess (1996) described these kinds of sports venue as "traditional urban", whereby the facility is placed adjacent to a mix of residential, commercial, and public land uses, because of that the viability of stadium can improve and it can lead to more economic benefits (Bess, 1996).

4.3.3 Land Use

The decision to integrate different functions within one stadium can also depend on the land use planning policy of municipalities. The land use plan is the guiding principle for real estate developments as based on the vision of municipalities. In a traditional land lease system, the municipality has a strong position. For the land that is owned by the municipality, the municipality can decide to agree upon a land lease agreement with a project developer. This means that the land is given in lease for the use of the land to a separate party. To be eligible to use the land the municipality asks for lease (in Dutch: canon), which is the financial compensation to use the land.

The lease price in The Netherlands contains the real estate interest rate, inflation and other risks (Municipality of Amsterdam, 2016, p. 9). The height of the land value is based on the proposed future developments. To calculate the land value, the residual land value method is often used (DiPasquale and Wheaton, 1996). This residual land value method is:

Land value = market value of the proposed development – building costs

The market value of the proposed development can be based on similar projects. However, the market value of a development is very dependent on the location. The future market value can also be calculated by the yearly rent incomes in combination with a yield percentage. There is some rule of thumbs that has an impact on the market value. The higher the density of a plot, the higher the land price will be. Secondly, if the building is a 'high quality' building, it means that the building costs will be higher, which results in lower land value.

So, to have an idea of the land value of stadium developments, the market value has to be estimated. However, due to the unique character of a stadium, this is extremely difficult. Often the market value is based on the estimated sale price of similar properties, which is also defined as the sales approach. As stated in the article 'Appraisal issues in the valuation of extremely large buildings' of Battuello (1996, p. 396): *"A building that is part of a business sale and has a price allocated to it as a portion of the overall going-concern cannot truly be used as an item of real estate market data.*" Battuello cautioned against the use of the kind of sales comparisons. The Appraisal of Real Estate 12th Edition notes that to value special-purpose properties, the cost approach can be seen as more reliable and appropriate (Appraisal Institute, 1996, p. 419). But it seems still quite difficult to estimate the market value of a stadium (and the land value). The main reason for this is the strong connection between the development of a stadium in collaboration with a sports club; stadiums are usually not sold. There is simply too little demand and sports clubs are often linked to a specific area.

As described in various studies (Tu, 2005; Ahlfeldt & Maennig, 2010; Humphreys & Nowak, 2017), the development of a stadium can lead to an increase of surrounding land values. A strategy from a governmental perspective could be to lease the land around the stadium after the development for a higher value.

In sum, estimating the land value for stadium development is difficult, because this is normally based on the market value of similar properties. Due to the unique character of a stadium, it cannot compare with similar properties which make it difficult for municipalities to estimate the land value.

4.3.4 Renovation vs. New construction

The building life cycle of a stadium can be defined as the period of the building component that can fulfil its requirements (Hermans, 1999, p. 1868). According to Hermans (1999), the life span information can serve several goals, such as calculating exploitation costs; the maintenance planning; determining depreciation periods; choosing between alternative building components, and calculating the environmental impact.

The life span of buildings can be divided into two different types: the technical life span and the economic life span. The technical life span can be explained as to what stage of deterioration a building still meets the requirements of the user. Or as simplified by Hermans (1999) as how many repairs are acceptable and when should a replacement be considered. Secondly, the economic life span can be explained as the period with lower or at least equal exploitation costs for a building component (Hermans, 1999, p. 1671). Exceeding the economic or technical life span of stadiums will lead to investments in a new stadium or in the current stadium, whereby the stadium can be renovated or newly constructed in order to extend the life span.

However, stadiums often involve emotional, historical and social values, especially for the fans. That makes these kinds of decisions often difficult. Sartori and Nienhoff (2013) stated that to demolish or build an entirely new stadium can be very difficult. In the case of renovations, important issue is the historic value that the stadium holds. What also plays a key role is the decision of whether a stadium can be used during construction works. Normally, it is very difficult for a sports club to find another suitable stadium during construction works where they can host the events. This will also impact the decision-making whether to choose for adapting the stadium or to choose for new construction possibilities.

Besides the requirements of the construction as formulated in the building regulations, which can be different for different countries, the stadium often has to deal with the requirements as formulated by sports unions. For example, the Union of European Football Associations (UEFA), which is the administrative body for association football in Europe, has a list of requirements for a stadium (UEFA guide to quality stadiums). If the stadium is not according to the formulated requirements, it is not allowed to organise events (Fenwick, Bornø, Favre & Tusell, 2011). So, for stadiums, it is extremely important to meet the requirements of sports unions.

4.4 Strategic perspective

In order to develop a successful and feasible business plan, a sustainable and commercial stadium management model is crucial. In this paragraph, the organizations that are responsible for strategic decisions-making are explained. This will create insight into the different parties who are responsible for real estate management practices of stadiums.

4.4.1 Political issues

As seen in the previous paragraph, stadiums and sports developments are mega projects where often public subsidies are involved. Cities are offering staggering financial support to sports clubs and stadium developments and rationalize their largesse on economic grounds (Baade, 1996). As stated by Delaney and Eckstein (2007) new publicly financed sports stadiums are often at the heart of new policies for new area developments. However, this strategy is flourishing academic criticism and increasing public scepticism. Municipalities often justify the subsidies by claiming that the stadium projects generate valuable public goods and other positive benefits (Johnson & Whitehead, 2000). Results of different scientific studies vary about the benefits for stadiums and cities. However, the studies almost unanimously conclude that the financial payoff from public investment in professional sports stadiums does not justify the use of scarce public subsidies (Delany & Eckstein, 2007, p. 332). It has to be noticed that municipalities always play a key role in the financing of stadium developments, but that it can be heavily criticized by the public due to the lack of proper justifications. Another reason for the relatively high media attention for stadiums is the number of visitors. As a result, decisions regarding the stadium are affecting a lot of people. This can declare the relatively high media attention related to stadiums.

4.4.2 Main stakeholders of a stadium

In the last 25 years, a proliferation of stakeholder theory has seen in the literature (Friedman & Miles, 2002). One of the first researchers in this field was Freeman, who defined stakeholders as “any group or individual who is affected by the achievement of the organizations objectives” (Freeman, 2009, p. 46). However, this definition has been criticized due to its broad definition. A more specified definition can be found in the Project Management Body of Knowledge (PMBOK), which is a fundamental resource for project management. The PMBOK defines stakeholders as *“organizations and individuals who are actively involved in a project, or where their interest is affected as a result of project execution of successful project completion*” (Larson & Gray, 2015). This definition will be used.

According to Phillips (2003) work on stakeholder legitimacy two different stakeholders can be distinguished: the normative and derivative stakeholders. Normative stakeholders are those to whom an organization has the intrinsic value (based on moral and philosophical arguments) and the right to participate in an organization's decision-making process. While on the other hand derivative stakeholders can be defined, according to Phillips as *“groups whose actions and claims must be accounted for by managers due to their potential effects upon the organization and its normative stakeholders”* (Phillips, 2003, p. 31).

O’Brolcháin, Colle and Gordijn (2018) used the distinction between normative and derivative stakeholders for the Croke Park Stadium in Dublin. This gives an idea of the most important stadiums involved in a large stadium. The following stakeholder groups were distinguished:

1. Normative stakeholders: Financiers and owners, employees, communities, suppliers, and customers.

2. Derivative stakeholders: Competitors, media, activists, future generations, and local authorities.

These findings can be visualized in a stakeholder map. Where the stakeholders with normative and derivative legitimacy are indicated. Figure 14 is based on the stakeholder map of O'Brolcháin, Colle, and Gordijn (2018).

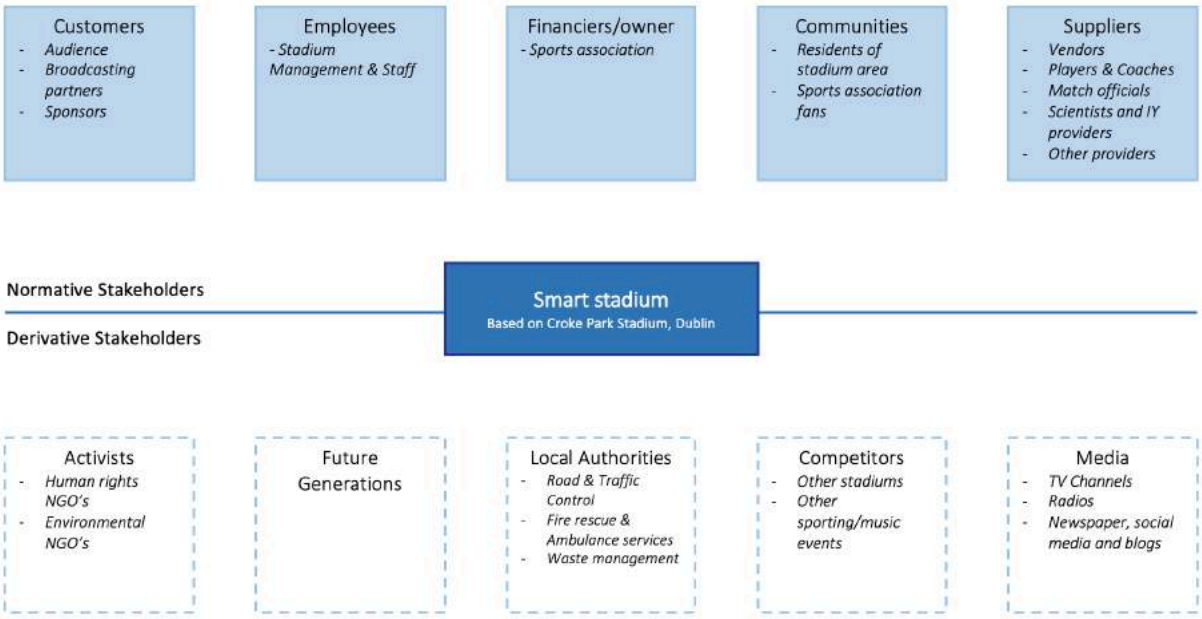


Figure 14: Normative and derivative stakeholders as seen in the Croke Park Stadium project (own illustration, based on O'Brolcháin, Colle, and Gordijn, 2018)

4.4.3 Organizations of stadiums

The stakeholder map gives an idea of all the stakeholders that are involved in stadiums and events. By focussing on the organizational of a club, it can be clarified which part of the organization is responsible for the stadium management. Stadium owners are typically the sports club, the municipality or other third parties. As seen in The Netherlands, most of the times the sports stadiums are a limited partnership that leases their stadium to the sports club and/or event organizers. However, the sports stadium is very dependent on the leasers, because they play a key role in the exploitation of the stadium.

Due to the key role that the users of the stadium (sports clubs and event organizations) play in the feasibility of the business plan, they are most of the times closely involved in the development of stadiums. Besides the traditional institutional investors in stadium developments, the municipality is also often a key investor in stadium developments. Stadium developments take an important place in modern cities (Bale, 1993, p. 9). In addition to municipalities as investors, sometimes sports clubs are also investors in their own stadium developments (Sartori & Nienhoff, 2013).

The stadium management as a limited partnership, which is the stadium owner, is responsible for the operations of the stadium. Sartori and Nienhoff (2013) distinguished two types of managing the operations: internal and external. Internal means that the stadium management incorporations the operational services within their organisation, while with an external management approach these services are outsourced. Typical services are catering, security, cleaning, and maintenance. It is also possible to transfer the operational responsibility to tenants. Advantages of these kind of constructions are the possibility to provide access to specific stadium operations management knowledge and to minimize the responsibilities. The disadvantage of outsourcing is the higher costs and the lack of quality control of the operational services.

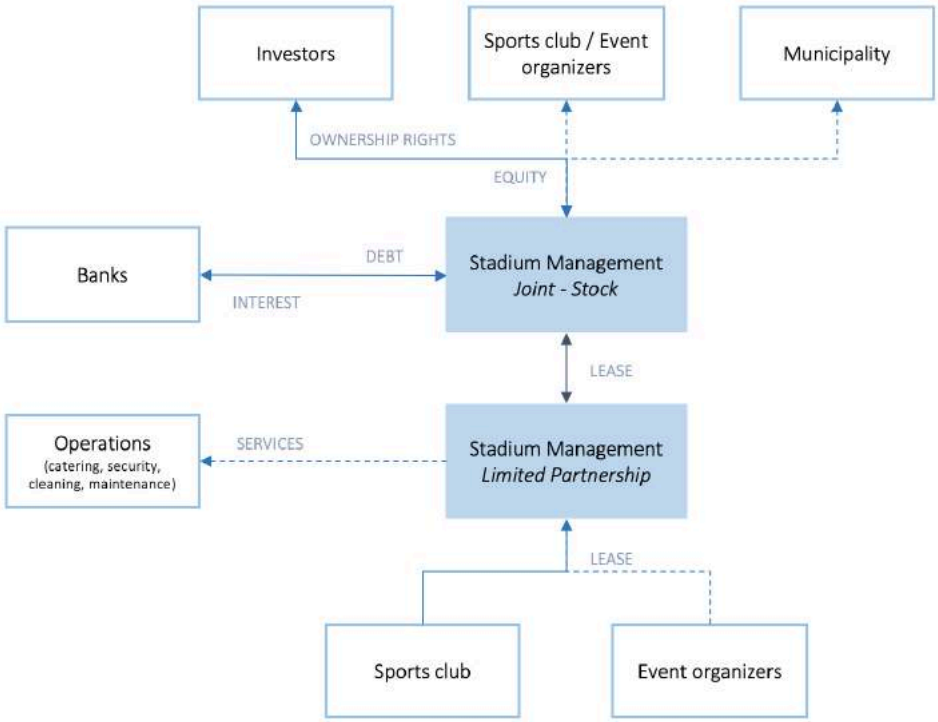


Figure 15: Typical organizational structure of stadiums, direction of the arrow shows the cash flow (own illustration)

Useful to highlight is the difference in the financing constructions between equity assets and debt assets. With debt financing, money is borrowed in order to acquire the real estate asset. Using debt financing allows the stakeholder to maintain their percentage of ownership. A bank loan is a commonly used debt financing. The return on investment is on based on the interest rate. Equity financing involves the funding of a real estate project based on own funds. The returns are based on dividend and long term. Examples of equity assets are stocks on the public market and private equity in the private market.

So, on first sight, stadiums seem to be managed as a separate entity with their own organizational objectives. However, stadiums are very dependent on their users and the municipality, which are most of the times the leasers. That is why most of the times municipalities and the sports clubs are having shares in the stadium, which is done by a joint-stock construction. As a result, that those decisions made by the stadium management entity is linked to the interests and demands of the investors, thus the users. If there is no particular interest from the key stakeholders, themes as innovation and technology are difficult to integrate by the stadium management (Geltner, Miller, Clayton & Eichholtz, 2001, p. 11).

4.5 Functional perspective

As demonstrated in chapter 3, the functional perspective is related to the added values of increasing user satisfaction, supporting user activities, and increase flexibility (Den Heijer, 2011). In order to understand and investigate the user experience, the Customer Journey is a useful method for researching this (Nenonen, Rasila, Hunnonen & Kärnä, 2008). Koljonen and Reid (2000) emphasize this importance by stating that: "an understanding of any professional service creation and the delivery system begins with a comprehensive description of the client service process" (Koljonen & Reid, 2000).

4.5.1 Ownership

As seen in the previous paragraphs, a general shift took place from stadiums' ownership from public to more private. As a result, stadiums are now owned by a private organization. As a result, financial independence is more and more important for stadium operators.

4.5.2 The spectator – the stadium management

In general, the core tenant of stadiums has the focus on the spectator (visitor) by organising live events, which can be seen as the most important user of the stadium is the spectator (Giulianotti, 2002). A stadium should focus on facilitating the demands of the spectator. As seen in the previous chapter, the organization that is responsible for this is the organization of a stadium, also defined as the stadium management. They are responsible for all the real estate decisions related to the stadium. Both the stadium management perspective and the spectator perspective are discussed more in-depth in this chapter.

4.5.3 Mixed-functions, different users

As already stated in the introduction of this chapter, modern stadiums are often containing mixed-use facilities. Often, other functions are integrated into stadiums. Based on the different functions, a different type of users can be found in stadiums with their own preferences. The size of other functions integrated into the stadium will influence this. Consequently, more functions mean multiple stakeholders, which usually lead to higher complexity. According to the book of Bryson (2018), attention to multiple stakeholders is important throughout any strategic management process, because "success" for an organization depends on satisfying key stakeholders according to their definition of what is valuable (Bryson, 2018).

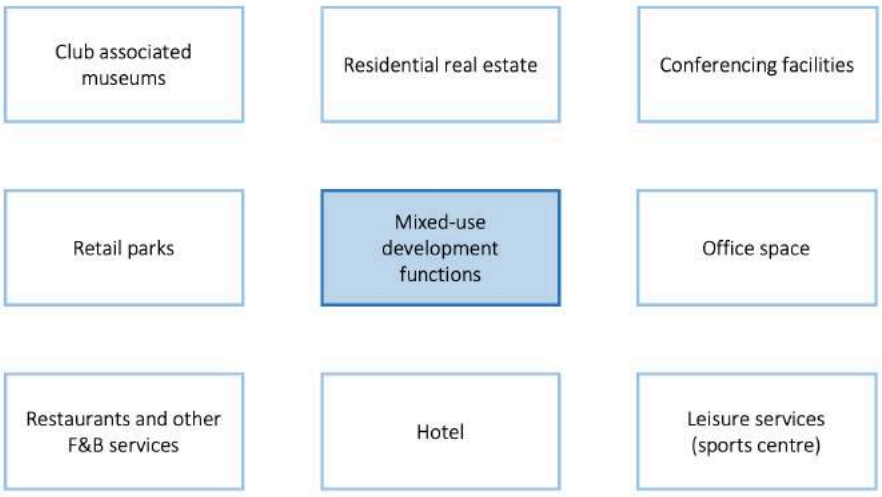


Figure 16: Typical mixed-use development functions of stadiums (Sartori & Nienhoff, 2013, p. 23)

4.5.4 The spectator: four types

Giulianotti (2002) set out a model of four ideal-type of spectator identities, based on the football industry. The following types of spectators were distinguished: supporters, followers, fans and flâneurs.

I. Supporters – The supporter has a long-term relationship with the club, both personal and emotional. This can be reflected by a conscious commitment by buying shares and/or merchandises in the club.
II. Followers – The relationship with the club is based on favourable interest and the follower has implicit awareness with a particular sense of identity that relates to a specific club. Most of the communication will be done through the cool medium of media.
III. Fans - The fan has a strong sense of intimacy with the club, which is a key element of the individual's life. This is also expressed by purchasing consumption goods (market-centered) of the club.
IV. Flâneur – The flaneur can be described according to Giulianotti as "The flâneur acquires a postmodern spectator identity through a depersonalized set of a market dominated virtual relationships, particularly interactions with the cool media of television and the Internet (Guilianotti, 2002, p. 38). The relationship is based on interaction with social media, television and the internet.

The four types of spectators can be placed in a model with four quadrants with two axes. The horizontal (traditional – consumer) axis measures the basis of the individual's investment in a specific club. Traditional clubs will have a more local relationship with the club, while consumer fans will a market centred relationship with the club. The vertical (hot-cool) axis measures the different degrees to which the club is central to the individual's project of self-formation. The hotter, the more intense the identification and solidarity will be with a club. The framework of Guilianotti can be found in figure 17.

Relevant for this research is the realization that the visitor is engaged differently to events than others. Some spectators are more committed and will, therefore, feel less need for integrating smart tools in stadiums, while other types of spectators will be more sensitive to this. Moreover, the archetype flaneur is very dependent on the use of social media and the internet. A stadium can encourage the use of this by having the right data network available.

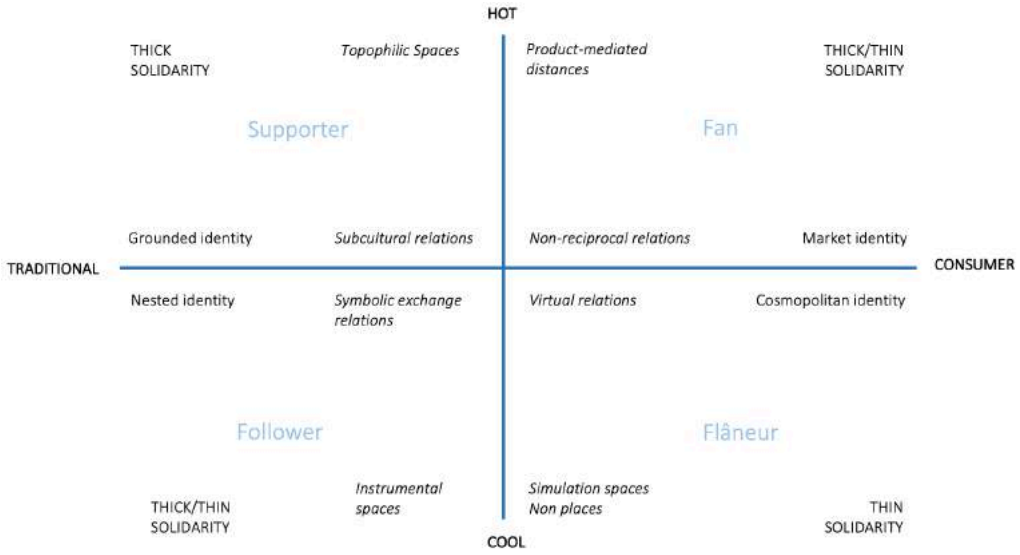


Figure 17: Four types of spectators (Guilianotti, 2002, p. 31)

4.5.5 Residence time of the spectator: around 3 hours

Contrary to other types of real estate assets, such as office space and dwellings, the residence time in stadiums during events is relatively short. In the research of Kuiken, Más, Haji Ghasemi, Blaauwbroek, van der Klauw, and Nguyen (2018) a probability density of the duration of stay of visitors who came by an electrical vehicle was studied. The highest probability of the residence time in the stadium of a visitor, in this case, is around 3 hours (during a soccer match, this can vary for other types of events). The probability density of the duration of stay of an EV at the Johan Cruijff ArenA as based on the research of Kuiken et al. (2018) can be found in figure 18.

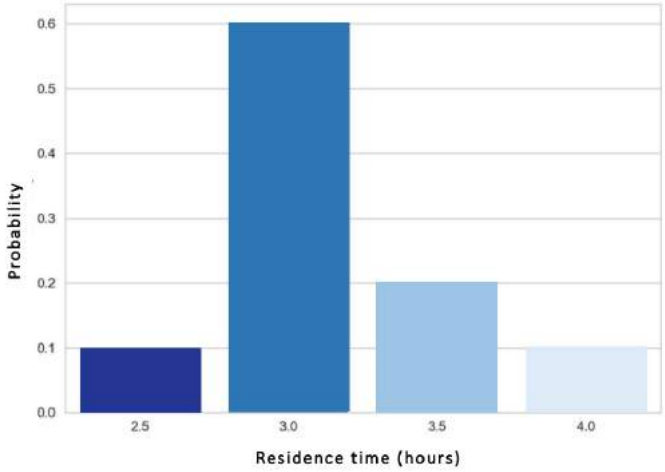


Figure 18: The probability density of the duration of stay of an EV at the Johan Cruijff ArenA (Kuiken et al., 2018, p. 13)

4.5.6 The customer journey

As stated by LaSalle and Britton (2003) societies are transforming more and more towards an experience economy, which means for building owners and facility managers that it is a challenge to create environments that enhance the user experience. Previously, building owners and facility managers focussed primarily on usability which is related to efficiency and effectiveness. While the user experience involves human experience dimensions. By using the Customer Journey Method this human experience is added, which includes perceptual and emotional components over time (Nenonen et al., 2008, p. 54). This method is very suitable in relation to a stadium because a stadium focusses very much on the spectator experience.

According to Richardson (2010), the customer journey map is a very simple idea whereby a diagram illustrates the steps your customer goes through in engaging with your organization, which is in this the stadium experience. This concept of the Customer Journey is a combination of customer satisfaction and the experience, which combines outcome-oriented objectives with the process. This combination provides the possibility to gather valuable data that can uncover small details that affect the visitor experience. In order to gather data, interviews and personal diaries are suitable techniques (Halvorsrud, Kvale & Følstad, 2016). According to Halvorsrud et al. (2016), The Customer Journey consists of different steps over time, which are also defined as “touch points”. These “touch points” are mapped in the process over time which results in the planned customer journey. The planned customer journey be visualized by using symbols and colours (Gustafsson & Johnson, 2003). The planned customer journey can be analysed in order to identify problems and see where data is missing to deliver the experience.

As seen in the research of Panchanathan, Chakraborty, McDaniel, Tadayon, Fakhri, O’Connor & Monaghan (2017) smart stadium project that enriches a fan’s experience were identified by considering the entire ‘journey’ of an event attendee. They stated that the fan's journey may include extensive preparation, planning and coordination for transportation to and from the stadium; their involvement on social media channels leading up to a live event as well as during and after the event itself; and activities carrying over to relevant events and activities happening before, during, and after the stadium event itself (Panchanathan et al., 2017, p. 3).

Also, in this research, this method will be used. Two customer journeys are developed from two different perspectives: the stadium management perspective and the spectator perspective. For these customer journeys, the framework of Richardson (2011) is used. For every step over time, the framework focusses on four subjects. Richardson explained these steps as:

1. Actions: What is the user doing at each stage? What actions are they taking to move themselves on to the next stage?
2. Motivations: Why is the user motivated to keep going to the next stage?
3. Questions: What are the uncertainties, jargon or other issues preventing the user from moving to the next stage?
4. Barriers: Wat structural, process, cost, implementation, or other barriers stand in the way of moving on to the next stage?

Besides the four subjects, the element of "touch points" are added, based on the previous explanation. The emotion is added as an important element of the spectators' experience (Gustafsson & Johnson, 2003). The journeys are based on literature review, personal experiences and observations, and interviews. Customer journeys are constructed from the spectators' perspective. The customer journey gives a better idea of understanding user preferences and experience. The customer journey can be found on the right page.

CUSTOMER JOURNEY SPECTATOR.

	HOME				STADIUM			BAR | HOTEL | RESTAURANT | HOME	
	Announcement of event	Ticket sell	Preparation & Mood making	Transportation to the event	Check-in stadium	Waiting in stadium before start of the event	Live event	Event ended: leave stadium	After event: re-experience the event
	 								 
ACTIVITIES	The visitor get informed and is aware of the event by (social) media channels, social activities, or other.	The spectator visits an online platform to buy a ticket or goes to a shop to buy physical ticket.	Reading news items about the live event. Spread the news with social connections that you are going to the event. Prepare for the transportation of the event. Print the ticket.	Reaching the stadium based on the best transportation method. This can be by public transport, private car, or by bike. Also different combinations are possible.	Arrival at the stadium. Find the right entrance gate. Waiting in the line to check-in the ticket. Eventually food and beverage consumption around the stadium, purchase of merchandise.	Use of facilities, such as toilets, food and beverages. Find your seat in the stadium. Social sharing of your experience through media channels. Connect with Wi-Fi.	Live experience, focus on the events. If available, watch replays on HD screens. Take pictures of the event. Enjoy food and beverages. Support the the team.	Leave the event, find out the best transportation method to leave.	Leisure activities: Restaurants and cafes. Re-experience the match experience. Watch highlights at home. Share social media updates.
MOTIVATIONS	As a result of personal bonding, social pressure and mood making, the visitor really want to go to the live event.	The spectator does not want to miss the event, this perspective keeps the fan motivated to continue.	Excited to go the event. Important to find out how to go to the event and how to check in there.	Motivation is to be on time at the event. Don't want to miss a minute. Strive for the most comfortable and cheapest option. Don't want to be surprised by changes in the transportation plan.	Excited to be in the stadium on time and experience the ambiance. Don't want to be late and be certain of a proper seat.	Start well-prepared for the event. Excited for the live event. Visitors care about the view and surrounded people.	Don't want to miss a single moment of the match. Emotions are affected by the results during the match.	Leave the stadium most efficient, with as less nuisance as possible.	Discuss the match experience Hungry and thirsty after the event.
QUESTIONS	When is the event? Do I already have other plans that date? With whom are we going? Where is the event?	Where to buy the tickets, are there enough tickets and how expensive are the tickets?	What is the best way to go to the event? What do I have to bring to the event? Do I have to print my ticket? Do I have to bring food?	Will I be on time at the event? Is there no delay in arrival time? Is there enough parking space? Are there no other uncertainties?	Where is the gate where I have to check in (way finder)? Where did I left my ticket? Which queue is the quickest?	Where are the facilities? Where is my seat? How do I feel? Am I hungry or thirsty? Can I go to the toilet? How is the view? How are the people surrounded by me? Will I be on time when buying food or drinks?	What is the best moment to use the facilities? When shall I take a picture?	Where is the closest exit? Where do I have to go? Where is it not crowded? Is my transport not delayed?	What is a nice place to have a drink? Where can I watch the highlights? Where is a place left? What's on the route home?
BARRIERS	Other plans at the date of the event. Nobody is able to join to the event. The event is unreachable within time and budget.	Costs of the ticket, availability of the ticket and the effort it takes to buy the ticket. Performance of the sports club.	No transportation means available. No possibility to print the ticket. Costs of transportation are too high. No possibility to park a car.	New uncertainties that will influence the estimated time of arrival at the event.	The waiting time in the line. The wayfinding of the right gate.	Long waiting lines for the different facilities. Bad view on the pitch. Annoying people surrounded by the seat.	The end-result of a live sports event impacts the emotion of the visitor.	Crowded area's. Long waiting times. Transportation issues.	Too crowded. No the right location. Too expensive.
TOUCH POINTS	(Social) media channels	Online platform for ticket sell (and ticket resell), ticket shop	(Social) Media channels & Transportation planner	Transportation services and transportation infrastructure	Ticketing check in, queue management, F&B facilities, merchandise sale.	Safety management, stadium facilities (F&B / toilets), waiting lines, way finder, Wi-Fi.	Live experience, Wi-Fi, safety, emotions	Transportation services.	Leisure facilities, social media.
EMOTION	Excited	Irritated	Anticipation	Hurried	Stressed	Excited	Joy *(anger or happiness, depends on the result)*	Hurried	Relaxed

Figure 19: Customer Journey of the spectator (own illustration)

4.5.7 Five phases of the visitor can be distinguished in the customer journey:

So, based on the constructed customer journeys, a more schematic customer journey is made whereby different phases are integrated. This schematic customer journey can be found in the appendix. Five different phases are distinguished in this model for the visitors of the stadium based on their time and location. These are:

1. Outside the stadium before the event
2. Inside the stadium before the event
3. Inside the stadium during the event
4. Inside the stadium after the event
5. Outside the stadium after the event

The potential of smart tools by measuring real-time information about space-use in the stadium could add value for these different phases. The images illustrate examples of the potential of smart tools within the different phases of the customer journey. The images can be found on the next two pages.

Outside the stadium before the event: navigate the visitor based on real-time information and reduce stress

The visitor is heading to the stadium.

Traditionally, people are using their mobile device to find their way to a stadium.

However, a stadium is so big and busy. Which entrance does I have to take?

Smart tool advices visitor which gate he/she has to take based on real-time information.

Due to the tool, the visitor is on time within the stadium, missing not a single minute of the match.

Inside the stadium before the event: speeding up the entry in stadium

Long queues are in front of the stadiums. The stress level of the visitors increase. The don't want to miss any minute.

Tickets are scanned based on RFID.

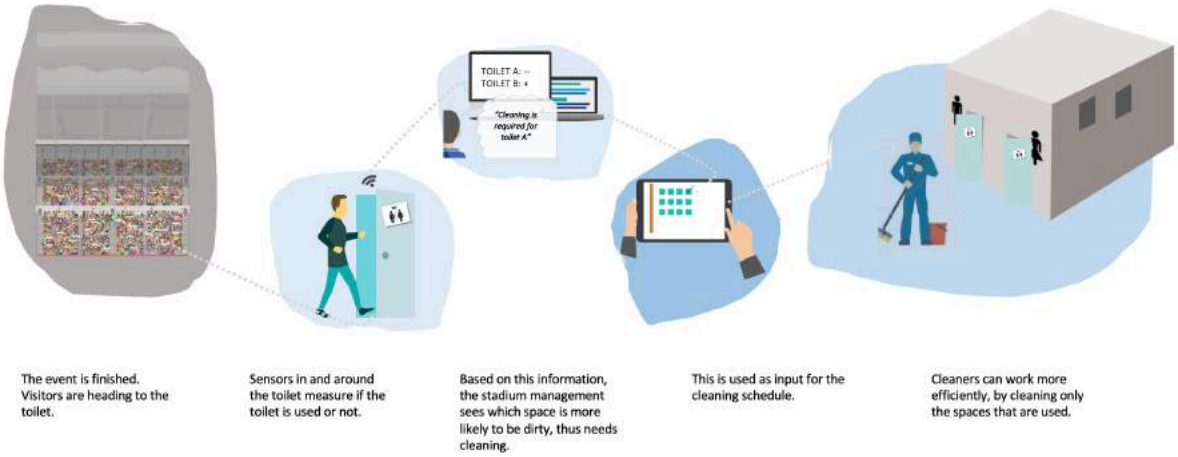
The stadium management is provided with real-time information due to the smart tool about how busy it is in front of the stadiums.

Based on this information, extra gates can be opened.

The flow has increased due to the extra gate, improving the visitors satisfaction and safety.

Inside the stadium during the event: optimize commercial opportunities

Inside the stadium after the event: efficient cleaning services



Outside the stadium after the event: enhance safety and security

Figure 20: Opportunities for smart tools in the five phases of the customer journey (own illustration)

4.6 Financial

Investments in innovation and new technologies can be seen as additional expenses for stadiums, which will impact their financial position. That is why it is important to understand the business case of stadiums which includes resources, operating costs and the financing of a stadium. In the end, implementing a smart tool will only be attractive for a stadium if it is worth the investment. This marks the relevance of the financial perspective of a stadium in relation to the integration of smart tools.

4.6.1 Business Case of a stadium

The business case is an explanation or set of reasons describing how a decision will improve business and how it will affect costs and income and attract investments (Cambridge Dictionary, 2019). Every stadium is unique with a different kind of facilities, which is reflected in a unique business case. However, business cases often contain the same elements, which are the following:

I. Initial investment costs: what are the required initial investment costs?
II. Operating phase: how will the net cash flow look like?
III. Financing: who will invest in the project?

As stated by Sartori and Nienhoff stadiums are valuable assets on clubs' balance sheets and can play a key role in achieving financially long-term success. However, stadium developments are quite capital intensive, whereby the costs of relatively small facilities are quite high (Sartori & Nienhoff, 2013, p. 3). That is why it is Important to develop a robust business plan, whereby stadium owner and operators are thinking ahead and identify expected expenditures and revenues over their planning. An important note is that the business plan has to consider that the sports-performance of the club will vary over time and that will impact the visitor attendance and the ticket price.

Expected revenues and the investments cost operating models

The different income and expenditure elements of stadiums can be found in table 6. An important factor that affects the revenues and investments of a stadium is the amenities and facilities of a stadium. Modern venues allow new operating models due to the possibility to host a different kind of events. For example, stadiums that can close the roof can organize other types of events. This could lead to more incomes for stadiums, because the stadium can be leased more often. That's why in table 6 a distinction is made between the standard incomes and expenditures of stadiums, and the ones related to the extra facilities of a stadium. Important to consider that incomes from ticketing go to the clubs and event organizations, while these organizations are in charge of paying the lease to the club. In table 6 this called "rental". Changes in additional expenditures, such as new construction and maintenance activities, are driven by the increase of the visitors' price (Sartori & Nienhoff, 2013).

In the end, deducting the expenditures from the costs a net profit or loss for the stadium can be calculated. For the exact net profit, interests, taxes, depreciation and amortization have to be considered.

Table 6: Incomes and expenditures of stadiums

Income (+)	Expenditure (-)
Standard	
Rental for live matches by sports club	Staffing
Sponsoring	Maintenance / Construction
Catering (Food & Beverage)	Energy & Utilities
Parking	Cleaning, Security
	ICT costs

	Technology
Dependent on facilities	
Rental for concerts / business events / dance events	Office costs
Office rent	
Innovation	
Tours / Sightseeing	
Consulting	
Net profit after interests, taxes, depreciation, and amortization.	

Financing

The financing of a new stadium development requires an investment budget. For new stadium developments the financing can be divided into two different phases:

1. Building phase: from start development and the building completion;
2. Operating phase: from the start of the exploitation.

As seen from the financial structures of recent stadium developments in Europe, the finance structures contain both equity and debts. The parties that are typically involved in the finance structure are:

- (Inter)national Banks;
- Institutional and private investors;
- Common equity by Municipality;
- Common equity by stadium;
- Common equity by social foundations;
- Common equity by the sports club.

This is in line with the interests of the parties as seen in the organizational structure as presented in paragraph 4.3. The ratio of the different elements is case specific. After the investments are done, a 'cashflow waterfall' is used which represents the project's cash flow. The waterfall shows the priority of each cash inflow and outflow. This method makes sure that debt services (principal repayments and interests paid) and distributions are done with priority.

As seen in the previous paragraph, there are various opportunities to measure real-time space use in stadiums. This information as gathered by smart tools can be used to improve processes that are linked to incomes and expenditures, which could lead to a better financial position in the end. So, by working data-driven by integrating tools, a lot of stadium processes could run more efficient. Which will reflect in the end in cost reductions.

4.7 Conclusions

Objective:	Economic: to understand the economic impact of stadium developments. Physical: to find out the physical characteristics of a stadium. Strategic: to find out who is responsible for the real estate management of stadiums and identify the key stakeholders. Functional: to understand the functional characteristics of stadium users and stadium management. Financial: to understand how the business case of stadium functions.
Question:	What are the characteristics of a stadium and how is this related to the need for smart tools?
Method:	Literature study

To understand the characteristics of a stadium five different perspectives are researched. The need for integrating tools that measure the use of space can be argued based on the findings from these different stadium perspectives. This resulted in the following conclusions:

Table 7: Characteristics of the stadium from five perspectives

 Economic perspective	Stadium developments can have an economic impact on the (local) area, however, this is on a lower scale than policy makers often claim. It is used as justifications for investing with public money. Stadium development can be used as a driver for new area developments. The smart tool can contribute to improve the image of a stadium for policymakers and to utilize the potential for 'smart-city concepts'.
 Physical perspective	Stadiums contain more and more different functions (office space, leisure), which can affect the type of tools needed. Stadiums are located in or around city centers, in urban areas, which means that events have a high impact on the infrastructural network and stakeholders. This can affect the need for smart tools: a lot of visitors and employees during a short period of time means an intense space use (both inside and outside the stadium).
 Strategic perspective	Stadiums are typically a combination of a partnership with sports clubs, municipalities, and other investors (also identified in the financial perspective). their interests are reflected in the stadium policy. Need for smart tools is strongly connected to the objectives of these 'partners. These have to be considered in smart tool investments and ambitions.
 Functional perspective	The most important user is the spectator as a visitor: visiting a stadium is all about offering visitors the best experience that requires extensive preparations. The visitors' experience is made understandable by constructing a 'customer journey'. The customer journey reflects the different critical touch points of a visitor, that can be solved by integrating smart tools. For the critical touch points in the customer journey, smart tools could contribute to adding value to these situations. Examples are visualized in this research. Besides the visitor, the smart tools can contribute to the activities of the stadium management. Which is mainly the operational part of the stadium.
 Financial perspective	Integrating tools seem to affect the different income and expenditures of a stadium, which shows that it has the potential to optimize a stadiums' business case. The most important income for the stadium organization is hiring out the stadium for events. Integrating smart tools can lead to a reduction in costs or create extra revenues, which can impact the financial situation of stadiums. Also, by creating extra value for the visitors by tools, it can lead to better competitive advantage to the stadiums.

5. The Smart Stadium

Smart as an adjective means to be quick or prompt in action. However, that sounds strange in combination with a sports stadium. Nowadays it is a trendy definition to use, but the exact definition is quite vague. In this section, the theoretical body of knowledge of the smart stadium concept will be discussed. This chapter aims to answer the sub-question: what are the characteristics of a smart stadium? Firstly, the research field is explored, before comparing different smart stadium theories. Lastly, it contains an exploration of the research field of smart stadiums.

5.1 Exploration of the research field

According to Scopus, research on the topic of smart stadium originated in 1998. In that year, the terminology of a "smart stadium" was defined for the first time. In this article of Coover (1998) he defines the Arizona Diamondbacks' as a "smart stadium". This is due to the fact that this is the first professional sports facility that integrated more than ten different communications and technology systems platforms into one functioning system (Coover, 1998).

However, this definition did not establish a foothold in the scientific body of knowledge; the rise of defining sports facilities smart starts around 2015. The trend of defining stadiums as smart seem to gain more scientific attention in the past few years. This can be explained by the growing role of "smart city" concepts. According to Bélissent (2010), a smart environment uses the information and communications technologies to make the critical infrastructure components and services of a city's administration, education, healthcare, public safety, real estate, transportation and utilities more aware, interactive and efficient. As stated in the research of Panchanathan et al. (2017) the use of a smart stadium is a perfect living laboratory to more easily deploy and evaluate technologies of the smart city concept. Due to the size and heterogeneity of the stadium environment that is small enough to practically trial but large and complex enough to evaluate effectiveness and scalability (Panchanathan et al., 2017, p. 2). This shows the connection between the two concepts. By comparing the developments of smart stadium literature and smart city literature, it seems that the growth of the smart stadium concept was a reaction to the growing smart city concept. In practice, there are some examples that support this theory, in both Dublin and Amsterdam, the development of smart stadiums is used as a living laboratory for smart city concepts (Smart Dublin, 2016; Amsterdam Innovation Arena, 2017).

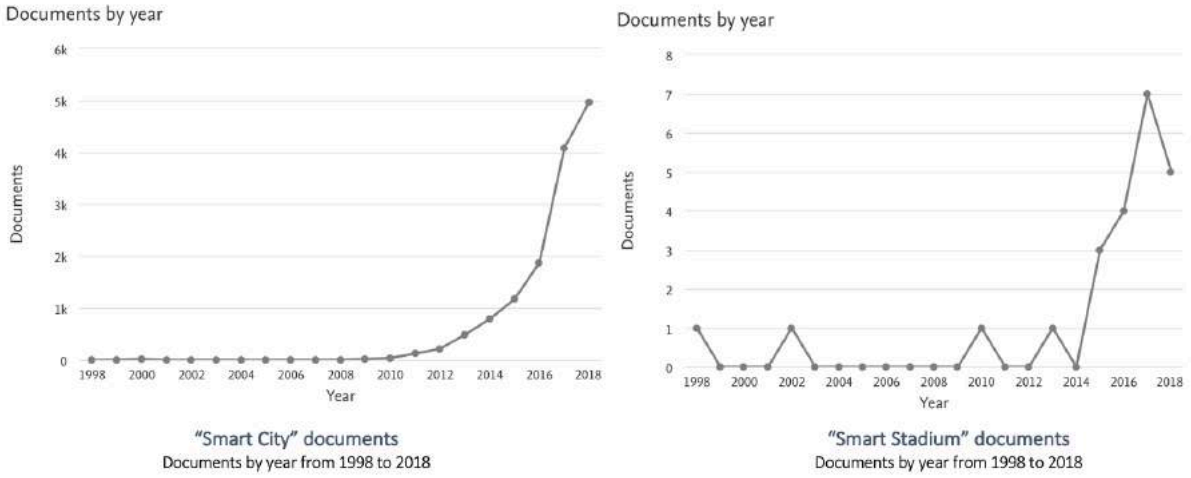


Figure 21: Documents by year for both "Smart City" and "Smart Stadium" documents (own illustration).

However, publications with the focus on smart stadiums are relatively underdeveloped. Because of the different definitions of a smart stadium (cloud-enabled stadium, connected stadium, etc.) publications were found by using on Scopus the search term of TITLE-ABS-KEY (smart AND "sports stadium" OR "Smart stadium" OR "Smart city" AND "Stadium"). In total, this resulted in only 23 publications on Scopus from 1998 to 2018, compared to 13.815 "smart city" publications. This can be explained by the recent development of the "smart stadium" concept, the lack of consensus about a "smart stadium" definition, and the niche of this topic.

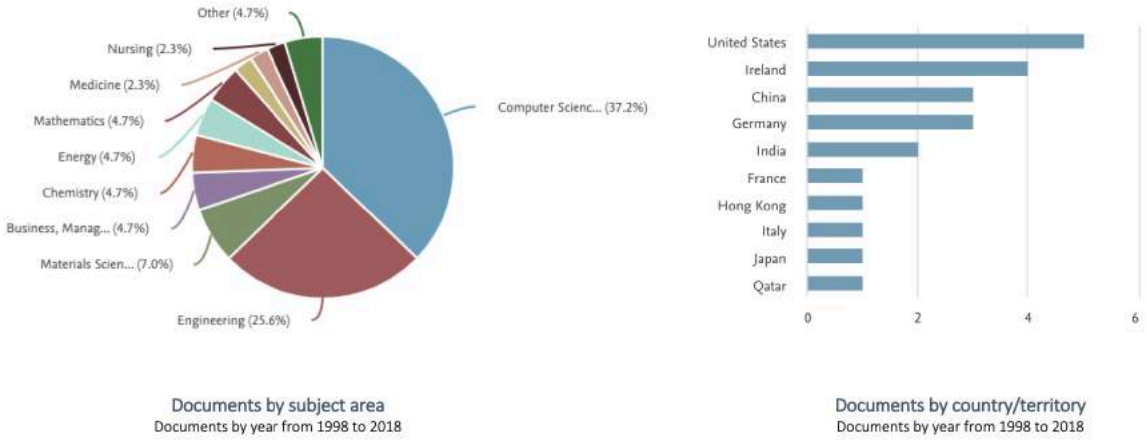


Figure 22: Documents by subject area and country/territory (Scopus, 2019)

Figure 22 presents the published documents by subject areas and country/territory. The publications by country show a diversified origin of publications, whereby The United States outperforms any other country with the most publications. More than a quarter of all the publications are related to the subject area of Computer Science. This is followed by the subject area Engineering. Other common related subject areas are Materials Science, Business & Management, Energy, Chemistry and Mathematics.

To conclude, the smart stadium concept seems to be fed with the growth of the smart city concept. However, the body of knowledge related to the topic of smart stadiums is quite limited. A lot of synonyms are also used, such as intelligent stadiums, connected stadiums, and cloud-enabled stadiums. As a result of the limited number of scientific researches, there is not a clear definition of a smart stadium and by this a lack of consensus among scholars.

5.2 The smart stadium concept

In this paragraph, the concept of a "smart stadium" will be explained. As seen in the article of O'Brolcháin, Colle and Gordijn (2018), a smart stadium can be defined as:

"the way sports stadiums are designed and managed by using smart technologies in order to enhance the experience of attending a live match through innovative and improved services for the audience, as well as for the players, vendors and other stadium stakeholders" (O'Brolcháin, Colle & Gordijn, 2018, p. 2).

The definition illustrates the importance of smart technologies as a mean to improve services for all the stakeholders involved. In their article, they added that the Smart Stadium project is in the process of turning stadiums into living labs designed to test IoT technologies. The reason for the IoT technologies is the assumption that these technologies have the potential to enhance the fan experience, improve the players and spectator's safety, and create new opportunities for stakeholder value creation (O'Brolcháin, Colle & Gordijn, 2018, p. 3). In addition to this, smart stadiums can also generate environmental benefits and the opportunity for technology developers to test their solutions and innovate them.

Wang (2016) uses two different definitions: the intelligent stadium and a smart stadium. As stated that an intelligent stadium is one of the important signs of modern sports venues, whereby automation, digital, and information developments are reflected. As a result, it cannot be unified defined if a stadium is smart or intelligent. Namely, the meaning of a smart stadium changes over time due to new developments. The base of a stadium is modern technologies, whereby over time new ideas and innovations are generated that will lead to "progress", as defined by Wang. This "progress" will give smart stadium new meaning, so as to enhance the intelligent level of sports stadiums and management (Wang, 2016, p. 82). So, the smart stadium is a solid foundation of a platform, which can be used for the development of smart innovations and technologies, which will change the meaning of the stadium.

The paper of Panchanathan et al. (2017) puts the focus, as seen in the first paragraph more on the relationship between the smart stadium and the smart city. Whereby the smart stadium is more a living laboratory of a smart city. The statement in the research is that smart cities can be characterized by the integration of open innovation frameworks in order to address the needs of the growing populace. This innovation framework can also be seen as a process. The consequence of these innovations is, from a city perspective, that cities who are performing well and excel will flourish through the creation of wealth and rises in productivity, paving the way for growth and long-term success (Hodgkinson, 2011). This explanation contains on one hand that a smart stadium can be characterized by continuous innovations, while on the other hand, it focuses on the opportunities and consequences of these integrations.

5.3 Opportunities for a smart stadium

It is an interesting proposition that a smart stadium is not a definition or an achievement, but more a process. Whereby a platform is a foundation for new technologies and innovations that will improve and enhance the experience of different stakeholder. In the definition of Wang (2016) the purpose of integrating new technologies in the stadium is lacking. While in de research of O'Brolcháin, Colle, and Gordijn, they focus on the potential advantages of the smart stadium, by the distinction of in total five different opportunities themes. These five opportunities of the smart stadium are explained in more detail.

Enhanced entertainment

This opportunity is based on the value of entertainment, whereby entertainment is considered as the experience of attending a live event in a stadium. IoT can enhance the entertainment possibilities available to many of the relevant stakeholders (O'Brolcháin, Colle & Gordijn, 2018, p. 8). There are various examples that support this opportunity. The audience can be stimulated by smart technologies to encourage greater crowd participation during games, which can enhance the entertainment value.

Commercial opportunities and improved customer service

Smart stadiums have the opportunity to provide the promotion of commerce. As stated by Bale (2000), stadiums are becoming 'tradiums', where leisure is linked with spending (Bale, 2000, p. 93). There are a lot of good reasons to promote commercial opportunities and customer services. As seen in the previous chapter stadiums are economically significant entities, which can bring commercial activity to an area, create employment, and earn revenues. Also, audiences will benefit, as the smart stadium innovations will make it easier for audiences to purchase goods and services more easily (O'Brolcháin, Colle & Gordijn, 2018).

In the research of Panchanathan et al. (2017), the focus is on enriching the fan experience, whereby one of the impact fields is efficiency and convenience of the spectator. During this project, the focus was on understanding the wait time and queue estimation during an event of the spectators. The spectator was providing access to wait times at restrooms and concession stands via a mobile app. Consequently, it allows fans to maximize their time

watching and enjoying a game rather than waiting in long lines during the course of a game (Panchanathan et al., 2017, p. 17).

Enhanced Safety and Security

With such large gatherings of people, as seen in stadiums, there are significant risks to public safety. By improving the understanding of the behaviour of large crowds of people within a stadium can help maintain safety and security (Panchanathan et al., 2017, p. 4). Large crowds in relationship with the use of IoT technologies have the potential to improve people's safety and security (D'Orazio & Guaragnella, 2014; Jargalsaikhan et al., 2015; Georgievska, Rutten, Amoraal, Ranguelova, Bakhshi, de Vries & Klous, 2019). As seen in earlier tragedies, crowd disasters have taken many lives and are a serious threat in stadium environments. The Love Parade disaster in Duisburg, 2010, the Ellis Park Stadium disaster in Johannesburg, 2001, the PhilSports Stadium stampede in Manila, 2006, are just a few examples. One of the major factors contributing to crowd disasters is critically dense spots (Georgievska et al, 2019). Sensor technologies will be able to determine whether crowds are behaving and how this have an impact on the safety of visitors. As a result, emergency situations can be detected earlier and that the response time will be more rapid.

In addition to the crowd control, technologies can also enable security or health services to respond quickly on emergencies and facilitate security for criminal and terroristic threats (O'Brolcháin, Colle & Gordijn, 2018, p. 9). Technologies could also be used in the aftermath of an event to detect anti-social abuse and violence in the stadium.

Sustainability, Reduced Environmental Impacts, and Energy Costs

In a time where the importance of sustainable developments, the environmental impacts of sporting events are commanding increasing attention. Quantifying the environmental impact of sporting events will become increasingly important. Sustainable development commitments become more mainstreamed (Collins, Jones & Munday, 2009, p. 837). In order to better understand the working of a stadium, sensor technologies can inform the stadium management about waste products, air quality, carbon footprint, energy consumption. This information can be made available in real-time and over the course of the life of the stadium (O'Brolcháin, Colle & Gordijn, 2018). Sensors can also be used to detect the status of the property, which can be linked to property and maintenance services. For example, sensors could detect if there is something broken in the stadium which has the be repaired.

In the end, the insights are valuable for reducing the stadium resources, utilize energy more efficiently, and managing and reducing noise and emissions. Also, costs can be made more explicit. This will make such costs visible and better considered. Which can also lead to a reduction of environmental impacts and energy costs.

Athletic Performance

As stated by O'Brolcháin, Colle and Gordijn (2018) another opportunity of a smart stadium is to improve the athletic performance. Data gathered from athletes can be used to analyse their performance and by these insights improve the performance. Due to modern technologies, motion sensing is made more accessible and prevalent than ever before. Multimodal feedback is more and more ubiquitous through the introduction of haptic, visual and audio feedback mechanisms in different devices. In addition to this, we see also that there is a rise of low-cost motion-sensing hardware (Panchanathan et al., 2017, p. 4).

5.4 Conclusions

Objective:	To find out what characterized a smart stadium and what kind of smart tools can be identified
Question:	What are the characteristics of smart stadiums?
Method:	Literature study

To conclude, the five opportunities as stated in the research of O'Brolcháin can be used as a goal for integrating new technologies in a stadium. But this does not mean that a smart stadium has to focus on all five opportunities. The five opportunities can be considered as guidance for stadiums; they demonstrate what the opportunities are to invest in innovation. It does not mean that these five opportunities are a checklist for a stadium to be classified as a smart stadium.

Smart stadiums can be characterized by the integrating of new technologies, such as smart tools. As a consequence, it can affect the five different opportunities of O'Brolcháin. It also means that integrating smart tools can contribute to becoming a 'smarter' stadium.

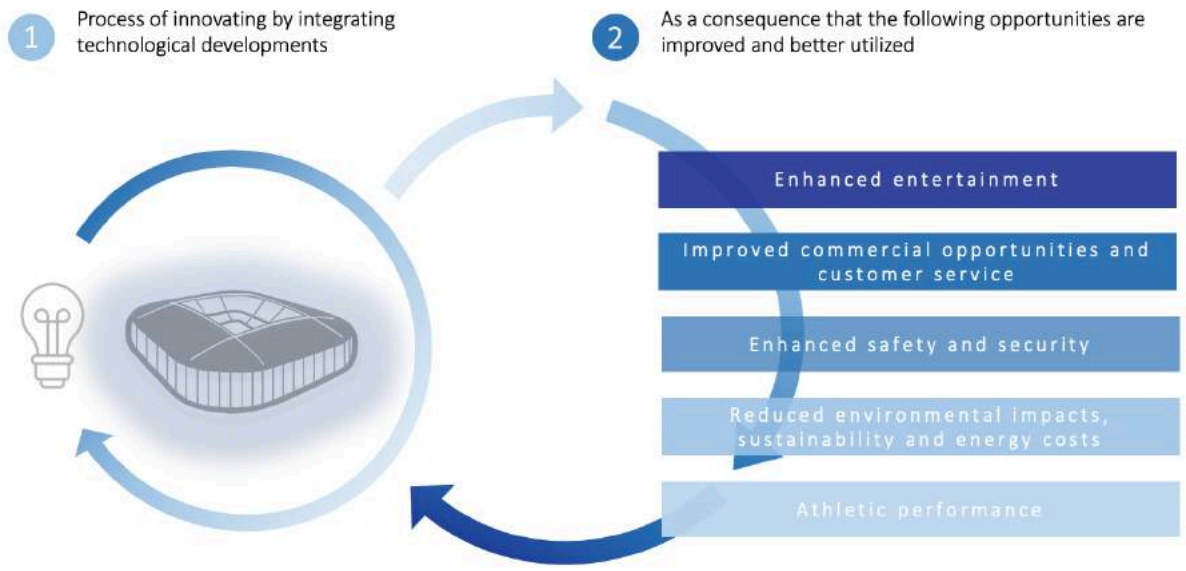


Figure 23: Smart stadium principle: process of innovating in order to utilize typical stadium opportunities (own illustration).

PART 3

PRACTICES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6. Case study: The Johan Cruijff ArenA

This part contains the empirical part of the research, which contains of the case study of the Johan Cruijff ArenA. Firstly, the selection of the case is explained and introduced. After this, the different smart tools are assessed, explained and analyzed.

6.1 Case selection

A method to obtain empirical knowledge is the use of a case study. This research consists of a qualitative research design, which means that an information-oriented selection procedure is the most appropriate to conduct a case study analysis (Yin, 2014). The objective of conducting case studies is to collect relevant empirical data about the integration of smart tools in a stadium.

6.1.1 Selection procedure

The case that will be used is the Johan Cruijff ArenA, which is a stadium that is located in Amsterdam. The goal of the stadium management is that by 2020 the Johan Cruijff ArenA must be the most innovative stadium in the world (Johan Cruijff ArenA, 2017) and by this create the first 'smart' stadium. The integration of smart tools and other innovations in the Johan Cruijff ArenA are among the precursors. So data from the implemented smart tools and the effects are interesting to evaluate and research. In the end, the case study of the Johan Cruijff Arena will give insights into the implementation of the different smart tools in a stadium.

6.1.2 Data collection

The next sources of evidence, as described by Yin (2014), will therefore be used while conducting case study research: (1) participant observation, (2) semi-structured interviews and (3) documentation. For the semi-structured interviews an interview protocol is used.

Semi-structured Interviews

The semi-structured interview will be used to assess the different available smart tools in stadiums. The reason to conduct these semi-structured interviews is to combine both knowledges from theory and practice, in order to come up with a complete assessment of the available smart tools for stadiums. The advantage of choosing for the semi-structured interview is that as an interviewer there is more latitude to ask further questions in response to what is seen as significant replies (Bryman, 2012, p. 212). Also, the interviewer has a series of questions that are in general protocol but is able to vary the sequence of the questions. Extensive interviews are held with specialists who are involved with the integration of new technologies in the Johan Cruijff ArenA, their names can be found in the Appendix A of this research.

6.2 Case description: The Johan Cruijff ArenA

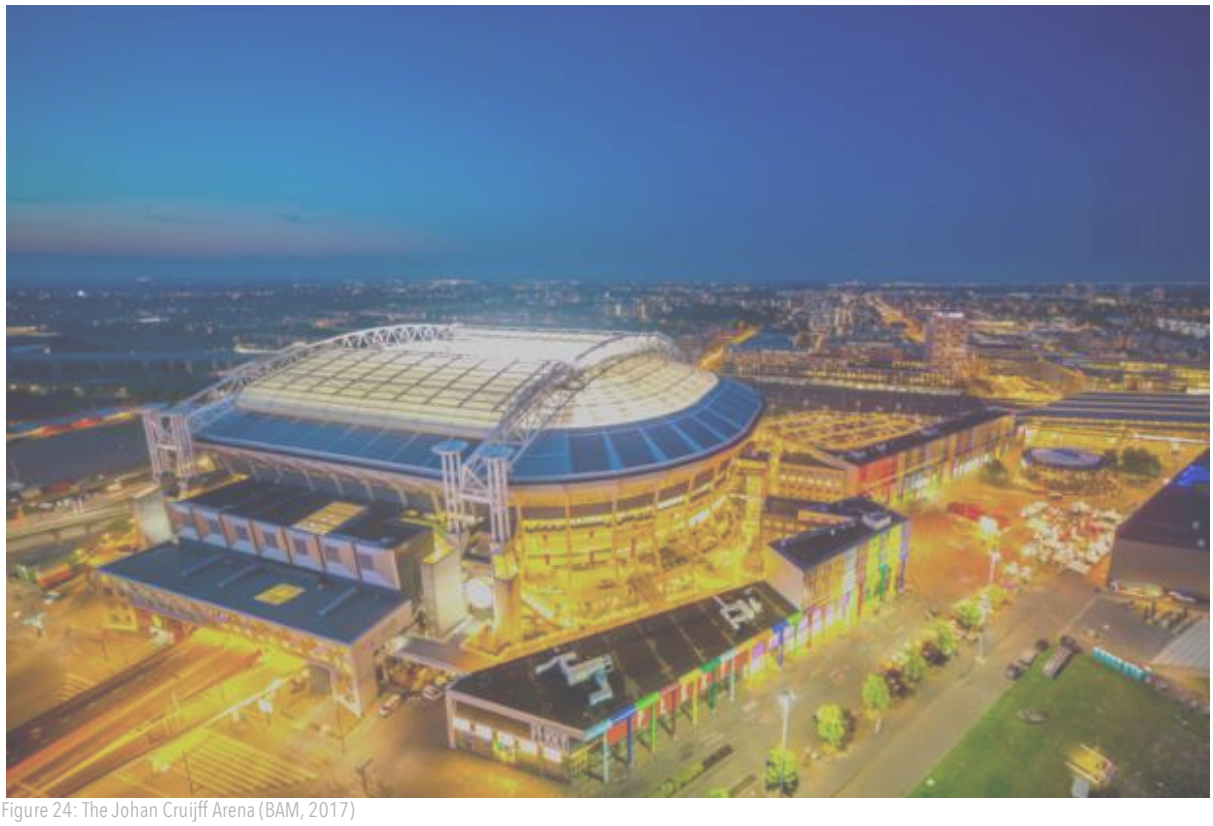


Figure 24: The Johan Cruijff Arena (BAM, 2017)

The Johan Cruijff ArenA (previous name: Amsterdam ArenA) was built between 1993 and 1996 with total construction costs of 96 million euros. The construction was executed by Ballast Nedam and Royal BAM Group and the design of the stadium was made by the architect Rob Schuurman. The Johan Cruijff ArenA officially opened on the 14th of August 1996. Nowadays, the stadium has a capacity of 53,748 seats. At that time, the Johan Cruijff ArenA was the first stadium in Europe with a retractable roof. It takes about 18 minutes to open or close the roof, which is accomplished by using 2 sliding roofs which is controlled by 8 motors. The stands have a very steep design, with on the second tier having an angle of 36,9 degrees (Johan Cruijff ArenA, 2018).

Besides facilitating soccer matches of Ajax and the Dutch national soccer team, the stadium is also used for major concerts, kickboxing events, festivals and business events. During centre-stage setups, the capacity of the stadium is extended to 68,000. Shortly after the opening of the stadium, it turned out that the grass growing conditions were very bad. The pitch had to be renewed up to 5 times a year. The Johan Cruijff ArenA resolved the problems with innovative grass growing technologies. In 2014 on the roof of the Johan Cruijff ArenA 4200 solar panels were installed, which would generate equals 10% of the stadium's annual electricity consumption (Johan Cruijff ArenA, 2018).

In 2015 the stadium presented plans to renovate the stadium's façade. The idea of the renovation was to provide better quality and services to the visitors. This was done by widening the walkway rings around the stadium. At that time, the stadium has been chosen to be one of the playing venues of the Euro 2020 tournament, which is played across different countries. This allocation also led to the acquirer of European subsidies.

In 2015, the Johan Cruijff ArenA opened an innovation centre in the stadium. This initiative was a concrete result based on the signed Innovation deal between the Municipality of Amsterdam and the Johan Cruijff ArenA in 2014. The innovation centre should lead to innovative ideas and solutions in the field of mobility, accessibility, energy,

sustainability, connectivity and the fans' experience (Johan Cruijff ArenA, 2015). At that time, Henk Markerink, CEO of the Johan Cruijff ArenA, stated that "*the Amsterdam ArenA has the ambition to be one of the world's most innovative stadiums. Innovation is in our DNA. The Amsterdam ArenA innovation centre is a platform open for everyone. It is, therefore, with great pleasure that we welcome the new innovation centre to our stadium"* (Johan Cruijff ArenA, 2015). In 2017, this ambition was specified: by 2020 the Johan Cruijff ArenA must be the most innovative stadium in the world (Johan Cruijff ArenA, 2017). In line with this ambition, the following goal was stated: "to create the world's first 'smart' stadium of the future, featuring a digital ecosystem to deliver the ultimate in fan experience, safety, sustainability, and overall efficiency" (KPMG, 2019). This Amsterdam Innovation Centre offers effective resources for research, development, and education by collaborating with the different partners. The centre can support global leading players in creating innovations for smart stadium solutions.

6.3 Technical layer & data governance

During the interviews, the technical layer of the stadium was obtained. The technical layer can be seen as the technology infrastructure of the Johan Cruijff ArenA, which is explained in more detail in this paragraph.

6.3.1 Technical layer

The data input for the smart tool can be divided into different elements as also discussed in chapter 2. The data collection and sharing is done in an open ecosystem, which is the technical layer or also known as the basic technology infrastructure. The technical layer of the Johan Cruijff ArenA can be divided roughly into four steps that process the data to input for the smart tool interfaces. The technical layer consists of (1) data sources and Application Programming Interfaces (API's), (2) the signals storage, transformations, stream analytics, (3) (historical) data storage and transformation, and (4) (advanced) analytics.

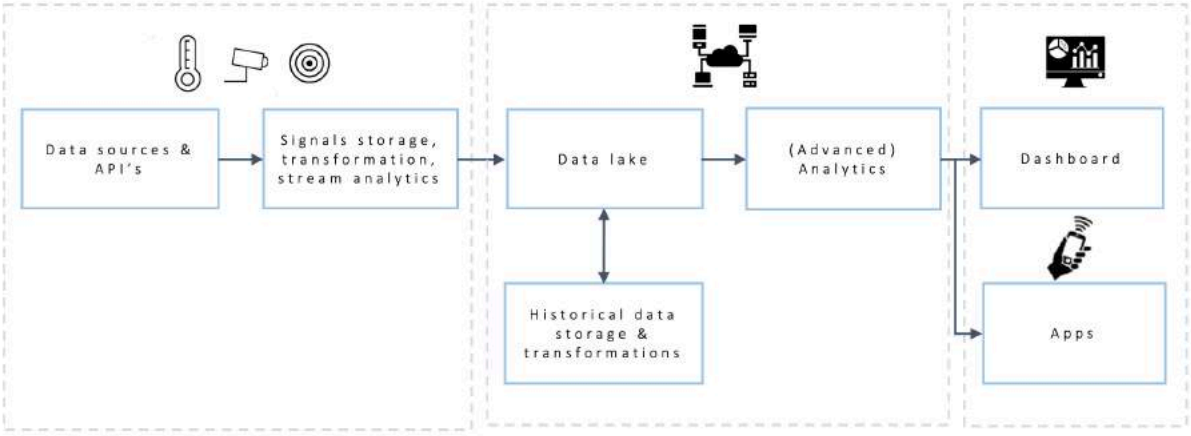


Figure 25: Technical layer Johan Cruijff ArenA (own illustration)

Data sources and API's

Data is interfaced from different signal systems and sensors (internal/external) to a central location. The data sources can have their own API or new API's can be developed. Application programming interfaces allow developers to build apps and other solutions by using stadium information.

Signals storage, transformations, stream analytics

The data from the signal systems and sensors come together to one central place. It contains different types of data: structured, semi-structured and unstructured data. Dependent on this type of data, transformations have to be made in order to deliver sustainable data quality. This data is placed into a data lake. Within the data lake, there is a data warehouse which contains raw, structured data. As described by S. Jeurissen, the data lake is the basis where all the available data is collected:

"Theoretisch is een data lake een centraal punt waar ze alle data opslaan. De doelstelling van de Johan Cruijff ArenA was dan ook van de afgelopen twee jaar om alle IT systemen daar op aan te krijgen. Wat ze doen is van het operationele systeem een periodiek en abstract te maken en dat erop te zetten. En de data lake is de basis voor alles. Daar kan je in grasduinen en zoeken naar alles en analyses op draaien" S. Jeurissen (personal communication, April 1, 2019).

Historical data storage

This is also a central place where all the historical data comes together, which is based on previously collected data. The 'older' the system or building the larger this amount of data becomes. Historical data can give insight in how the stadium is used during certain periods, based on previous use. The historical data can be analysed with the data from the data lake.

Advanced analytics

The data from the data lake and/or the historical data storage is analysed via descriptive analytics (explorative), predictive analytics (forecasts and machine learning), or prescriptive analytics (scenario evaluation).

Dashboard / Apps

Based on the analytics the data can be visualized based on the goal of the tool. The dashboard and apps are tailor made based on the demands and preferences of the user. Important to notice is that in order to develop a smart tool, the needs and demands of an organisation need to be clear. As emphasized in the interview with C. Disseldorp:

"Eerst van belang om de behoefte te begrijpen, welke data is er al en mist er nog iets. Dan sensoren toevoegen of andere manieren om data te verkrijgen (ruwe data). Dit is dan het fundament voor het data lake en ultiem gezien de front-end tooling en smart tool." C. Disseldorp (personal communication, April 18, 2019).

6.3.2 Data governance

The data collection and analysis is done in an open ecosystem, where different people have access to the data. This requires a good governance framework whereby the right people access the data. In order to do this, the Johan Cruijff ArenA employed six full-time equivalents in a control centre who are responsible for the data governance. The data governance of the Johan Cruijff ArenA is done according to guiding principles. The guiding principles of the data governance guarantee the quality, lifecycle, automation, control and responsibilities of the data.

6.4 Assessment of smart tools

So, based on the results of the interviews, different smart tools that are integrated within the Johan Cruijff ArenA were distinguished. For each of the smart tool, templates were filled in during the interview as far as possible or afterward by the interviewer. The different smart tools are illustrated in the next sections and displayed in alphabetical order. The assessment of the different smart tools is based on the structure as used in the research of Valks et al. (2016). For some of the smart tools, impressions of the tools have been made available to publish, these can be found in the Appendix. For the other tools, no permission was given to publish these impressions, because it contains sensitive information.

6.4.1 Smart tool: Cash registers

PHASE	DURATION	STAGE	ACTUALITY
Implementation	April 2018	Monitoring & Control	Real-time

Project description

The whole cash desk system in the Johan Cruijff ArenA is recently renewed, which are connected to a POS System. The POS System is a power bank that is connected with one cable, which contains the power supply and the internet connection. The power bank gives an external signal to the payment terminals and the cash desk system. The employee selects the product on the cash desk system, whereby a signal is given to the payment terminal. As soon as the payment is done and processed, a signal will be transferred back to the cash desk. The paid products are processed in the cash desks database, which is linked to the Johan Cruijff Azure server and data lake. Based on the input in the data lake, a power BI dashboard is made. Based on this, a real-time variant, varying between 2 to 3 seconds, that gives insight in all the payments and type of payments which are done. At this moment, the dashboard is used mainly for monitoring the payments during the events. There have been some trials with 'early-bird', whereby new events are prepared based on experience from previous events. Also, tests have been done to the efficiency of employees within one kiosk, whereby the kiosk manager could steer employees on their performance.

Foreseen developments

On the long term, based on monitoring the performance of each sector in the stadium, decisions can be made related to adding extra kiosks or expanding the current square metres. Based on a recent extension in the Johan Cruijff ArenA whereby extra square metres were added, it resulted in higher sales. A second future development is that a profile can be set up for different types on events saving data that turns into historical data. This profile shows the expected characteristics of the event, whereby the operational preparations can respond to this. Another possible foreseen development is the concept of seat delivery during the event. Whereby the employees are used more effective, while the visitors can be unburdened of going to the kiosks.

"Het dashboard leert welke producten het beste renderen en welke kiosken het beste draaien. Op basis van deze informatie moeten we het stadion logischerwijs op de juiste plekken verder uitbreiden en eventueel extra verkooppunten creëren" W. Hegen (personal communication, April 15, 2019).

Profile

Table 8: Profile of the cash register tool

Why: Objectives	To get better insights in the sale of the different products and thus increase the revenue by creating better predictions of the sale of different type of products per event and a better idea of the required supply.
Why: Goals (Strategic, Functional, Financial, Physical)	1. Financial – decrease costs (increase revenues) 2. Functional – support user activities, increase user satisfaction 3. Strategic – stimulate innovation
What: Measurement (Frequency, Occupancy, Identity, Activity)	Frequency, Occupancy & Activity: Payment transactions linked to cash register.
How: Measurement method (Manual, booking, sensors)	Sensors
User information	User: Real-time information about a lot of variables (the type of transaction, the amount, the type of products, the location, time, number of orders, average, bars per sector, type of payment). This shows real-time how busy the different kiosks are. Management: The data in reporting goes from real-time to as far back as possible, and will be stored in order to do historical analyses and improve the catering offering during different types of events.
Access level	Management Johan Cruijff ArenA, Department Operations.
Benefits (what is the progress since implementing the tools)	The data confirms that the extension of a sector did lead to higher revenues for catering transactions.
Partners	-

6.4.2 Smart tool: Cleaning

PHASE	DURATION	STAGE	ACTUALITY
Product development	February 2019	Optimization	6 hours (4 times a day refreshed)

Project description

A dashboard is being developed whereby the booked spaces, the duration, and the price of the spaces are shown. This dashboard is used by the cleaning services to know which spaces they should clean. The input for the SEM dashboard is done manually based on the confirmed booking, whereby the dashboard is refreshed four times a day.

Besides this, there has been a pilot study done to a more real-time method to measure the use of space by Arduino sensors. This was done in a collaboration between the Johan Cruijff ArenA and the Amsterdam University of Applied Sciences. However, this project has never set ground.

"Het dashboard zal leiden tot lagere kosten voor het schoonmaken en minder werk voor de schoonmakers" N. Zootjes (personal communication, March 25, 2019).

Foreseen developments

At this moment of writing, the dashboard is under development. The next development is that the dashboard will be used by the cleaning services during their daily operations. Based on this experience, the use of the tool can be optimized. Another possible development is the integration of the crowd dashboard based on Wi-Fi tracking with the cleaning services.

Profile

Table 9: Profile of the cleaning tool

	Why: Objectives	A more efficient approach and scheduling in order to reduce the costs of cleaning operations.
	Why: Goals (Strategic, Functional, Financial, Physical)	1. Financial - decreasing costs 2. Functional - support user activities
	What: Measurement (Frequency, Occupancy, Identity, Activity)	Occupancy
	How: Measurement method (Manual, booking, sensors)	Booking
	User information	User: the user, which are the cleaners, are informed which spaces there have to be cleaned. Management: the management knows which spaces there are booked, cleaned, and for which price. This data is refreshed 4 times a day.
	Access level	Facility Management of the Johan Cruijff ArenA
	Benefits (what is the progress since implementing the tools)	Not available
	Partners	-

6.4.3 Smart tool: Crowd Control

PHASE	DURATION	STAGE	ACTUALITY
Research and product development	December 2018	Monitoring	Near real time

Project description

The crowd density in the Johan Cruijff ArenA is estimated by anonymous, non-participatory, indoor Wi-Fi localization of smart phones. This is done by detecting the MAC addresses by Wi-Fi access points (API's). The Wi-Fi signals that are transmitted from phones are captured by Wi-Fi access points. These captured signals contain information about the measured received signal strengths (RSS). Based on this information, an estimation of the coordinates of a visitor can be given (Georgievska, Rutten, Amoraal, Ranguelova, Bakhshi, de Vries, and Klous, 2019, p.3). The Wi-Fi tracking is done inside the stadium, the 'ring' around the stadium, and close around the stadium.

The Wi-Fi tracking was part of a research project which was done in collaboration with the University of Amsterdam. However, the Johan Cruijff ArenA has the ambition to measure the crowd in real time during events.

Foreseen developments

Constructing a dashboard that will show the crowd movements based on the Wi-Fi tracking during the events, which can be viewed real-time.

"Het interessante is dat je bewegingen van publiek in het stadion we beter inzichtelijk krijgen wanneer het stadion helemaal leeg, ... of wanneer er essentiële momenten zijn ten tijden van een evenement" W. Hegen (personal communication, April 15, 2019).

Profile

Table 10: Profile of the crowd control tool

Why: Objectives	The goal of the tool is to better understand crowd movements in the stadium during different moments of time and to know essential moments. Whereby these insights can be used to improve safety of the visitors and to enhance commercial opportunities, such as open extra selling points and optimize advertising strategies.
Why: Goals (Strategic, Functional, Financial, Physical)	1. Functional - support user activities (safety) 2. Financial – decrease costs (increasing revenues)
What: Measurement (Frequency, Occupancy, Identity, Activity)	Occupancy
How: Measurement method (Manual, booking, sensors)	Sensors
User information	User: The Johan Cruijff ArenA itself has real-time insight into the location of the visitors and their density. It also gives a clear insight into the behaviour of visitors, especially the moments when they do use their mobile device. Management: The data will be analysed over a longer period of time.
Access level	Management of the Johan Cruijff ArenA
Benefits (what is the progress since implementing the tools)	A new method is developed for estimating indoor crowd density based on wireless technologies. The method does not rely on participation or mobility of the crowd.
Partners	University of Amsterdam

6.4.4 Smart tool: Energy consumption and battery

PHASE	DURATION	STAGE	ACTUALITY
Implementation	July 2018	Monitoring	Real-time

Project description

A dashboard is developed that shows real-time energy consumption in the Johan Cruijff ArenA. However, the dashboard is based on information from an external company which is not very detailed. In order to generate sustainable energy, a new energy system was developed. During events, it is crucial that the energy supply for the Johan Cruijff ArenA is not interrupted. Previously, the Johan Cruijff ArenA had two diesel generators which were only suitable for emergency supply. As a result, event organizers often brought their own generators. As a result, a new energy storage system was developed in the Johan Cruijff ArenA. The system uses second-life and electric vehicle batteries to store energy, which is also named a large-scale battery energy storage system (BESS) (Vo & Nguyen, 2018). Sustainable energy is generated by solar-panels (7000 m2) on the roof of the stadium. In total, the three-megawatt storage system is more reliable and efficient in supplying energy. The storage system will also support and stabilize the power grid during peak demand and supply.

"Je kan het omschrijven dat duurzame energie die je opwekt tijdelijk kan opslaan of in geval als er een overschot van energie, zodanig dat je die ook kan opslaan. Zodanig dat je die op een ander moment kan inzetten, of in geval van een noodsituatie" H. Pasman (personal communication, May 6, 2019).

Foreseen developments

The first foreseen development is to double the current battery energy storage system from three-megawatt to six-megawatt. A second foreseen development is that the energy consumption of the different spaces within the Johan Cruijff ArenA needs to be specified and the insights in the energy consumption can be linked to the energy generation (solar-panels and battery).

"Nu alleen nog inzicht in het energieverbruik van de hele Johan Cruijff ArenA, streven naar meer specifieke informatie over de verschillende ruimtes en waar de energie vandaan komt" N. Zootjes (personal communication, March 25, 2019).

Profile

Table 11: Profile of the energy consumption tool

	Why: Objectives	It is part of a sustainable agreement with the Municipality of Amsterdam whereby the main objective is to stimulate electrical transport. Better insight in order to reduce the energy consumption within the stadium.
	Why: Goals (Strategic, Functional, Financial, Physical)	1. Physical - reduce CO2 2. Functional - supporting user activities 3. Strategic - stimulating collaboration, supporting culture 4. Financial - reduce risks
	What: Measurement (Frequency, Occupancy, Identity, Activity)	Frequency
	How: Measurement method (Manual, booking, sensors)	Sensors for the battery, energy consumption is measured based on data collection from an external company.
	User information	User: The real-time the total energy consumption and supply of the (whole) Johan Cruijff ArenA. Management: the data in reporting goes from real-time to as far back as possible, and will be stored in order to do historical analyses.
	Access level	Management of the Johan Cruijjf ArenA, Tennet
	Benefits (what is the progress since implementing the tools)	Not available.
	Partners	Nissan, Eaton, BAM, The Mobility House, Huawei

6.4.5 Smart tool: Mobility Portal

PHASE	DURATION	STAGE	ACTUALITY
Implementation	January 2016	Control	Near real time

Project description

The Mobility Portal is an online platform that offers visitors to the Johan Cruijff ArenA a real-time, multimodal travel advice. The visitor fills in their location and based on this information travel advice is given to the visitor. Besides the travel advice, the visitor can also book and purchase extra services, such as parking, taxis, bus transport and hotels. The function of the mobility portal can be described as three fold. Firstly, the Mobility Portal is a service for the visitors to advice, inform and help about their mobility. Secondly, it is used as a service provider to the tenants of the ArenA. The Mobility Portal is referred to the tenants to be used in order to inform their visitors. Third, it gives the Johan Cruijff ArenA very important information about the transportation methods and the location of the visitors. Moreover, a piece of guidance can be given to visitor's transportation method.

Foreseen developments

The ambition of the mobility portal is to focus more on mobile device users. Around 60 to 70% of the mobility portal visitors are using their mobile device. Besides this, there is the ambition to advice the visitor better while they are already on their way to the event. Another ambition is to implement the mobility portal in more different venues and to integrate more services in the application. Lastly, there is the ambition to scale up the mobility portal for other use cases, but this is difficult due to the fact that there are alternative providers who offer their service for free.

"Het is echt een tool voor pre-trip. Maar als men onderweg is hebben we niet zoveel mogelijk om nog te benaderen. Dat is iets waar we nog heel hard aan willen werken" M. van Hövell (personal communication, April 10, 2019).

Profile

Table 12: Profile of the mobility portal tool

	Why: Objectives	Originally the objective was to be a 'one stop shop' for the entire Amsterdam Bijlmer area, which create sa better experience for travelers to the venues in this area. Lastly, another objective is to aim for a modal split amongst the visitors, whereby less motorised individual transport is used.
	Why: Goals (Strategic, Functional, Financial, Physical)	1. Functional – increasing user activities, increasing user satisfaction 2. Strategic – stimulating collaboration 3. Physical – reducing footprint (CO2)
	What: Measurement (Frequency, Occupancy, Identity, Activity)	Identity & Activity. The location from the visitors (identity) and the travel method (activity).
	How: Measurement method (Manual, booking, sensors)	Booking.
	User information	User: the user, which is the visitor, got advised on all the different transportation methods to the Johan Cruijff ArenA based on their preferences and location. Management: the management of the Johan Cruijff ArenA has insight into the visitor's characteristics, such as their location and their chosen transportation method.
	Access level	Open access to the portal. For the visitor characteristics it is open for the management of the Johan Cruijff ArenA and the developer BeSite
	Benefits (what is the progress since implementing the tools)	Since the mobility portal is used, already 750.000 advices have been given to visitors of the area. However, the effect of this is unknown.
	Partners	BeSite, Municipality of Amsterdam.

6.4.6 Smart tool: Smart turf monitoring system

PHASE	DURATION	STAGE	ACTUALITY
Implementation	February 2017	Optimization	Near real time

Project description

The smart turf monitoring system monitors the health and quality of the pitch based on data produced by sensors in the turf. In total, fifteen sensors are placed underneath the pitch that monitors the quality of the soil. One weather station on the pitch and four weather stations on the roof track the climate conditions. Besides this, light sensors are placed on the roof and on the field to establish whether the turf is getting sufficient light. Moreover, scanners measure the growth activity of the grass (Wageningen University & Research, 2019).

All the data are processed for display in a dashboard that is available for the grass team. The dashboard shows when the turf needs light, feeding or water in real time. Measurements the can take in order to set ideal climate conditions including humidity, air flow in the stadium and temperature.

"Hoe langer wij die top kwaliteit kunnen leveren zal zorgen voor een zo hoog mogelijke benutte exploitatie. Exploitatie betekent enerzijds de voetbalwedstrijd, welke is een slijtageslag voor het gras, maar ook tussentijds evenementen zoals een dance evenement, waardoor het gras gesloten moet worden" H. Pasman (personal communication, May 6, 2019).

Foreseen developments

The Johan Cruijff ArenA has implemented the smart turf monitoring system, but is still busy in improving the system. The most important point to improve is to find a better algorithm that can predict the status of the pitch based on historical data. Besides this, there is a lot of international interest and the ambition is to sell the product internationally.

Profile

Table 13: Profile of the smart turf monitoring tool

Why: Objectives	To improve the quality of the pitch and to optimize the operation and recovery time of the pitch.
Why: Goals (Strategic, Functional, Financial, Physical)	1. Strategic - improve quality 2. Functional - support the user experience 3. Financial - decreasing costs 4. Strategic - stimulating innovation
What: Measurement (Frequency, Occupancy, Identity, Activity)	Activity
How: Measurement method (Manual, booking, sensors)	Sensors
User information	User: The grass team of the Johan Cruijff ArenA got insight in the status of the grass pitch. Management: The data of interventions as a result of the information from the dashboard are reported.
Access level	The grass team of the Johan Cruijff ArenA.
Benefits (what is the progress since implementing the tools)	The system saves on costs and prevents waste of resources. It ensures that not too much water, fertilizer or light is used. Which requires few maintenance hours.
Partners	Wageningen University & Research, Royal Dutch Football Association

6.4.7 Smart tool: Staffing

PHASE	DURATION	STAGE	ACTUALITY
Product development	January 2019	Monitor	Near real time

Project description

In preparation of events, the Johan Cruijff ArenA has to ask stewards, medical staff, security officers, hospitality employee and catering staff. This is done by an employment agency. A lot of communication goes between the Johan Cruijff ArenA and the employment agency. Based on a request from the Johan Cruijff ArenA, the agency encodes shifts. This process consists of a lot of manual work. A new dashboard is developed which is an open platform, whereby both the external organization and the Johan Cruijff ArenA will have real time insight in how many people are needed and how many encoded their shift. This is important to make sure that enough people are available during the event. As mentioned in the interviews, it is a big challenge for the Johan Cruijff ArenA that when an event takes place, the working capacity shifts from around 60 employees to more than 1500 employees in a period of around 5 hours, which involves a lot of challenges.

Foreseen developments

Future development will be the that employees can check in at the Johan Cruijff ArenA which will give insight into the number of staff that are already insight the stadium. If this is the case, the stadium management knows better how many staff is in the stadium and which positions are taken. Based on this real-time information, it could be possible to steer the staff within the stadium. Another foreseen development is linking historical data from previous events to new events. The historical data can be used to optimize the staffing for new events based on the characteristics of an event.

"Als je al die evenementen over elkaar heen legt dat je daar weer patronen in kan zien voor nieuwe evenementen. Hier kan je dan aanvraag op aanpassen op basis van risico inschatting van een evenement, waar heb je mensen nodig, op welke plekken zijn de meeste incidenten" W. Hegen (personal communication, April 15, 2019).

Profile

Table 14: Profile of the staffing tool

	Why: Objectives	To improve efficiency in the communication: more accurate updates about the available and present personnel, and quicker response to staffing shortages. Secondly, less time consuming: reduction of interaction between the employment agency and the stadium management.
	Why: Goals (Strategic, Functional, Financial, Physical)	1. Financial – decrease costs 2. Functional – supporting user activities (safety)
	What: Measurement (Frequency, Occupancy, Identity, Activity)	Occupancy
	How: Measurement method (Manual, booking, sensors)	Booking
	User information	User: The number and type of personnel needed and encoded for an event, as visible for the employment agency and the Johan Cruijff ArenA. Management: The data for the management will be collected and compared to the different type of events. This can be used for reporting and predicting the needs of the organization of new events.
	Access level	The grass team of the Johan Cruijff ArenA.
	Benefits (what is the progress since implementing the tools)	Not implemented yet, the staffing dashboard will be used for the first time during an event in May 2019.
	Partners	Employment agency

6.4.8 Smart tool: Technical maintenance

PHASE	DURATION	STAGE	ACTUALITY
Product development	February 2017	Optimization	Near real time

Project description

The technical maintenance tool is also named as the building management system. During the past 1,5 years, the old building management system is migrated by a new system. This migration contains a complete upgrade of the sensors in the building in combination with a new building management system application. This new cloud-enabled building management platform helps prioritize building maintenance activities where they can have the most impact on overall building performance based on the sensors. These sensors give insight into the technical state of the building. Disruptions are detected earlier based on signals from the sensors. So, maintenance activities will shift from protocol based maintenance to predictive, data-driven maintenance.

"Een nieuw gebouw beheersysteem applicatie is neergezet die alle data vergaard … om te tegelijkertijd een slag te slaan met het vergaren van de data in het systeem ten behoeve van onze data lake" H. Pasman (personal communication, May 6, 2019)

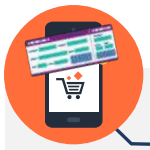
Foreseen developments

The project is still in development because the data acquisition is not optimized yet and is still under improved. The quality of the data that is also transferred to the data lake is being improved.

Profile

Table 15: Profile of the technical maintenace tool

Why: Objectives	To realize a cost reduction for the energy consumption, maintenance and facility management of the stadium using the new system. Besides this, the quality of the spaces is improved.
Why: Goals (Strategic, Functional, Financial, Physical)	1. Functional - increasing user satisfaction, supporting the user activities 2. Financial - decreasing costs 3. Strategic - improve quality of place 4. Physical - reduce footprint
What: Measurement (Frequency, Occupancy, Identity, Activity)	Occupancy & Activity
How: Measurement method (Manual, booking, sensors)	Sensors
User information	User: Employees and visitors of the Johan Cruijff ArenA got insight in the different measurements of the different spaces in the stadium. Management: Facility management will receive the technical status real-time, and base their activities on it.
Access level	Management of the Johan Cruijff ArenA and partners.
Benefits (what is the progress since implementing the tools)	Not available. The tool is still under development.
Partners	Honeywell, BAM



6.4.9 Smart tool: Ticketing check-in

PHASE	DURATION	STAGE	ACTUALITY
Implementation	June 2018	Monitoring & Control	Near real time

Project description

The whole ticketing process can be divided into two different systems. The first system focusses on selling the tickets, whereby on the website a ticket for an event will be sold. The second system, which is the smart tool, is the ticketing entrance authorization system. The barcode on the sold ticket, which is linked to a box, row, and seat number, will be scanned at the tourniquet, the entrance gate of the stadium, which will lead to a movement of the gate, that gives entrance to the visitor. Scanning the barcode is the data source, whereby the signal will be transferred to the data lake of Azure of the stadium. Based on this, the attendance per gate can be calculated, the in-check time per gate and the relation with the number of tickets that are sold. However, different combinations can be made between the data received from the ticket sales and the entrance authorization. The data is transformed to information and this is represented in a dashboard, that can be viewed on a mobile device or a laptop by the stadium management. This dashboard is used during the event, whereby it is mainly used to show how many people there are already inside the stadium, if they are on schedule compared to the expectations. The ticketing dashboard is not used for controlling the crowd in the queues, this is done by the control room who based on CCTV camera's. If the line is very long, the control room can decide to open extra entrance gates in order to speed up the check-in process.

"De eerste stage, het monitoren van de ticketverkoop, is een heel erg belangrijke stap. Door rauwe data visueel weer te geven, zie je direct heel veel mogelijkheden. Mensen die in aan operationele kant werken en die beslissingen nemen, is het visualiseren een essentiële stap." W. Hegen (personal communication, April 15, 2019).

Foreseen developments

To use the available data in order to improve the operation during events. Be more pro-active instead of reactive. Also, long-term insights can lead to modifications of the check in gates. Another important development is that historical data collection is very useful in predicting the characteristics of an event. For example, the number of people that are not going to an event.

Profile

Table 16: Profile of the ticketing check-in

Why: Objectives	The dashboard is based on the motivation to work data-driven. This means that the operation can be more efficient, with better results, safer, higher satisfaction of visitors. Also the demand and supply of the ticketing can be balanced better and linked to the catering.
Why: Goals (Strategic, Functional, Financial, Physical)	1. Financial – decreasing costs (increase revenues) 2. Functional – increasing user satisfaction (safety), support user activities 3. Strategic – stimulating innovation
What: Measurement (Frequency, Occupancy, Identity, Activity)	Frequency, Occupancy & Identity: Barcode scans in combination with ticketing sale.
How: Measurement method (Manual, booking, sensors)	Sensors
User information	User: the number of people that check in in combination with the sold tickets, so how many still have to check-in. Management: the data in reporting analyses all the check-in information from real-time to as far back as possible that can be used to optimize ticket-sell and check-in efficiency.
Access level	Management of the Johan Cruijff ArenA .
Benefits (what is the progress since implementing the tools)	Not available. The tool is implemented recently.
Partners	-

6.4.10 Conclusion

Based on the definition of a smart tool, 9 different smart tools are identified in the case of the Johan Cruijff ArenA. For some of the tools impressions can be found in the appendix. The smart tools (in alphabetical order):

Table 17: Profile of the crowd control tool

	1. Smart tool: Cash register
	2. Smart tool: Cleaning
	3. Smart tool: Crowd control
	4. Smart tool: Energy consumption and battery
	5. Smart tool: Mobility portal
	6. Smart tool: Smart turf monitoring system
	7. Smart tool: Staffing
	8. Smart tool: Technical maintenance
	9. Smart tool: Ticketing check-in

In the next paragraph, the nine smart tools are analyzed in order to identify how they contribute to the different objectives and how this could be improved.

6.5 Analysis of the smart tools

The nine smart tools have been analysed whereby the focus was to understand the goal and the objectives for each tool and to find out to what extent the tool (if already integrated) already did contribute to this goal. During the interviews, various questions have been asked what could be improved during the next steps of integrating the tool and to understand limitations that affected the tool. All these findings are structured in table 18. Coding the different interviews resulted in different key codes, which are the findings on how the use of smart tools can be optimized. These different findings are compared and used as input for chapter 7.

Table 18: The progress of the different tools in relation to their goals

									
Name smart tool	Smart turf monitoring system	Crowd control	Mobility portal	Technical maintenance	Cash registers	Cleaning	Staffing	Ticketing check-in	Energy consumption & battery
Priority goal (4 perspectives)	Strategic	Functional	Functional	Functional	Financial	Financial	Financial	Financial	Physical
Phase	Implementation	Research and Product development	Implementation	Product development	Implementation	Product development	Product development	Implementation	Implementation
Goal of the tool	"Higher quality of the pitch & higher utilization of the pitch"	"To understand and possibility to control the behaviour of people within the stadium" "Safety"	"Better travel experience for visitors to the area" "Reduce motorized transport"	"To realize a cost reduction for energy consumption, maintenance, facility management" "Improve quality of living areas"	"Increase revenues, better service, cost reductions, more certainty and less risks."	"Reduce cleaning costs"	"Higher efficiency in communication and better idea of the time registration "	"A more efficient ticketing check-in"	"To reduce energy consumption"
Progress since implementing the tool	"The pitch only needs replacement ones a year instead of multiple times a year"	The tool is not implemented yet.	"750.000 travel advices given to people"	The tool is not implemented yet.	"Based on the current information it can be confirmed that the extension on the second ring are generating more revenues."	The tool is not implemented yet	The tool is not implemented yet	"Better insights in the attendance of visitors during events".	"Better insight in the energy consumption" "Sustainable energy production"
Specific points of improvement and ambitions to achieve the goal	"Historical data"	"Historical data"	"Better real-time response"	Not available	"Historical data" "Better real-time response" "Connect to ticketing check-in"	"Better real-time response"	"Connect to a digital check-in" "Historical data"	"Historical data" "Better real-time response"	"Connect to the building management system"
Points of attention	"Measurement method"	"Privacy" "Measurement method" "Technical layer"	"Measurement method" "Collaboration with partners" "Privacy"	"Technical layer"	"Collaboration with partners (suppliers)" "Privacy"	Not available	Not available	Not available	Not available

Firstly, the analysis focusses on how smart tools should contribute to the different goals which are explained in the first section. In the next section the progress for the different smart tools (since implementation) are discussed. Thereafter, different specific points of improvements that came out of the interviews were discussed. Lastly, limitations of the smart tools as described by the interviewees are discussed.

6.5.1 Objectives are primarily functional and financial

Due to the recent rise of integrating smart tools within stadiums the exact effects, it will have on the stadium and the users are not clear yet. However, by integrating a tool within the stadium there should be the ambition to improve something and to achieve a certain goal. The interviewees were asked to answer: what the goals are of the tool, which goals have to be achieved with the tools and what the progress is on these goals since implementing the tools. For classifying to which goals the tools contribute, the thirteen added values as introduced in the research of Den Heijer (2011) were used.

In table 19, for each of the smart tool, the goals are listed as derived from the data collection. As seen in this list, the goals that are formulated for each smart tool are quite broad. Specific percentages or numbers that have to be achieved with the tool is lacking which makes it difficult to measure the impact of a smart tool in comparison to the stated goals and to define if the goals are achieved.

The Johan Cruijff ArenA management did state some general goals which have to be achieved with innovations that are developed in the innovation lab. This consisted of six goals. These six goals are also general which makes it difficult to see a connection with the integration of the different tool.

In order to classify the stated goals from each tool, the thirteen added values where the tool will contribute to were presented to the interviewees and they were asked to prioritize them. The results of their responses are displayed in table 19. The results show that almost all the smart tools that are integrated into a stadium focus on both the functional perspective that (support user activities) while on the other hand, it has the financial goal of decreasing costs.

Table 19: Goals of the tools

Smart Tool	Priority	Strategic						Functional		Financial			Physical	
		Stimulating innovation	Stimulating collaboration	Supporting image	Supporting culture	Improving quality of place	Supporting user activities	Increasing user satisfaction	Increasing flexibility	Decrease costs	Increasing real estate value	Controlling risks	Optimimze m2 footprint	Reduce CO2 footprint
Cash registers	Financial	👍					👍	👍		👍			👍	
Cleaning	Financial						👍			👍				
Crowd control	Functional						👍	👍		👍				
Energy consumption & battery	Physical		👍	👍	👍					👍		👍		👍
Mobility Portal	Functional		👍				👍	👍						👍
Smart turf monitoring system	Strategic	👍				👍	👍			👍				
Staffing	Financial						👍			👍		👍		
Technical maintenance	Functional					👍	👍	👍		👍				👍
Ticketing check-in	Financial	👍					👍	👍		👍			👍	

Financial: Focus is on cost reduction

Besides the mobility portal, all the other smart tools have to contribute to a reduction in costs. As described in chapter 4, a stadium most important source of income is renting out the stadium. If the operating costs are as low as possible, the profits for the stadium can be higher: if the costs reduce of organizing events in combination with the frequency of renting out the stadium, it will lead automatically to higher stadium profits. This can declare why a lot of the smart tools are integrated or planned to be integrated into the stadium because it has value for the stadium due to their potential financial savings. Unfortunately, from none of the smart tools that are already integrated, there are specific numbers available which show what the exact decrease in costs is.

Various strategic goals

Various strategic goals are identified for the tools. Stimulating innovation can be declared by the formulated goal of the Johan Cruijff ArenA that it has the ambition to be the most innovative stadium in the world. Interesting is that none of the tools are linked to the goal of supporting the image of the stadium. Interesting because it would be expected that due to the public interest in stadiums and the number of visitors the image of a stadium could be very important in order to obtain competitive advantages.

Physical goals are not having priority

There are some tools that contribute to a reduction of CO2 footprints and to the optimization of the m2 footprint, but the importance of the stadium management to optimally achieve these goals are quite lacking.

Functional: Supporting user activities

Another goal as derived from the interviews that play an important role in the different smart tools is supporting the user activities. This type of interventions is closely connected with the increase in the satisfaction of the user. This can be done by a quicker response to changing demand. The user can be the visitor of the stadium, but part of the stadium management. For eight of the nine tools, the user is the management of the Johan Cruijff ArenA itself. So, the only tool that can be used for the visitor is the mobility portal.

However, as emphasized in chapter 4 the visitor is key and can be seen as one of the most important users of the stadium. In order to support user activities, the smart tool can give insights to the visitor to improve this 'fans' experience. So, based on the result that all the smart tools have the objective to support the user activities, it would also be expected that the tools are focussing on the visitors and have open access for them. On the other hand, the user is not specifically the visitor of the stadium, but this could also be the stadium management.

The tools do touch different phases of the visitor's experience. As seen from the analysis of the different smart tools in the previous section, the only smart tool that can be accessed by the visitor is the mobility portal. The mobility portal gives the visitor to the stadium personalised travel advice. However, from the nine smart tools, this is the only smart tool which is accessible by the user, which seems illogical because the focus of a lot of smart tools is to improve the user experience. See the access levels of the tools and the information that is provided in the table below.

The 'user information' and the 'management information' shows that data is generated from the visitors. This information is only accessible for the stadium management and services, despite the mobility portal tool. These findings are compared to the stakeholders from theory at the end of this report, see discussion.

Table 20: Information given and access levels for the different tools

	Access levels					Information	
Smart Tool	**Specification**	**Managers**	**Support**	**Users**	**Open Access**	**User information**	**Management information**
Cash registers	Only the operational management of the Johan Cruijff ArenA can access the cash registers app.	👍				The number of people that check in in combination with the sold tickets, so how many still have to check-in.	The data in reporting goes from real-time to as far back as possible, and will be stored in order to do historical analyses and improve the catering offering during different types of events.
Cleaning	Only the management of the Johan Cruijff ArenA can access the cleaning dashboard.	👍		👍		The user, which are the cleaners, are informed which spaces there have to be cleaned	The management knows which spaces there are booked, cleaned, and for which price. This data is refreshed 4 times a day.
Crowd control	The Johan Cruijff ArenA management can access the crowd dashboard.	👍				The Johan Cruijff ArenA itself has real-time insight in the location of the visitors and their density. It also gives clear insight in the behaviour of visitors, especially the moments when they do use their mobile device.	The data will be analysed over a longer period of time.
Energy consumption & battery	Only the management of the Johan Cruijff ArenA can access the energy dashboard.	👍				The real-time the total energy consumption and supply of the (whole) Johan Cruijff ArenA	The data goes from real-time to as far back as possible, and will be stored in order to do historical analyses.
Mobility Portal	Everyone can access the mobility portal. The back-end of the mobility portal are accessible to the management and an external company. This is translated in a real-time dashboard.	👍			👍	The user, which is the visitor, got advised on all the different transportation methods to the Johan Cruijff ArenA based on their preferences and location	The mobility management of the Johan Cruijff ArenA has insight in the visitors characteristics, such as their location and their chosen transportation method.
Smart turf monitoring system	Only the grass team of the Johan Cruijff ArenA can access the smart turf monitoring system.	👍		👍		The grass team of the Johan Cruijff ArenA got insight in the real-time status of the grass pitch.	The data of interventions as a result of the information from the dashboard are reported.
Staffing	Both the management of the Johan Cruijff ArenA and the employment agency can access the staffing dashboard.	👍		👍		The number and type of personnel needed and encoded for an event, as visible for the employment agency and the Johan Cruijff ArenA	The data for the management will be collected and compared to the different type of events. This can be used for reporting and predicting the needs for the organization of new events.
Technical maintenance	The facility management of the Johan Cruijff ArenA and the contractor can access the technical maintenance tool. Visitors and employees of the ArenA do have insight in the different measurements of the living spaces.	👍		👍		Employees and visitors of the Johan Cruijff ArenA got insight in the different measurements of living spaces.	Facility management will receive the technical status real-time, and base their activities on.
Ticketing check-in	The management of the Johan Cruijff ArenA and the different parties that are involved in the control room can access the dashboard.	👍		👍		The number of people that check which reflects how busy the check-in gates are.	The data for the management goes from real-time to as far back as possible, and will be stored in order to do historical analyses. that can be used to optimize ticket-sell and check-in efficiency.

This observation can be supported by the customer perceived model of Porter (1980) who defines two variables the price and the quality. In order to gain the best service for a product, which is, in this case, the stadium, the focus should be on minimizing the costs on one hand while improving the quality of the product. This would lead to a better value of a product (in this case a stadium). So, the first goal, decrease of costs is in line the y-axis of this model that will lead to a reduction of the price, while on the other hand the supporting of the user activities would lead to superior quality. This combination can be declared as a competitive advantage. This is in line with the theory in the field of strategic management of *'Porter's generic strategies'* (Porter, 1980). The Porters generic strategies describe how competitive advantage across a market scope can be achieved. So, a company can pursue competitive advantage by focussing on differentiation or reducing the costs. So, a product can have a competitive advantage due to the lower costs or by offering a more attractive product that distinguishes from other products. It seems that smart tools do contribute to costs reduction, whereby also the user activities (and eventually satisfaction) will be improved.

6.5.2 Progress since implementing the tools

There seems consensus between scholars that it will lead to a better alignment of real estate portfolios more frequently in time on a higher level of detail in space to the needs of the user due to the provision of real-time data, this could improve the energy usage, efficiency, longevity, comfort, and satisfaction. More specifically in a stadium environment, it can lead to an improvement of safety and security, the fan experience, sustainability, commercial opportunities, enhanced entertainment (O'Brolcháin, Colle and Gordijn, 2018). It would be interesting to see if this can be confirmed, based on this case study.

Measuring progress difficult due to the immature character of the tools

As derived from the data collection, it can be seen that for four smart tools statement about the progress cannot be made due to the fact that the tools are not implemented yet. Only five of the tools were operational at the time of the interviews, the other four were still under development. These four are planned to become operational before January 2020. As shown in the timeline of the different smart tools in figure 26 the tools are implemented or developed recently. For the tools that are already integrated, it is quite difficult to describe the progress since the implementation of the tool. This was also observed during the interviews: it was for the interviewees quite hard to define the exact progress for each of the tools. However, there have been made progress for the tools, which will be discussed and explained in the next sections.

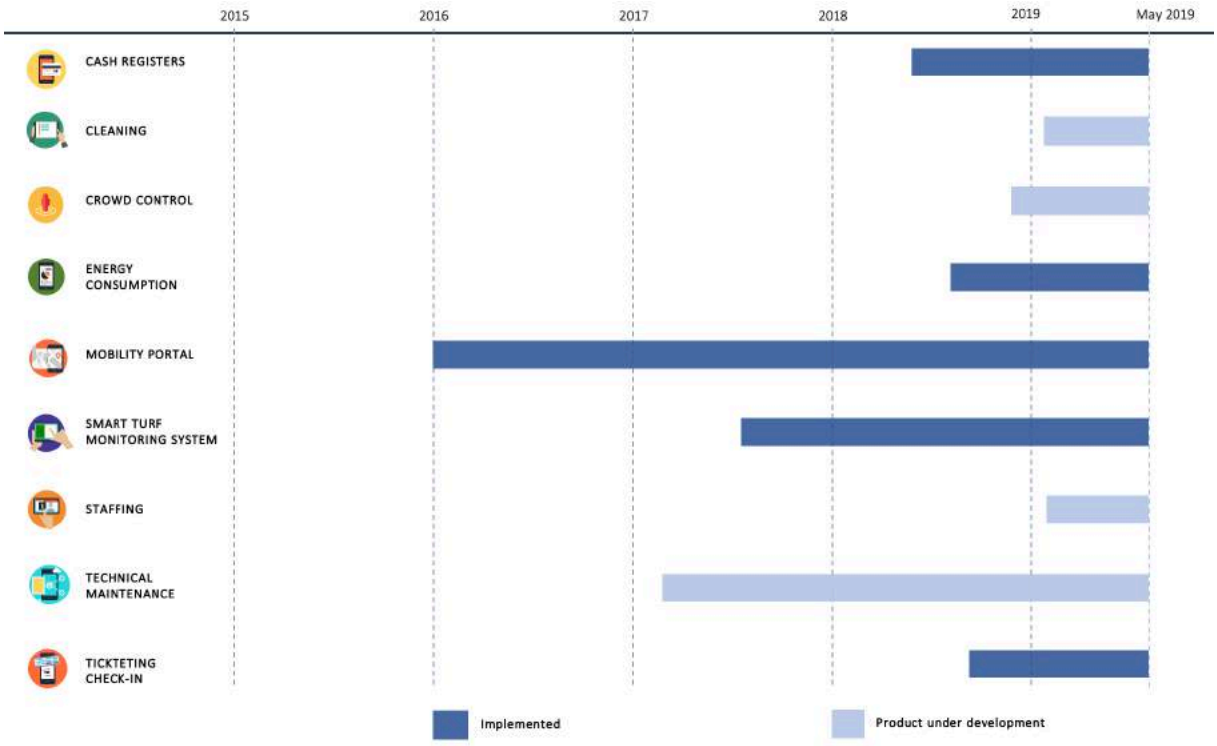


Figure 26: Timeline of the different tools

Smart turf monitoring system

Since the implementation of the smart turf monitoring system it has led to a reduction of pitch replacements. Also, a higher quality is shown in the 'pitch-score' for the yearly contest among the clubs in the Dutch football competition. So, this emphasizes the importance of a stadium to obtain a smart tool that focusses on the pitch. Due to the better quality of the pitch, it will lead to a reduction of pitch replacements, which will, in the end, reduce costs.

Cash registers

The information generated by the cash register tool did already generate some valuable insights. As seen from the first data analyses it reflects how busy the different kiosks are within the Johan Cruijff ArenA and which catering products are popular. The cash register tool monitors the financial performance of the different cash registers during events. The tool shows which kiosks are performing well and which not, based on this information extra kiosks and floor space can be added. This statement is underpinned by the information shown in the tool. On the second ring of the Johan Cruijff ArenA, which is extended recently higher revenues are visible due to the extension of the number of kiosks and floor space. As mentioned in the interview, more products are sold in the new second ring extension. To develop long-term real estate strategies, these kinds of observations are very interesting in calculating what the final impact would be for the addition of extra floor space area within the stadium.

Mobility portal

Since the implementation of the mobility portal in 2016 already 750.000 personalised travel advice has been given to the user of the tool. However, the impact that the mobility portal has on the travel behaviour of the visitors is difficult to translate into different variables. This is due to the fact that different events contain different characteristics, which makes it hard to measure the exact impact of the use of the mobility portal. Nevertheless, as mentioned in one of the interviews there are ambitions to measure if there is a modal split as caused by the use of the mobility portal. For now, this is not the case yet.

Ticketing

As stated in one of the interviews, real-time information from the ticketing check-in is shown to the stadium management: *"Nu vooral de opkomst meten, en dan kunnen we real-time, in de vorm van een app zien … hoeveel mensen zijn er binnen, wat is de omzet, lopen we voor of achter ten opzichte van de verwachting"* W. Hegen (personal communication, April 15, 2019). Based on how many people there are already inside the stadium, stadium operations are attuned to this information. In addition, the app informs the stadium management real-time which check-in gates are busy. As mentioned by the interviewee that if they see that there are possibilities to open extra gates for a specific section in order to reduce the length of the queues, this can be done based on input from the app. This leads to a reduction of waiting time and it helps to get the visitor in the stadium on time. Specific numbers related to the reduction of the waiting time are not available.

Energy consumption and battery

The energy consumption of the Johan Cruijff ArenA is made insightful. According to the interviews, there is not done a lot with this information. The energy battery did save energy costs due to the replacement of diesel generators. Also, the exact numbers were not available for this tool.

So, these five smart tools, which are in use in the Johan Cruijff ArenA, did show progress in achieving their goals, however, specific numbers were not available. It would be helpful that in the future the progress of the different tools is translated in number. Besides this, in order to make more progress and achieve the goals, different points of improvement were observed during the data collection which will be discussed in the next section.

6.5.3 Points of improvement

Based on the data collection different points of improvement for each of the smart tool were coded by using keywords. These codes were used for the different smart tools and there came out to be some overlap between the different smart tools. It can be observed that there are some points of improvements occur more frequently for different tools. The following points of improvements that came out the analysis are discussed in this section: (1) better use of historical data, (2) steer the visitor more real-time, (3) link with other systems.

Use of historical data

As part of the interview protocol, the interviewee was asked how the different smart tools are related to the four different stages of an IoT product (monitoring, control, optimization, and autonomy). These four stages are based on the theory of Bäumer, Von Oelffen and Keil (2017). These results of the different stages of the tool, as expressed in figure 27. Ideally, the tools will have the best impact if they are focussing on optimization and eventually autonomy. However, the current status of the tools is monitoring and controlling.

One of the interventions to make this shift is to enable algorithms based on historical data in order to allow predictive diagnostics and enhance performance. This was also reflected in the different interviews and coded as "historical data". For four different smart tools, this ambition was explicitly stated that the use of historical data is very valuable to make progress. One of the interviewees summarized that ambition well: "*van de historische evenementen die we hebben gehad dan kunnen we die gegevens opslaan en daar een soort van basisprofiel van gebouwd. Op basis van die historische gegevens kunnen we eigenlijk al zeggen dat is te verwachten*" W. Hegen (personal communication, April 15, 2019). It can be concluded that the next challenge for the smart tools will be to use the historical data, which is generated by the tool itself, and use this for predicting and optimizing events held within the stadium. This will contribute in shifting the tools from a more monitoring and control function towards optimizing.

Figure 27: Stage of the tool according to the theory of Bäumer, Von Oelffen and Keil (own illustration)

Better real-time response on the information

Another point of improvement what came out of the interviews is the ability to respond real-time to the information obtained from the smart tool. This statement will be explained shortly for the different smart tools. For the mobility portal, this means that during the trip, based on real-time information the visitor can be reached and steered. For the ticketing check-in gates, real-time information should be used better in order to improve the flow and reduce the waiting lines. For the cash desks, real-time information about the performance of the different kiosks can be used to determine which kiosks are performing well and which not. Based on this information, real-time measures could be taken, such as extra marketing for certain products. Lastly, for the cleaning tool, there have to be done tests to provide better real-time information about the use of spaces. The information that is now provided for the tool is based on a booking system.

Possibilities to create a 'better real-time response' is the possibility to inform the visitor of events in order to steer them. Only the mobility portal has now open access for visitors. This will be elaborated more in the next chapter.

Link to other systems

One of the characteristics of autonomy is the ability of self-coordination of operation with other systems. For three of the smart tools, the importance of linking the tools to other systems was mentioned. Combining different systems can lead to valuable insights and could stimulate automated processes.

6.5.4 Points of attention

The importance of the technical layer

As specifically emphasized by three of the interviewees it is important that the technical layer, which is the process to obtain and process the data into information for the end-user, is properly constructed. The technical layer is also known as: 'basic technology infrastructure'. The technical layer is the basic infrastructure that provides the right data to the smart tool. The technical layer is also described as the back-end by some of the interviewees, while the smart tool is sometimes described as a 'front-end tool'. As mentioned in one of the interviews, the rule of thumb for the workload between the back-end and the front-end is respectively around 80% for the back-end, while 20% for the front-end. If the technical layer is obtaining the right data, it will be a lot easier to integrate a smart tool. As described in one of the interviews as: "*als de backend niet goed is en de relatie in je datamodel niet goed in elkaar zit, dan gaat visualiseren heel veel werk zijn. Dan moet je vaak 3 stappen terug om de achterkant goed in te richten*" C. Disseldorp (personal communication, April 18, 2019). A well-functioning technical layer will reduce a lot of time and costs during the integration of a smart tool.

The importance of a well-functioning back-end is well reflected in the technical maintenance smart tool. Hereby all the old sensors throughout the Johan Cruijff ArenA are replaced during the last 1,5 year. There has been a complete upgrade for all the sensors within the Johan Cruijff ArenA. As stated in one of the interviews this replacement is very important for the quality of the data lake, which is part of the technical layer. Currently, with the technical maintenance tool, the project partners are still scaling up various elements of the data acquisition. This whole process took already 1,5 years and it is still in progress. It reflects the effort it takes to build a solid technical layer with the right data acquisition and the importance of it.

Another statement that came out the interviews was the importance of obtaining the right data. There are various ways to obtain data as described in chapter 3. To choose the right type of data source it is very important that the goals and the objectives why a smart tool is needed are clear. As mentioned by two of the interviewees that if you work with real-time data, you need a goal to analyse things at all. Data can be used for all different kind of purposes, only if there are a clear goal and strategy it can be used and deployed successfully. In another interview it was stated that if there is a specific need for certain information, but the data is not available, it will take a lot of time to integrate the right data sources. By critically analysing on what the stadium wants to know, why they want to know and which data is already available, it would contribute to a more successful implementation of (new) data sources and in the end a well-functioning technical layer without wasting a lot of time and efforts.

Important addition is that for the following tools: technical maintenance, the ticketing check-in, and the cash registers a new technical system has to be installed and replace the old one in order to make the tool functioning. For the technical maintenance tool, new sensors had to replace the old one. For the ticketing check-in, an access gate (tourniquet) with a scanner incorporated that can scan a barcode. As seen from the cash registers, the whole payments system had to be replaced with a new system. The point from these examples is that sometimes well-functioning systems have to be replaced for new (IoT) systems in order to gather the right data.

Lastly, an important addition to the technical layer statements is the role of Microsoft products. As seen from the data collection in every step of the technical layer Microsoft products are used in order to process the data. This extensive use of computer software products, in this case, Microsoft, was not mentioned in the theoretical part of this research, however, during the case study, it came out that it does play a key role in every step of the technical layer. Different Microsoft definitions were used during the interviews.

Privacy and security risks

Some of the tools can be limited due to the ethical challenge of violating the privacy of visitors. This risk was also expressed earlier in theories, namely in the research of O'Brolcháin et al. (2018). In order to prevent privacy issues, a good data governance structure could help in minimizing this risk. This was also reflected in the Johan Cruijff ArenA, since the different tools are developed and integrated, a team of 6FTE is working on the data governance. The keynote of the issue of privacy is that there are limitations of collecting data from the visitors and that all the data collection has to been treated carefully. A good method to make sure that the tool is in line with the legal conditions, the EU's General Data Protection Regulation (GDPR) can be used.

Collaboration with partners: partner ecosystem

In order to develop and integrate a smart tool, the collaboration with external partners seems crucial, whereby these partners use their services and expertise. As seen in this case study seven smart tools contain an extensive collaboration with partners. On one hand this can be seen as an advantage because specific expertise is brought within the stadium. On the other hand, it could also have negative consequences, such as different interest, rights of ownership, higher prices of products and inefficient collaboration and communication. Summarizing, stadiums that want to integrate smart tools in their stadium have to seek partners with the right expertise, however, they have to consider the potential risks this collaboration brings.

Accuracy of measurement methods

The last stated limitation that came out of the interviews is that the measurement method of some of the tools causes for problems, which makes the data not totally reliable. An example is the crowd-control based on the Wi-Fi signal given by the mobile device of a visitor. But if the visitor does not carry their mobile device, they cannot be traced.

6.6 Conclusions

Objective:	To assess the different smart tool and that are integrated in the Johan Cruijff ArenA. To understand the objectives of integrating smart tools. To find out how the potential of smart tools can be optimized and improved.
Question:	Which smart tools are integrated in a stadium and what are the objectives for integrating them? What is the progress since the integration of the smart tools and what can be improved?
Method:	Case-study research: semi-structured interviews, observations, documentation.

According to the case study of one of the most innovative stadiums, the Johan Cruijff ArenA, the following smart tools were assessed:

- In total 9 smart tools are distinguished, which are on alphabetical order: cash registers, cleaning, crowd control, energy consumption and battery, mobility portal, smart turf monitoring system, staffing, technical maintenance, and ticketing check-in.
- Only five of these tools were operational at the time of the interviews, the other four were under still under development. These four are planned to become operational before January 2020.
- The tools clearly express two objectives that seem to be important: reducing costs and supporting user activities.

The progress since the integration of the smart tools:

- It is hard to figure out the effects of integrating the smart tools within a stadium, due to the recent integration of the tools. There has been some progress for some of the tools that are integrated, however specific numbers of the progress since integrating the tools are not available.
- A well-functioning technical layer is required for smart tools. In all the interviews the importance of the technical layer was emphasized. This technical layer is still under development, but a lot of progress is already made. That is why a lot of tools are currently developed and integrated on the technical layer.

As seen from the different tools that were integrated, the following points were mentioned during the interview that needs improvement in order to make more progress:

- In order to improve the current use of smart tools the following point came clear from the interviews: better use historical data to predict different processes, improved real-time response, and linking the tools with other systems (or tools).
- Other points that require special attention are privacy issues, the collaboration with partners and the accuracy of the measurement method.

PART 4

SYNTHESIS


SPORTING
SPORTING
SPORTING
ATÉ MORRER

7. Optimize smart potential of stadiums

The goal of this chapter is to come to possible interventions that can contribute to optimizing the 'added value' potential of smart tools in stadiums. So, this chapter focusses on the possible next steps on how the use of the smart tools could be optimized and what kind of possible tools could be used for it. This will provide an answer on the research question of what can be done to optimize the effects of integrating the smart tools.

7.1 Cases description

As seen in the previous paragraph, the main objectives of the tools, that are integrated in the Johan Cruijff ArenA are focusing on reducing costs and supporting the user activities. In order to improve cost reductions and support the user activities better here is concluded that based on the data collection from the case study, that a proper technical layer is very important, historical data could be deployed for predictive, connecting the systems with each other, and a better real-time response can steer the visitor is recommended. The set-up of this chapter is displayed in table 21.

To understand how stadiums, have to deal with integrated tools for a longer period of time, a smart real estate system that is already in use for a longer period of time is analyzed. Useful recommendations can be done based on the experience in such cases. In the next section, this will be explained.

Another point of improvement was that more tools should focus on steering the visitors in order to anticipate better on the information provided by the current tools. To find possible solutions, different innovations are analyzed which specifically focusses on improving the visitors' experience in stadiums. This will be discussed in the third section of this chapter.

Table 21: Points of improvements to optimize smart tools

Goals	Reducing costs Supporting user activities	
To improve	Technical layer Use of historical data Linking the tools	A better real-time response on visitors (more insight visitor)
Conditions	Real estate asset that: - Has a similar technical layer, which can be characterized as a smart system. - Is in use for more than one year and thus has collected real-time data for a longer period of time. - Branded as a smart building.	Tools that are: - Innovations which focus more on the visitor - And contains real-time information, whereby this information can steer the visitor.
Cases	Edge Olympic Office	Market analysis - Innovation challenge 'Change the Game'

7.2 Smart system: The Edge Olympic office

Figure 28: The Edge Olympic Office (Edge Technologies, n.d.)

The Edge Olympic is branded as a smart building. According to the developers, OVG Real Estate and their subsidiary EDGE Technologies, this building is the improved edition of another smart office Edge. The Edge also defined as 'the smartest building in the world' (Bloomberg, 2015). For the integration of smart solutions within the Edge Olympic, the lessons learned from the Edge were considered. The Edge Olympic building has approximately 11.100 square meters of office space, which was a redevelopment project. The tenant of the building is the developer itself, OVG Real Estate and EDGE Technologies. Besides them, there are some various other tenants.

The Edge Olympic was delivered in May 2018, which makes it one of the smartest buildings at the moment which is already in use for around a year. This development seems to be very successful. The building received various certifications regarding the performance (Energy label A, BREAAM Excellent, WELL Platinum, Cradle2Cradle). This in combination with the prime location made the building very desirable for possible tenants. Also, user satisfaction increases a lot within the Edge Olympic. Based on this information, it can be stated that this building is a frontrunner for successful smart buildings. Findings from the Edge Olympic, despite the different type of use, it might be a valuable contribution and validation for the statements that were done in the previous chapter. As described here, the importance of a proper technical layer, the use of historical data and the possibility to link the different tools together were mentioned as important conditions to achieve the different stated goals.

7.2.1 Importance of the technical layer

According to the website, the Edge Olympic is based on a digital infrastructure that connects everything and everyone within its walls to a single cloud platform (EDGE Technologies, n.d.). The technical layer of the Edge Olympic shows a lot of similarities as the technical layer of the Johan Cruijff ArenA. Different data sources, with different types of data (internal and external), are collected in a Microsoft Azure back-end, which can be seen as the data lake, whereby based on programming API's and doing advanced analytics dashboards are made. So, the occupancy of space is based on the different sensors and reservations made. The information is visible for the managers of the building and for the users. The information for the users is provided by a mobile application. Through this mobile application, the users of the office can control temperature and lightning, find workspace, book parking & lockers and find colleagues. The selected preferences in the mobile application are using the internet to transfer this data in the Azure data lake. This can also be defined as connectivity. As a result of this

technical layer, which is the basic infrastructure for different tools, extra services can be added very easily to meet the changing demands and needs.

This is the main difference in this set-up as compared with the Johan Cruijff ArenA. Where there are no options in the mobile applications that allow the user to select preferences, which signal is transferred to the data lake. The information that is generated from a mobile application which is accessible for the users provide valuable data input. In the Edge Olympic a user application is connected with the sensors into a data platform. So, many things in the building can done in an automated way (J. van Kerkvoort, personal communication, May 16, 2019)

In comparison with the development of 'the first model', the Edge, sensors were linked to a data lake, whereby a separate mobile app was used to control some of the functions (lightning and temperature). The management information gave insights into the status of the real estate asset, based on this information adaptive management features were enabled (adaptive maintenance, lighting, climate). According to Jens van Kerkvoort (personal communication, May 16, 2019) in the Edge Olympic processes are more automated in comparison with the Edge. This means that the building automatically responds to different input from data sources. For example, if there are a lot of people in the room detected, the system will automatically add fresh air in the room in order to improve the air quality.

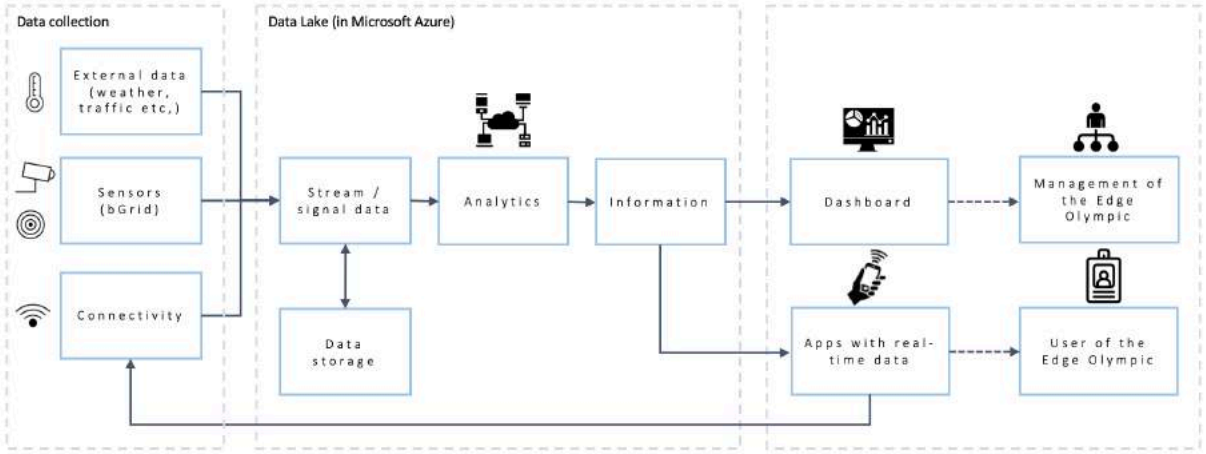


Figure 29: Technical layer of the Edge Olympic (own illustration)

7.2.2 How is data saved and used?

In the Edge Olympic, the collected data is saved which turns it into historical data. This is done for different use cases. Firstly, data is collected for defining the occupancy of different spaces within the Edge Olympic. This information can be used for better decision-making on the long-term in order to use the different spaces more efficient. Which can lead to a change of the interior design of the building. Also, the historical data of the occupancy in rooms are saved and used in combination with the booking schedule for the cleaning services. The information is used to optimize the cleaning schedule.

The data of the different cash desks in the office are not saved and used. This is because the catering services are outsourced to an external party. They do not save this data.

7.2.3 Are there tools linked to other systems?

According to Jens van Kerkvoort (personal communication, May 16, 2019) the data platform is very functional and simple. As a result, the data can be linked to each other, a lot of information can be generated. So, linking the data is not the problem, the challenge is more to find out needs to be made available in order to achieve different goals.

What they did in the Edge Olympic is that they compare the data collection with different performance goals. So, for example, the different performance goals for the air quality as needed for a WELL Certification. By comparing these performance goals with the current status of the building. These kinds of insights can lead to an adjustment of the building system to meet the performance goals.

7.2.4 Quite some similarities between the Edge Olympic and the Johan Cruijff ArenA

In comparison with the observations from the case study of the Johan Cruijff ArenA, a lot of similarities are found for the technical layer in comparison with one of the smartest buildings, the Edge Olympic. An interesting difference is that the preferences as selected by the user in the mobile application, are input for the data lake through 'connectivity'. The technical layer is flexible whereby extra services can be easily added. Moreover, the Edge Olympic consists of more automated processes. This is the result of linking the data collection with performance goals, whereby this can lead to different actions. In the Edge Olympic historical data is also used for different purposes, especially to improve decision-making in the long term. Lastly, the technical layer is designed in such a way that the different data and tools can be linked to each other. But, due to the similar set up of the technical layer as the Johan Cruijff ArenA, this seems simple.

7.3 Stadium innovations: future applications

One of the conclusions from the case study was that the information that has been generated by the tools can be used better in order to control and steer the visitor (in and around the stadium). And by this maximize the benefits of the tools. Also, an application that can be used by a visitor provides also valuable input for the data lake, as seen by the Edge Olympic. This could have a positive impact on the stated goals for each smart tool, but also in reducing costs and supporting the user experiences. If a stadium has a solid basic infrastructure, this kind of solutions can be integrated easily on the platform.

The stadium innovations were selected from the 'Change the Game' innovation challenge. During this challenge different innovative start-ups, scale-ups and enterprises could submit their solutions around five different themes to improve the fan experience in stadiums. In total, 198 solutions were submitted from 32 countries in the period of January 2018 till April 2019, whereby 35 solutions were selected by different juries. The solutions that were submitted are frontrunners for technologies that can be integrated into stadiums. Which makes it interesting to dive into these possible solutions.

All solutions focus on different touch points of the customer journey. The 35 solutions that were selected by the jury were researched and plotted on the different touch points of the customer journey, which can be found in the appendix. More importantly, the solutions were compared to the formulated goals as obtained from the interviews. Based on this analysis a list with solutions that could be implemented by stadiums in order to book more progress on the different stated goals was selected. The different solutions for the different areas of application can be found in the next section. Thereafter, each of the solutions will be discussed more in-depth.

Table 22: Possible innovations that can contribute to the current smart tools

Visual					
Possible future application	Mobile ordering platform	Pro-active and adaptive visual communication	Guide users throughout a venue by using innovative features (such as Gamification, Augmented Reality, and Virtual Reality)	Smart map solutions for venues	Facial recognition technology
Perspective	Financial	Functional	Functional	Functional	Financial / Functional
Goal	"Increase catering revenues, better service, cost reductions, more certainty and less risks"	"To understand the behaviour of people within the stadium" & "Safety"	"To understand and possibility to control the behaviour of people within the stadium" "Safety"	"Better travel experience for visitors to the area" "Reduce motorized transport"	"Higher efficiency in communication and better idea of the time registration" & "A more efficient ticketing check-in"
Current Tool	Cash register smart tool	Crowd control	Crowd control	Mobility Portal	Ticketing check-in & staffing
Examples of companies	Bitz	AVEX b.v.	Digital Ventures, Forward Game UG, Eyecandylab, Foot Analytics, Hey Digital Ventures LDA	Wizzy Maps	COMPO Software, Hikvision

Mobile ordering platform

Mobile ordering platforms give customers the possibility to place their orders and pick-up by themselves, saving time, optimizing staff costs and improving the guest experience. The visitor can download a mobile application to do orders, pay cashless, track the order, and pick-up the order at the kiosk. By using a mobile ordering platform, it can reduce long waiting times, solve manual ordering problems, communicate menus easily and data can be easily connected.

Pro-active and adaptive visual communication

This solution is focusing on informing the visitors in the stadium by showing relevant information on the screens in- and outside a stadium. Nowadays many of the content is scheduled and non-responsive to a changing situation. The information on the screens can be optimized for visitors when information changes. A smart combination of information can stimulate decision making of visitors in a stadium. Some examples are to navigate people from the station to waiting lines that are smaller, offer visitors discounts to keep them longer in the stadium, because of the traffic jams outside, and automatic changing menu boards. With this tool, the real-time information from the smart tools can communicated more efficiently to the visitor by using the different screens within the stadium.

Guide users throughout a venue by using innovative features

There is various app-based solution that can guide the user throughout a venue through different features, like Geo-referencing, Virtual and Augmented Reality, Gamification, 3D sounds. By using these kinds of features, the visitors can be steered through a venue. For example, by doing location-based game objects that need to be discovered on the map. The effect of these features is that visitors can be controlled and steered within the stadium, that they will spend more time in the stadium and that it can be used for marketing purposes to offer discounts. That's why it can be linked to crowd control. Also, the products, as seen from the innovation challenge, there are various start-ups, scale-ups, and enterprises that offer these experiences.

Smart map solutions for venues

Advice regarding mobility are often ending at the last public transport stop or parking lot. This "last-mile", that describes the difficulty of getting people from a transportation hub to their final destination, which is in the stadium the seat. There are online map platforms that navigate the user to their specific location, which is especially interesting for locations which are new for a user, such as stadiums, shopping centres, airports or museums. In addition, the smart map solution can also display the different facilities around the stadium, who can benefit from events. Based on real-time updates, the visitor can be steered during their journey to their seat in the stadium.

Facial recognition technology

Due to the current state of the art of facial recognition technology, it can detect and verify individuals. This technology can be used for various potential applications for stadiums, such as access control, payments, and time registrations for human resources. The advantage of this tool it that it will improve the efficiency for checking in at stadiums. Besides this, it will improve the visitors' experience, due to the new technology. Important for this technology is the level of acceptance and trust for users. This means that the user has to in control of their own biometric identification and that the system should be privacy proof. If this is the case, it could be a very efficient tool to improve the efficiency for checking in, to conduct time registrations for human resources and to do quicker payments.

7.4 Conclusion

Objective:	To come with various possible interventions as seen from practice that can optimize the use of the tools
Question:	What interventions can be recommended to optimize the use of the tools?
Method:	Literature review, interviews, observations

As concluded from the case study of the Johan Cruijff ArenA there are improvements to make in order to maximize the benefits of the tools. In this chapter, the goal was to find practical solutions that could contribute to optimizing the benefits of the tools. This was done by analyzing a successful smart system, the Edge Olympic. A second conclusion from the case was that information obtained by the tool is not used to steer the visitors. Possible interventions that could contribute to this goal were selected from an innovation challenge.

As compared with the Edge Olympic, the following recommendations for possible interventions are:

- The smart system is similar to the one of the Johan Cruijff ArenA. This means that it will be easy to link the different tools with each other.
- In the Edge Olympic, the information obtained from the tools were compared to performance goals. This made it possible to automate different processes.
- Preferences, as selected by the user through a mobile application, are used for input in the data lake.

Other future applications that can be used to improve the current benefits of the tools were selected, based on an analysis of innovation challenges. The selected innovations can be used to improve the current tools, measure space use, and/or control the visitor more. These innovations are:

- Mobile ordering platform.
- Pro-active and visual communication to steer visitors more on real-time information.
- Guide users throughout a venue by using innovative features.
- Smart map solutions.
- Facial recognition technique for ticketing and staffing check-in.

8. Conclusions

The aim of this chapter is to come to conclusions derived from the research. This will be done by answering the sub research questions and the main research question in the first part of this chapter. In the second part of this chapter, a discussion on these conclusions is presented. Thereafter, in the last section of this chapter, the limitations, validity and reliability of the research are discussed

8.1 Answering the research questions

Before answering the main research question, how the use of smart tools can be optimized in stadiums, the conclusions of the seven sub-questions are presented.

8.1.1 Research sub question 1:

Objective:	Define the principle of a smart tool
Question:	What are 'smart tools'?
Method:	Literature study

- A smart tool is part of the smart environment of real estate, whereby it provides the user with real-time information about space use in the real estate asset.
- The information received from the smart tool can change the decision-making of the user on the short term and on the long-term. The hypothesis is that it can improve the use of real estate assets, thus contribute to the thirteen added values of real estate.
- The smart tool can be explained according to the visualisation in figure 10.

8.1.2 Research sub question 2:

Objective:	Understanding of the principle of real estate management theories and the role of smart tools related to real estate management.
Question:	How is the integration of smart tools related to real estate management theories?
Method:	Literature study

Real Estate Management theories:

- Real Estate Management differs from Corporate and Public Real Estate Management.
- The real estate decisions of stadiums are based on public and corporate objectives. Theories on Corporate Real Estate Management (CREM) are applicable.
- Based on these theories, a better alignment of demand and supply through real estate can lead to added values for the organization, which in the end can lead to a competitive advantage and costs reductions.
- In total, thirteen different added values can be distinguished from literature.

Relation technological developments and CREM:

- We are currently in the fourth industrial revolution, which is impacting our daily lives. One of the pillars is IoT, which is also impacting the real estate sector. This digital change in the real estate sector is also described as smart real estate.

- Smart real estate is about using technological developments for building progression to attune the real estate supply with changing demands, which can lead to different added values for the organization as described in different CREM theories.
- The maturity of an IoT product can be expressed according to four stages: monitoring, control, optimization, and autonomy.

8.1.3 Research sub question 3:

Objective:	Economic: to understand the economic impact of stadium developments. Physical: to find out the physical characteristics of a stadium. Strategic: to find out who is responsible for the real estate management of stadiums and identify the key stakeholders. Functional: to understand the functional characteristics of stadium users and stadium management. Financial: to understand how the business case of a stadium function.
Question:	What are the characteristics of a stadium and how is this related to the need for smart tools?
Method:	Literature study

To characterise a stadium five different perspectives are researched. The need for integrating tools that measure the use of space can be argued based on the findings from these different stadium perspectives. The following findings that are derived from the literature review are stated in the table below:

Table 23: Conclusions from the five stadium perspectives literature review

 Economic perspective	Stadium developments can have an economic impact on the (local) area, however, this is on a lower scale than policy makers often claim. It is used as justifications for investing with public money. Stadium development can be used as a driver for new area developments. The smart tool can contribute to improve the image of a stadium for policymakers and to utilize the potential for 'smart-city concepts'.
 Physical perspective	Stadiums contain more and more different functions (office space, leisure), which can affect the type of tools needed. Stadiums are located in or around city centers, in urban areas, which means that events have a high impact on the infrastructural network and stakeholders. This can affect the need for smart tools: a lot of visitors and employees during a short period of time means an intense space use (both inside and outside the stadium).
 Strategic perspective	Stadiums are typically a combination of a partnership with sports clubs, municipalities, and other investors (also identified in the financial perspective). their interests are reflected in the stadium policy. Need for smart tools is strongly connected to the objectives of these 'partners. These have to be considered in smart tool investments and ambitions.
 Functional perspective	The most important user is the spectator as a visitor: visiting a stadium is all about offering visitors the best experience that requires extensive preparations. The visitors' experience is made understandable by constructing a 'customer journey'. The customer journey reflects the different critical touch points of a visitor, that can be solved by integrating smart tools. For the critical touch points in the customer journey, smart tools could contribute to adding value to these situations. Examples are visualized in this research. Besides the visitor, smart tools can contribute to the activities of the stadium management. Which is mainly the operational part of the stadium.
 Financial perspective	Integrating tools seem to affect the different income and expenditures of a stadium, which shows that it has the potential to optimize a stadiums' business case. The most important income for the stadium organization is hiring out the stadium for events. Integrating smart tools can lead to a reduction in costs or extra revenues, which can impact the financial situation of stadiums. Also, by creating extra value for the visitors by tools, it can lead to better competitive advantage to the stadiums.

8.1.4 Research sub question 4:

Objective:	To find out what characterized a smart stadium and what kind of smart tools can be identified
Question:	What are the characteristics of smart stadiums?
Method:	Literature study

Smart is a trendy but vague definition. As seen from current scientific research it can be stated that integration of new technologies in stadiums have five potential to enhance entertainment, commercial opportunities and improved customer service, enhanced safety and security, sustainability, reduced environmental impacts and energy costs, and improved athletic performance. By integrating new technologies (also referred to as innovating) the potential of these opportunities can be utilised better. So, based on the current literature, a smart stadium can be characterized by the process of continuous integrating innovations whereby this can result in improved services for different the different stakeholders, which can be categorized into five different types of opportunities, as presented in the research of O'Brolcháin, Colle and Gordijn (2018). It also means that integrating smart tools can contribute to becoming a 'smart stadium'.

8.1.5 Research sub question 5:

Objective:	To assess the different smart tools that are integrated in the Johan Cruijff ArenA. To understand the objectives of integrating smart tools. To find out how the potential of smart tools can be optimized and improved.
Question:	Which smart tools are integrated into a stadium and what are the objectives for integrating them? What is the progress since the integration of the smart tools and what can be improved?
Method:	Case-study research: semi-structured interviews, observations, documentation.

According to the case study of one of the most innovative stadiums, the Johan Cruijff ArenA, the following smart tools were assessed:

1. In total 9 smart tools are distinguished, which are in alphabetical order: cash registers, cleaning, crowd control, energy consumption and battery, mobility portal, smart turf monitoring system, staffing, technical maintenance, and ticketing check-in.
2. Only five of these tools were operational at the time of the interviews, the other four were under still under development. These four are planned to become operational before January 2020.
3. The tools clearly express two objectives that seem to be important: reducing costs and supporting user activities.

8.1.6 Research sub question 6:

Objective:	To find out what the progress was since integrating the tools and how this potential of smart tools can be optimized and improved.
Question:	What is the progress since the integration of the smart tools and what can be improved?
Method:	Case-study research: semi-structured interviews, observations, documentation.

It is hard to figure out the effects of integrating the smart tools within a stadium, due to the recent integration of the tools. There has been some progress for some of the tools that are integrated, however specific numbers of the progress since integrating the tools are not available. An important finding was the importance of a well-functioning technical layer is required for smart tools. In all the interviews the importance of the technical layer was emphasized. This technical layer is still under development, but a lot of progress is already made. That is why a lot of tools are currently developed and integrated on the technical layer.

As seen from the different tools that were integrated, the following points were mentioned during the interview that needs improvement in order to make more progress: In order to improve the current use of smart tools the following points of improvements were identified:

1. Improve the use of historical data to predict different processes,
2. A better real-time response to the visitors based on the information from the smart tools
3. Ambition to link the tools with other systems (or tools).

Points that require special attention are (1) privacy issues and threats of the smart tools, (2) the collaboration with partners and the (3) accuracy and reliability of the measurement methods, and the importance of (4) technological infrastructure / technical layer.

8.1.7 Research sub question 7:

Objective:	To come with various possible interventions as seen from practice that can optimize the use of the tools
Question:	What interventions can be recommended to optimize the use of the tools?
Method:	Literature review, semi-structured interviews, observations

As concluded from the case study of the Johan Cruijff ArenA there are improvements to make in order to maximize the benefits of the tools. In this chapter, the goal was to find practical solutions that could contribute to optimizing the benefits of the tools. This is done by analyzing a successful smart system, which is the Edge Olympic. A second conclusion derived from the case study is that information obtained by the tool is not used to steer the visitors. Possible interventions that could contribute to this goal were selected from an innovation challenge.

As compared with the Edge Olympic, the following recommendations for possible interventions are:

1. The smart system is similar to the one of the Johan Cruijff ArenA. This means that it will be easy to link the different tools with each other.
2. In the Edge Olympic, the information obtained from the tools were compared to performance goals. This made it possible to automate different processes.
3. Preferences, as selected by the user through a mobile application, are used for input in the data lake.

Other future applications that can be used to improve the current benefits of the tools were discussed. These applications can be used to improve the current tools, measure space use, and/or control the visitor more.

1. Mobile ordering platform.
2. Pro-active and visual communication to steer visitors more on real-time information.
3. Guide users throughout a venue by using innovative features.
4. Smart map solutions.
5. Facial recognition technique for ticketing and staffing check-in.

8.1.8 Main research question:

Objective:	(1) To define which smart tools can be used in stadium, (2) what the effects and advantages are of integrating smart tools in a stadium and (3) how the use of smart tools can be optimized. This will lead to a better understanding of these elements that can contribute to improved decision-making for stadium operators about integrating smart tools.
Question:	Which smart tools can be identified in stadiums, and how can the use of these smart tools be optimized?
Method:	Explorative empirical research

This main research question can be divided into two parts: assessing the smart tools that were integrated in the Johan Cruijff ArenA and to identify how the use of the tools could be optimized. In order to answer this question, empirical data was collected from the Johan Cruijff ArenA.

Which smart tools can be identified in stadiums […]?

Based on an extensive analysis of the Johan Cruijff ArenA, nine different smart tools can be identified. These results demonstrate the potential of these technologies for smart stadium solutions and the usefulness of investigating technologies within stadiums. These nine different smart tools are analysed from different theories as found in the literature. It shows that the nine smart tools focus on different touch points: payments (cash registers), cleaning activities, crowd control, energy consumption, mobility, turf quality, staffing, maintenance, and ticketing. Input for the tools is based on different (theoretical) frameworks that are obtained in the literature study. The focus of smart tools is mainly on reducing costs (financial) and supporting user activities and increase users' satisfaction (functional).

However, not all nine smart tools are already integrated and part of daily operations. Four out of the nine smart tools are still under development. It can be stated that the integration of smart tools implemented is stadiums are in their infancy.

[…] how can the use of these smart tools be optimized?

Due to the fact that a large part of the tools is still under development or integrated recently, concrete numbers of the progress since integrating the smart tools are missing. Experiences with the tools that are already integrated did generate some valuable insights on how the tools can be used better.

Before integrating smart tools in a stadium, it is recommended to state clear objectives related to the smart tools. A second valuable finding is that the basic technology infrastructure (technical layer) is very important.

The first advice how the use of the smart tools can be optimized is to make a profile for different events, based on the historical data collected by the different smart tools. The second advice is that the advantages of smart tools can be used more when the stadiums' visitors are steered based on real-time information. There are various ways to do, such as pro-active and visual communication, guide visitors by innovative features, and smart map solutions. Moreover, technologies such as facial recognition and mobile ordering platforms can be used to improve the efficiency of the current tools. Lastly, the tools can be linked between each other or linked to performance goals, in order to create new valuable insights and to stimulate automation.

8.2 Discussion

The outcomes of this research are discussed in this section. The main topics that will be discussed are: (1) relation between the outcomes and existing theories, (2) relation between the outcomes and practice, (3) relation between the outcomes and other research projects and (4) the limitations, validity and reliability of this research.

8.2.1 Theoretical implications

The findings from the literature study, that covered chapters 3, 4, and 5, are discussed in this paragraph. The focus in this section is to identify the relation between the outcomes of the research and outcomes from theory.

Added values

As a result of the literature study to the added values of real estate, in this research the thirteen added value's as stated in the theoretical framework based on the research of Den Heijer (2011) are used as input for the interviews. The utilization of this theoretical framework in the empirical part of this research proved to be difficult. During the interviews, it came clear that there are other 'added values' important for stadiums than stated in the list. 'Enhancing safety' was an important added value that was mentioned a lot during the interviews. However, it was not included in the list of the thirteen added values. So the importance of 'enhancing safety' is now lacking in the results. This research showed that smart tools, and especially within stadiums, have the need to enhancing safety and therefore should be added as an 'added value'.

A second added value that was remarked in the interviews as important was the need to 'increase revenues'. In the current list, there might seem some overlap with the added value of 'increasing RE value'. But in essence, this is not the same. As stated in the interviews, some of the smart tools can optimize commercial opportunities, which will result in an increase in revenues. Besides this, it was stated in chapter four that stadiums are rarely sold to other owners, so valuing a stadium hardly ever occurs.

Smart tool

Existing literature was focused on the use of smart tools on university campuses. The insights gained by this research broaden the existing smart tool knowledge by focusing on a different type of real estate. This made it difficult to find out if a solution could be considered as a smart tool. There is not a universal and well-known definition of a 'smart tool'.

Five perspectives of stadiums

The stadium was researched based on 5 different perspectives. It might be the case that based on this classification certain aspects of stadiums are not included, resulting in a withheld of important stadium characteristics related to smart tools. However, by adding an extra perspective to the model of Den Heijer (2011) the researcher tried to minimize this risk.

Smart stadium

Researches to smart stadiums can be seen as a niche in the scientific body of knowledge, as illustrated in chapter 5. The literature study related to smart stadiums was mainly based upon the findings of Wang (2016), O'Brolcháin, Colle and Gordijn (2018), Panchanathan et al. (2017). The latter two publications were based on the cases of the Sun Devils Stadium and the Croke Park stadium. The findings of this research of the tools are especially in line with the findings in the research of O'Brolcháin, Colle and Gordijn (2018). In this research five different 'smart stadium themes' were identified: (1) enhanced entertainment; (2) improved customer service; (3) commercial opportunities; (4) enhanced safety and security; (5) sustainability, reduced environmental impacts and energy costs. All the tools that were identified in this research are fitting in four of the themes and in some cases in multiple themes, as shown in table 24. None of the tools fit within the theme of 'enhanced entertainment'.

However, one of the conclusions of this research is that in the future the tools should focus more on the visitor, whereby solutions were given that focus on enhancing the entertainment. So, the identified smart tools in this research support current literature about smart stadiums.

Table 24: Identified smart tools show overlap with the 'smart stadium themes' as described in the research of O'Brolcháin, Colle and Gordijn (2018)

5 themes as described in the research of O'Brolcháin, Colle, and Gordijn (2018)	 Smart turf monitoring system	 Crowd control	 Mobility portal	 Technical maintenance	 Cash registers	 Cleaning	 Staffing	 Ticketing check-in	 Energy consumption & battery
1. Enhanced entertainment	no	no	no	no	no	no	no	no	no
2. Improved customer service	no	no	yes	no	yes	yes	yes	yes	no
3. Commercial opportunities	yes	yes	no	no	yes	no	no	yes	no
4. Enhanced safety and security	no	yes	no	no	no	no	yes	no	no
5. Sustainability, reduced environmental impacts, and energy costs	yes	no	no	yes	no	no	no	no	yes

8.2.2 Practical implications

The findings from different elements of the empirical part of this research are discussed in this paragraph.

Case study: Johan Cruijff ArenA

The first point that should be discussed is the case selection for this single case study. The Johan Cruijff ArenA was the only stadium within the scope of the research that was branded as 'innovative' and 'smart'. Based on this information it was selected because it will be assumed to as a frontrunner in integrating smart tools in stadiums. As a result, a selection of multiple cases did not take place.

The case study of the Johan Cruijff ArenA provided empirical information about the smart tools that are integrated in relation to the objectives. An unexpected finding compared to the theory was the importance of developing a data lake for the stadium. It took for almost 2 years to set up the data lake which is still not finished. This was not clearly stated in the studied literature. Secondly, as compared to literature, managing the personnel for events turned out to be a serious issue for stadiums in practice.

As mentioned in the theoretical implications there is not a universal and well-known definition of a 'smart tool'. This was also experienced as difficult during the interviews. The definition had to explain thoroughly. This resulted in some incomprehension and inefficient, because the definition seems quite general and vague.

Need for innovation: traditional organisations.

Another important point of discussion is the need for change. As experienced in the case study and seen from literature, organizations that are often involved in and around stadiums are 'traditional' organisations and companies. It can be said that innovation is often a big challenge for these traditional organisations, because it is new and it is not what they always do. However, smart tools in (large) stadiums will have a signification impact on the industry. So, in order to keep a competitive advantage, these organisations should be helped and reminded of the importance of innovations. The innovative mindset was present at the Johan Cruijff ArenA and their partners.

Users of the smart tools

The 'user information' of the different smart tools that were integrated in the Johan Cruijff ArenA did show something interesting. It shows that the tools are focusing on the stadium services, which is the stadium management and operations. Only one small tool focused on informing the visitor, while the data is mainly generated by the visitor. The users of smart tools are mainly the stadium management and operational services. In comparison with the theoretical part of this research, it focuses on the 'employees' and the 'suppliers', as seen in the stakeholder model of O'Brolcháin, Colle and Gordijn (2018). These normative stakeholder groups are important in smart tool developments.

There was only one tool focusing on informing the visitor. The visitor is categorized in another stakeholder group according to O'Brolchain, Colle and Gordijn (2018), which are 'customers'. A possible declaration can be found in the organizational structure of sports stadiums, as shown in figure 13. Event organizers or sports clubs are leasing a stadium. To attract the visitors is not the core responsibility of the stadium. Which makes it difficult to 'reach' these visitors with tools. On the other hand, it has the potential to reduce costs and to increase the lease price (it is a service). However, this reasoning can declare the current users of smart tools.

Case study: Edge Olympic Office Innovation Challenge

The case study of the Edge Olympic provided empirical information about how another smart real estate asset, that is running for a longer period of time, is dealing with the different findings derived from the case study. As a result, it was identified that the technical layer is quite similar to the Johan Cruijff ArenA and some lessons learned were stated. An important remark for these findings is that the Edge Olympic is an office building, that contains a lot of different characteristics compared to stadiums, thus different demand for smart tools.

Innovation Challenge Change the Game

The last part of the research contained a selection of innovations that can contribute to improving the current smart tools in achieving their objectives. In this innovation challenge, 198 solutions that could improve the visitors' experience stadiums were submitted, whereby 35 solutions were selected by different juries. In this research only these 35 solutions were analyzed, whereby most of the solutions are submitted by start-ups and scale-ups. It has to be noticed that due to the innovative character of these solutions and they don't have a proven record of success. This can be seen as a risk. At the same time, these innovations are frontrunners in their industry, giving it a lot of potential for the future.

8.2.3 Limitations of the research

As stated at the beginning of this research, the nature of this study is explorative due to the lack of a lot of previous research on this topic. This means that there is a limited qualitative body of knowledge. As a result, a qualitative research method is used whereby only one case is used, which is the Johan Cruijff ArenA. As such, this type of methodology can harm the external validity of this research. According to the book of Yin, the external validity is the extent to which the findings from the case study can be analytically generalized to other situations that were not part of the original study (Yin, 20140, p. 238). Often defined as the 'generalisability' of research findings. So, recommendations for future research is to focus on multiple stadiums, and by this analyze how smart tools are integrated, in order to improve the external validity of this research. This can be done by conducting a cross-case analysis. An important remark to this statement is that stadiums are a ubiquitous 'industry', which operates similarly worldwide, increasing the likelihood that this study will also be applicable in other cases. Operating stadiums is prevalent. It is then to be expected that similar smart tools will be assessed in other stadiums. Another consequence of the explorative character of this research is the lack of clear definitions and consensus amongst scholars about smart stadiums.

A second important limitation is associated with the neutrality and credibility of this research. Due to the fact that interviews are held with mainly specialists from the Johan Cruijff ArenA and KPMG. This can harm the heterogeneity of the research. Unfortunately, during the research not a lot more interviewees from different organizations were available. This could minimize the risks of matters such as advertising, incentivizing and avoidance of bias (Robinson, 2014).

Another risk related to qualitative research is the challenges with respect to the analysis of the data. In this research not, a specific format for analyzing the smart tools witch each other is used. As a result, there is the risk that the researcher's observations and interpretations of the data collected are causing subjectivity, information allocation and misinterpretation of the collected data. To minimize these risks the findings of the research could be validated by feedback on the reports. However, a better validation method that would more actively validate the research participants is to organize an expert panel or to conduct a Delphi method (Estimate-Talk-Estimate).

A fourth limitation of this research is the important aspect that stadiums are a small niche within the real estate industry with very specific characteristics. Therefore, the propositions and findings as derived from this study cannot easily be generalized for other types of real estate assets present in the industry. It should be noted that for generalizing the findings of this research it should consider to what extent this will limit the results of the study when applied to other types of real estate.

The stadium is observed or over some delimited period of time (2 months). Often referred to as the diachronic (temporal) elements of any case study, which can lead to issues. As seen in this research, a lot of smart tools that are assessed during the case study were in the development phase. As a result, that effects of integrating tools are mostly unknown, because they are not integrated. For the tools that were integrating, it was also hard to define the exact progress since implementing. This can be declared by two elements. Firstly, the progress since implementing the tools are not monitored well by the Johan Cruijff ArenA. Secondly, the exact effects of smart tools are unclear. For the management of the Johan Cruijff ArenA it was difficult to state specific goals that have to be achieved by the different tools. All things considered, clear findings with numbers are lacking in this research about the progress of the different smart tools.

9. Recommendations

The recommendations are derived from the conclusions as stated in the previous chapter. The recommendations are divided into two parts: (1) recommendations for practice and (2) recommendations for further research.

9.1 Recommendations for practice

Based on the research conducted in this report and the conclusions that have been drawn from this, various points of advice are given to stadiums who have the intention to integrate smart tools within the stadium and would utilize the full potential of smart tools

State clear objectives and goals that have to be achieved by the smart tools: what adds value to the stadium

In order to make sure that functionalities, where stadiums do not want to pay for, are not added and integrated in a stadium. Stadiums may be tempted to integrate as many new smart tools in their stadium, especially given to the often-low marginal costs of adding more sensors and software applications in combination with the relatively large costs of the technical layer (Porter & Heppelman, 2014, p. 78). But integrating extra tools does not mean that it will add value to the stadium and achieve the objectives. So, in order to find out which processes the stadium would like to improve, it is important that clear objectives are formulated. They have to find out which tools will add value and thus contribute to the objectives. Based on this smart tool could be selected.

To find out what adds value to the stadium various identification techniques can be used. In this research touch points as derived from analysing a customer journey were derived. However, also stadiums' own expertise can be very useful, experience from other stadiums might help, and lastly, surveys could collect useful data from stadiums' key stakeholders.

Assess clearly which data is needed to achieve the goals

The stadium management should critically reflect which data is already available and which is missing to make a smart tool operating. The organisation should keep questioning "what do we want to know and why?". This is important because otherwise new applications (such as sensors) are added, while there is no demand for.

Monitor the progress of the smart tools

After the objectives are stated and smart tools are selected, it is important that the progress since implementation is monitored. As seen for the Mobility Portal that was integrated in the Johan Cruijff ArenA two years ago, this is not the case (yet). As a result, that the effect that people use the mobility portal is not known, and thus the (dis)advantages of the smart tool are not clear.

Integrating smart tools require new capabilities: be aware of a partner ecosystem

As shown in the Johan Cruijff ArenA the whole data network and technical layer require 6FTE people that are maintaining and operating the technical system. Developing the whole technological infrastructure requires specific skills and knowledge that are traditionally not present in stadiums, such as data governance, system engineering, and software engineers. So, stadiums must choose which activities they would maintain and develop within their organisation and which one they want to outsource to specialists. For each of these decisions, there are pros and cons. Internal knowledge and skills is cheaper, and it is easier to retain control over the smart tool developments. While outsourcing can lead to extra costs, but specialized knowledge can be integrated efficient.

So, stadiums should identify which elements they would like to outsource and which not, based on which will offer the greatest opportunities. In the case of the Johan Cruijff ArenA, the data governance was originally outsourced, but this knowledge is now taken internal. In line with this development 4 of the smart tools developed internal.

Stadiums should be aware that different elements of a smart system require different suppliers and thus partners. As seen in the Johan Cruijff ArenA, despite the fact that more capabilities are developed internal, there are still a lot of partners involved. Such a partner ecosystem requires a lot of managerial efforts and collaboration. Also, the different partners need to be facilitated.

Potential to connect to the smart city

Stadiums are impacting their surrounding area's heavily during events. Various smart tools are not only relevant for integration within the stadium, but also for the close surroundings. Municipalities are benefitting for certain implementations, that are also useful for other 'smart city' implementations. It would be recommended that a collaboration with a municipality could be very useful for integrating smart tools. Besides the fact that municipalities are a powerful stakeholder, smart tools solutions could also interact and solve issues what affects municipalities.

Basic technology infrastructure takes a lot of time and effort to be implemented

As derived from the research, in the Johan Cruijff ArenA it takes already for almost two years to develop the technological infrastructure. So, stadiums should be aware that it will take quite a lot of time to identify their objectives, the needed data, right partnerships, and a proper technical layer. In general, these steps have to be taken before the smart tools can be integrated and working effectively. The advice would be to take this into account and don't wait too long, that will give competitive stadiums the opportunity to gain a foothold.

Be aware of privacy and security risks

As seen in the findings of the result, there are various privacy and security risks involved in the implementation of smart tools. Stadiums' management should consider data governance, ownership and access rights of all the different data.

Visitors are focussing on a live experience; smart tools can disrupt this experience.

Stadium managers should critically assess smart tools and the possibility that it can disrupt the live experience. Also, as described in chapter 4, different types of visitors with their own fan engagement are distinguished. It is recommended for stadium managers that smart tool is assessed critical in combination with the target group of a smart tool.

9.2 Recommendations for further research

In the future, hope to see improvement in research into smart tools that are integrated in stadiums. Based on the limitations of this research as described in paragraph 8.2.4 recommendations for further research are described in this paragraph. In general, due to the explorative character of smart tools and the niche in the real estate industry of stadiums, the current scientific body of knowledge is limited. New research into this research field can easily add value to the current scientific body of knowledge.

Conduct research with multiple case studies

In order to improve the external validity of the research, it will be interesting to research various 'smart stadiums' and compare the findings with each other. It will be interesting to compare the different experiences with smart tools with each other. Moreover, it is also interesting to compare the different smart tools that are integrated in different stadiums and see if there are common findings visible.

Conduct the same research in a few years (when all the tools are integrated)

The main reason to conduct the same research is at the moment a lot of smart tools are still under development. The goal of the Johan Cruijff ArenA is to be the most innovative stadium in 2020. This suggests that the smart tools are integrated in 2020. This can lead to adjustments to the current list of smart tools. Arguments, why certain decisions are made, could be very valuable.

Conduct quantitative research to the effects of the smart tools

In order to better understand the effects of integrating smart tools in stadiums, it is recommended to conduct a quantitative research to come with statistical evidence of the effects of smart tools (preferably before and after integrating the tool). Eventually, a research could also combine both elements in a mixed method approach. Possible insights from quantitative research could then be validly used as arguments why a stadium should integrate smart tools, and this can lead to better decision-making.

Research into the 'value' of smart tools in stadiums

Research to the preferences of the visitor of the stadium is recommended. A survey could be a suitable method to identify the different preferences for a visitor and how certain smart tools could contribute to these preferences. This could also be done for stadium operators.

Broaden the scope of stadiums to other types of real estate

There is room to shift the scope of this exploratory study broader to other types of real estate that involves a lot of visitors. Examples of real estate that could be relevant are airports, cinema's, festivals, shopping malls, and theatres. The reason to the broaden the scope is to improve upon the qualitative basis that this research is built.

Create consensus

As a consequence of the explorative and nascent character definitions such as 'smart stadiums' and 'smart tools', further research should contribute to clarify these definitions and by this contribute to the current scientific body of knowledge. This will also help in the argumentation why certain definitions are used.

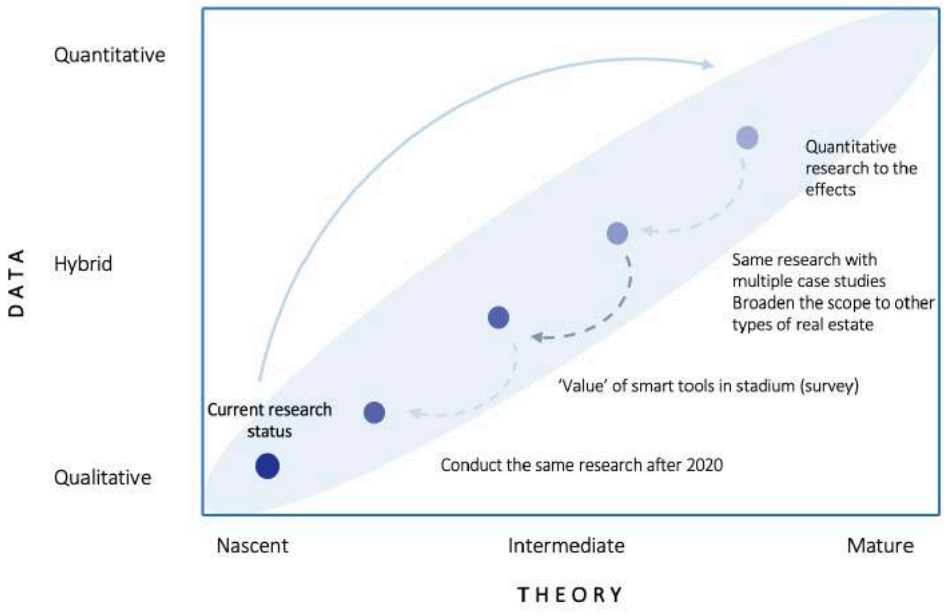


Figure 30. Further research recommendations in relation to the methodological fit (own illustration, based on Emdondson & McManus (2007))

10. Reflection

The following chapter aims to present the final reflection of writing this research. This chapter starts with a reflection on the research process based on the different phases of the research. In the next sections, the research topic and methods are critically reflected. After this, a reflection on the original goal of the research in relation to the outcomes is presented. This chapter closes off with the relevance and dissemination of the research.

10.1 Research process

Towards P1

What I found difficult at the beginning of this whole research was to find a research topic. Based on my personal interests for stadiums and new technologies and the relevance of this research I decided to conduct research to smart tools in stadiums. However, at the beginning of the research process, I was struggling with defining and understand the whole principle of smart tools. We had not gained a lot of knowledge about this specific subject during courses. However, through reading and by conversations I started to understand it better. Reflecting on this, I would have written down the properties and characteristics of a smart tool in order to improve the smart tool selection procedure.

The second point that I experienced as difficult was to choose the right research method. What I experienced as the main issue for this is the uncertainty if certain data was available. My first research proposal focussed more on quantitative data analysis. I did not have the guarantee to obtain quantitative data. In a future research project, I should really make sure from the beginning that data is available. On the other hand, I learned a lot during this period about different research methods.

Towards P2

After the P1, I had to specify my research method in more detail. I found it difficult to make decisions because there were still a lot of uncertainties related to available data. But by reading, discussing and contacting, thins were specified more and more. What I learned the most from this, is that to come to a good research proposal, will take a lot of time. I experienced very clear as a process, whereby it was difficult to immediately appoint the right research strategy. This felt sometimes a little bit frustrating, but in the end, the result is there. I think the insight and the reflection that a research proposal is more a process, which can be very helpful for my future professional career.

I also experience that the conditions to write this research proposal are also important, which I experienced as very pleasant. My first supervisors Alexandra & Bart managed to meet on a regular base. Sometimes individual and sometimes in groups, which was very useful. Luckily, after some weeks Philip became my second mentor, these meetings were also very useful because it's slightly a different point of view on the research. I also think, compared with other students that my process went quite smooth. I could not appoint some big problems despite some injuries after heading a hockey ball. So, the comments I received on my P2 presentation were positive. I was totally ready to start my research in February based on the formulated research proposal.

Towards P3

Due to my internship, it was quite easy to derive case study information about the Johan Cruijff ArenA. I also worked every Thursday in the Johan Cruijff ArenA. This made it very easy to contact different people, to do observations and ask questions. This information was very useful to understand what kind of tools are planned to be integrated, which people would be useful to interview and which companies were involved in the Johan Cruijff ArenA.

As a result of this, I came really quick to the conclusion that a lot of smart tools were still under development. As a result, it was difficult to find out what the exact effect was of every smart tool, which resulted in a shift from more quantitative to qualitative in my research approach. I hoped to find out more specific number from the Johan Cruijff ArenA how the tools lead to benefits.

My internship made it also possible to contact different interviewees very easily, who had a lot of knowledge regarding smart tools in stadiums. However, during the period that I was doing my interviews, the soccer club that is performing their matches in the Johan Cruijff ArenA did a very good job in the Champions League. As a result, most of the possible interviewees were very busy and did not response to my requests. A lot of appointments that I scheduled were postponed. This was a little bit annoying, however, I collected enough data in the end.

Towards P4

The feedback I got after my P3 was still positive. However, a challenge for me was to analyse the different smart tools. There was not a specific research method for this. This took more time than I would expect. In order to make these findings more practical, I decided to compare them with a smart system and different innovations.

During this phase of my research, the results of the case study came clear. I expected that the Johan Cruiijff ArenA was very 'smart' already. However, I learned from the interviews that a lot is still in progress and under development. The last weeks before the P4 deadline I was very busy with writing the report. This took more time than expected. Normally assignments are not that long. The thesis is a larger document, which lead to different issues, such as the quality control of the report. What also took a lot of time is that adaptations who were made in this phase of the project also had to change consequently throughout the thesis.

In the end, the results are different than I expected when I started in February. I had expected that the Johan Cruijff ArenA was further with the integration of smart tools, and thus could give better statements regarding the progress of the tools. However, the observations are still very useful for other stadiums. Lastly, I I had the opportunity to meet a lot of interesting people from practice, where I have learned a lot from.

Towards the P5

The main feedback I got during my P4 was to that the whole story was complete, however, I had to improve the storytelling of the research. Things that I had to improve were the visual attractiveness of the presentation, make it better understandable for people with no background in this topic, and lastly, take more a position regarding the implementation of the tools. Towards the P5 I was quite busy with improving these last pieces of the research, which took more time than expected. I learned from the feedback that it is important that the findings derived from the research should be made attractive and taking a stronger position will strengthen the research findings.

Whole process

I look positively back on the whole process. The deadlines that were set in the planning the P2 report turned out to be feasible and realistic. The only part that was delayed was the interviews. Due to the timing in the year and the performance of Ajax, a lot of interviewees were very busy. Reflecting on this I would contact them earlier and already sent an introduction of the research on beforehand. This was not the case, whereby it took a lot of time to explain different elements during the interviews, which was valuable time. For the next time, I would shorten

up the period that was scheduled for the literature study and extend the period for interviews. I had scheduled six months for the literature study, which was quite long, while only 2 weeks for the interviews were too short. Luckily, the postponed interviews did not cause a delay in my research. During this period, I could still work on the research by using the time to already elaborate the other interviews. In addition, I integrated a buffer in the planning, which reduced the pressure.

10.2 Research topic

10.2.1 Position within the faculty

This thesis was conducted in the context of the Chair of Public Real Estate from the department of Management in the Built Environment, Faculty of Architecture and the Built Environment at the Delft University of Technology. The Chair of Public Real Estate focuses on the challenges of managing public real estate portfolios by building theory on improving decision-making processes and finding new concepts for the built environment (Delft University of Technology, n.d.). Since, the tools support stadium users and by this optimize the existing use of real estate it can be argued that the research is applicable to real estate management practices, such as Public Real Estate. The main expertise of this Chair is university campuses, also described as 'managing the university campus'. In 2016, the first research that focussed on 'smart tools' was published, whereby a research team was set up called the 'Smart Campus Tools research team'. In 2018, a second book was published called 'smart campus tools 2.0'. These two publications focussed on exploring the existence and experience with smart tools at Dutch and international universities.

Meanwhile, this research does not focus on campuses. It can, therefore, be stated that it does not fit entirely within the 'managing the university campus' or the 'Smart Campus Tools research team'. During my graduation process, other students were researching the integration of smart tools in other types of real estate. So, it would be interesting to have a research team that focusses in general on 'smart tools'. By this, similarities between smart tools integrated into different real estate assets can be distinguished. Also due to technological developments, it is expected that the use of smart tools in the real estate industry will increase. All this creates fertile ground for a 'smart tool' research team or laboratory.

10.2.2 Two propositions related to the topic

In September 2018 the first meeting with my supervisors took place in Delft. During this meeting, a workshop was held to think about different propositions related to the research subject. Based on this session, the integration of smart tools in stadiums could be related to two propositions. These propositions can be used to critically reflect on the research goals and results. The relevance of propositions is explained by Franssen et al. (2009), where is stated that technology is itself value-neutral, but it can be put to good or bad use. The experiences gained during this thesis are compared with the different propositions, which are:

1. More available information is better
2. Protect people from technology

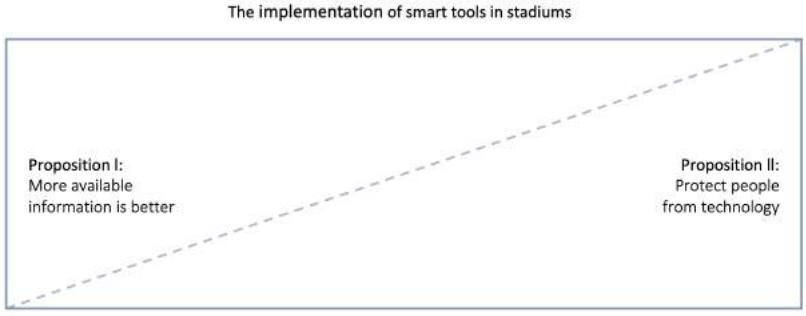


Figure 31: Implementation of technology in stadiums in relation to two propositions (own illustration)

Proposition I: More available information is better

Before this research was started as stated in the P2 report, my hypothesis was that the more information you can obtain will result in improving safety, profitability, the visitors' experience and/or sustainability within and around the stadium. And by this, the first proposition that more available information is better would be true. However, I have learned during this research that this is not the case and that too much information is useless if there is no demand for it. This research did clearly emphasize that information is needed to operate a smart tool. One of the issues that clearly is expressed in this research is that all kinds of data and information can be made available, however, in order to make sure that functionalities where stadiums do not want to pay for, it is important that the right information is made available. Moreover, the more information there is available, as seen in the data lake of the Johan Cruijff ArenA, the more difficult it is to extract the right information into dashboards and apps.

Proposition II: Protect people from technology

Originally my hypothesis for this proposition was that new technologies can interfere with the experience of attending a live event, therefore protect people from technology might be the case for stadiums. As learned in this research there are different types of spectators in a stadium. Some might have a higher demand for technologies while other not. Especially our younger generations are much more focussed on mobile devices. So, I think there is a lot of potential for technology if only the right user groups are assessed.

This answer focussed only on the spectator of stadiums. During this research, I did find out that smart tools have a lot of potentials to solve a lot of issues for different stadium stakeholders. It can, for example, reduce costs, improve sustainability, increase the user activities and so on. These are all arguments against this proposition, that people should be protected from technology.

What I would like to add is that during the research the importance of privacy and security risks related to technology. This is for me, not an argument that people should be protected from technology, but at least technology should be regulated and people should be aware of the privacy and security risks involved.

To conclude, my hypothesis for both propositions changed due to the experience of doing this research. Both propositions are not completely true or false; they are an adversary to each other which need to be in balance (see figure 31). This should be considered in further developments of smart tools integration.

10.3 Research method

Originally, the plan as described in the research proposal was to use a mixed-method approach according to an exploratory sequential design. In a mixed method approach, both qualitative and quantitative research methods are used (Lousberg, 2018). The qualitative data would be obtained by conducting interviews in order to assess different smart tools that are available for stadiums, while the quantitative part should on identifying the different effects due to the smart tools. This will be done by analysing data sets from the Johan Cruijff ArenA. To synthesize both methods the True Value Method was selected. The true value method considers not only the financial earnings of technology but also the social, environmental and economic impact. The impact of the technology will be translated into one common financial metric, which is called the "true earnings".

With this intention, I started this research. Quite soon I realized that no quantitative data was available. Moreover, against my expectation, many smart tools were not integrated at all and were still under development. As a result, I had to slightly change the research method. Reflecting on this, I had to make sure before I started with the research that I really was sure that quantitative data was available.

Further reflecting, I think the final used research method was a good chose. Due to the explorative character, a qualitative case study is a good method. However, by only analysing the Johan Cruijff ArenA I missed the 'optimization' by only analysing a case study. Also, it would lead to research with limited transferability and validity.

That is why I decided to compare the findings from the case study to another case which is also a smart real estate asset, which was the Edge Olympic. Based on these observations I tried to come with concrete solutions from the Change the Game Innovation Challenge. In the literature, I could not find similar research designs, which made it during the execution a little bit of a puzzle.

By comparing the findings to the Edge Olympic and the innovation challenges, extra value is added to the findings. During the research on the Johan Cruijff ArenA it became clear that the interviewees only could provide a rough estimation and guess of the effects of the different smart tools. Another point that I experienced as difficult was to compare the different findings as obtained from the interviews to each other. I could not find a proper research method that would help in facilitating this process.

Al in all, by studying the different research methods I have learned a lot about the different scientific methods. During my research, I had to adapt my research design because the data was missing. I do not think this is a bad thing since I was able to answer the research question with the current research method within the scope of the research. This will be elaborated a bit more in the next paragraph.

10.4 Outcomes: relation of initial goal and outcomes

The initial goal of the research was to help key stadium stakeholders to integrate smart tools effectively in the stadium by improving the decision making of key stadium stakeholders, and to contribute new insights from the research to the scientific body of knowledge. I often received the question which smart tools if I would recommend smart tools for stadiums and if so, which ones I would recommend. I would definitely recommend stadiums to think 'smarter' and be more innovative because smart tools can improve certain aspects of stadium operations. To give an answer on the second question seems more difficult based on this research. This is because the specific effects as a result of integrating smart tools are not obtained in this research. Therefore, it makes it difficult to prioritize different smart tools. In the initial goal, of this research, I expected that the effects of the smart tools would be clearer, and by this, a framework could be developed that prioritized the tools.

In order to answer this question, based on this research, I would advise stadiums to structure their operations in different 'themes', for example, a theme could be 'ticketing'. Based on the different 'themes', I would recommend to find out what needs improvement in their stadium and if smart tools could contribute to this. The smart tools that are assessed in this research did show the possibilities and potential. The smart tools that are integrated into the Johan Cruijff ArenA can be a showcase for other stadiums. Also, the recommendations in this research would be very valuable if a stadium decides to operate more 'smarter'.

In sum, the results obtained in this research make it difficult to prioritize the different smart tools (which was the original goal of the research). Despite prioritizing the different tools, valuable recommendations can be given to key stadium stakeholders in order to integrate smart tools more successful.

10.5 Dissemination

As described in the first chapter, this research is relevant to the scientific community and also for practice. In this section, the potential dissemination for this research is explained.

Stadium managers

The results of this thesis are relevant for stadium managers. The different recommendations and the analysis of the smart tools can be used for supporting future decision-making processes for stadium managers. The main benefits of this research for stadium managers is that it shows the possibilities, the experience of integrating tools, and the potential for adding value.

Universities and knowledge institutions

The research will contribute to the available scientific body knowledge on smart stadiums, which is limited as concluded in chapter 5. The important part of the contribution to the scientific field of knowledge is clarifying the terminology of a smart stadium, which is useful to come to a common consensus between scholars in the future. Moreover, it adds value to the current smart tool research and it proposes different alternatives for further research.

Municipalities

Originally, the whole innovation lab of the Johan Cruijff ArenA was set up by the Municipality of Amsterdam. Moreover, various smart tools also focus on the area outside the stadium and on safety. Panchanathan et al. (2017) propose the use of a smart stadium as a living laboratory to more easily deploy and evaluate technologies within the smart city concept. Due to the size and heterogeneity of the stadium environment that is small enough to practically trial but large and complex enough to evaluate effectiveness and scalability (Panchanathan et al., 2017, p. 2). Smart tools that are developed in and around stadiums are interesting for municipalities, and thus this research would also be interesting for stadiums.

Companies that can partner in smart tool projects

The integration of smart tools involves a lot of 'partners'. These partners consist of a diverse group of companies, such as contractors, IT suppliers, technology companies and some consultancies. For all these parties this research can show how the opportunities for them to share their expertise in stadium developments, and by this create new business potential.

10.6 Relevance

It is important that the research has both societal as scientific relevance. In this paragraph, the question what the added value of this research is for both the societal and the scientific body of knowledge will be answered.

Visiting a stadium is all about offering visitors the best experience (Campbell & Giorgio, 2016, p. 127). Which is an important part of our society; the first known stadium was built in the ancient Greeks in the 8th century BC. Visiting live events in stadiums is part of societies. In order to successfully implement smart tools and enhance the potential of 'smart stadiums', there is a need for a better understanding of smart tools and their effects within stadiums. Besides this, the research focusses on stadiums. However, findings from the research field of stadiums can be linked to other types of real estate assets where a lot of visitors are involved. This research can support stadium managers who participate in the decision-making processes concerning the implementation of smart tools in their stadium. This research can help key stadium stakeholder in making choices better structured and well-informed. In the end, by making the right choices, it can result in a better alignment of the stadium with the demands, as mentioned in the first paragraph.

Lastly, the research of Panchanathan et al. (2017) proposes the use of a smart stadium as a living laboratory to more easily deploy and evaluate technologies within the smart city concept. Due to the size and heterogeneity of the stadium environment that is small enough to practically trial but large and complex enough to evaluate effectiveness and scalability (Panchanathan et al., 2017, p. 2). This can be seen as a strong justification in favour of the development of 'smart stadiums' that can serve as a test-case for smart tools which also can be used for entire (smart) cities. This development can also be seen in practice. In both Dublin as Amsterdam, the development of smart stadiums is used as a living laboratory for smart city concepts (Smart Dublin, 2016.; Amsterdam Innovation Arena, 2017).

10.7 Concluding remarks

In the research proposal that was published in January 2019, two study targets were set that I wanted to achieve in this research. The first goal for me was to learn more about smart technologies in real estate and stadiums. It gave me new insights into the whole technical system of smart tools, but also the dynamics of stadiums and how stadiums are financed, organized and managed. This was a learning process that I would never forget.

Secondly, I wanted to gain practical experience in this research field. Both the interviews I have held during my research and the graduation internship helped me in achieving this goal. I spoke to a lot of experts in this research field, whereby a lot of practical knowledge was shared.

The research was finished on time, which was my ambition. The whole research process has been a journey where I strived to go for high quality. Of course, the process goes with ups and downs, difficult moments and happy moments. The will always be recommendations for improvement, but I am pleased to confirm that this report satisfies me. I hoped that you enjoyed reading this report.

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Appendices

Appendix A

Introduction

Welcome to this interview. First of all, I would like to thank you for participating in this research, I really appreciate this!

I will shortly introduce myself. My name is Simon van Heck and I am a graduate researcher at the TU Delft at the department of Public Research Estate Management. I am conducting a research to smart tools within the construction industry. The purpose of the research is to get insight in the different available smart tools in stadiums and their effect. Smart tools can be defined as a service or a product to provide (real time) information to its users. You were invited to take part in this research because of your experience and expertise in the integration of smart tools in stadium projects.

Before I start with this interview, I would ask your permission that this interview will be recorded. The recording will be used for transcription purposes and gathering the core information from the answers provided. The recordings collected in the interview are strictly confidential and will not be distributed to other parties. Also, all the answers will be presented anonymous in the final report, keeping the respondents anonymously.

At the end of the interview you have the opportunity to leave comments and questions regarding the interview and research.

Thank you very much for your collaboration and effort!

Kind regards,

Simon van Heck
Contact: simon_van_heck@hotmail.com

Interviewprotocol (based on the information visible in the template)

(name smart tool) - Stadium

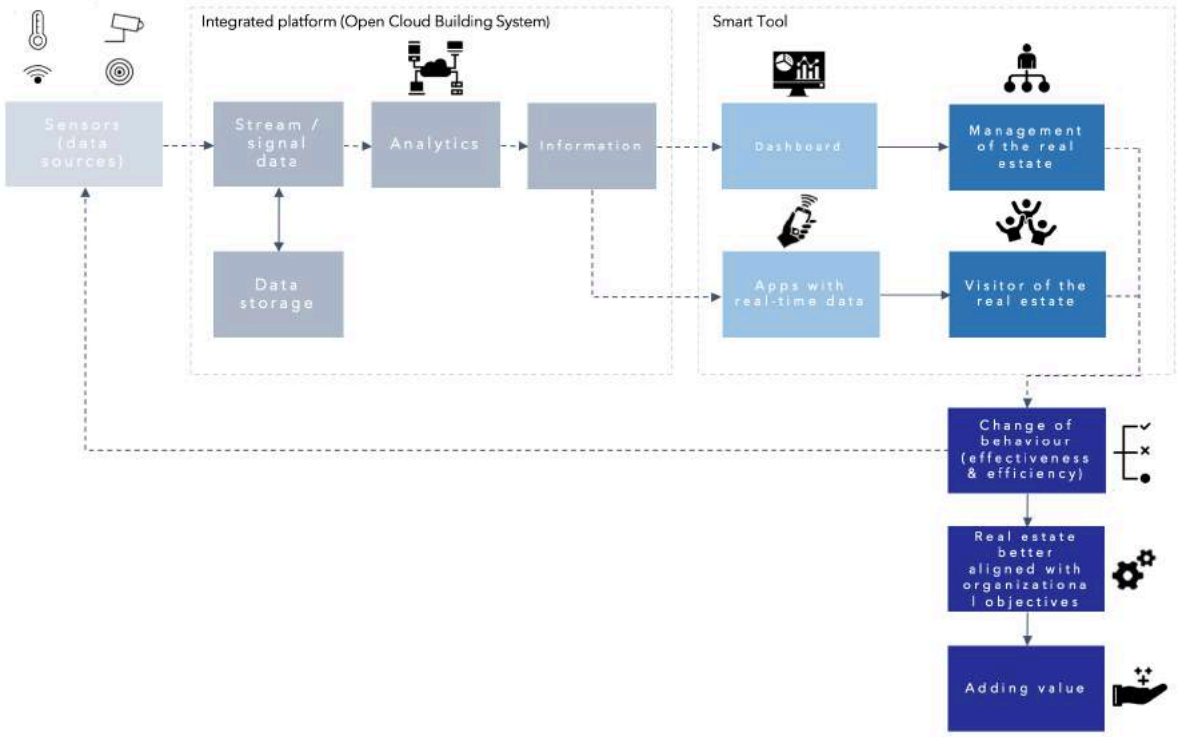
Interview	no.	Fields in template
	1	**Organisation-#**
		Fill in the abbreviated name of the organisation and a number to distinguish multiple smart tools at the same university.
input		
	2	**Project description**
question		Could you indicate how the initiative for this smart tool was taken (problem) and why this smart tool has been chosen (solution)
answer		
	3	**Phase**
question		In which phase of implementation is the smart tool?
options		
		Options? Research – if the smart tool is part of a scientific project Product development – if the smart tool is being developed towards a market-ready product Pilot – if the smart tool is market-ready and being tested with the objective of assessing if it can be applied on a large scale Expansion – If the smart tool is currently being implemented on a large part of the portfolio Implementatie – If the smart tool has been implemented and is now part of the regular operation
answer		
	4	**Scale**
question		Could you indicate how large the application area of the smart tool is, in m2 Gross Floor Area and amount of buildings?

	10	**Operating costs (per m2 GFA)**
vraag		Could you indicate what the operating costs of the smart tool are, in € per m2 gross floor area?
explanation		
answer		
	11	**Benefits**
vraag		What objectives are defined to be achieved with the tool, and what is the progress on these objectives since implementing the tool?
explanation		For example: the tool must lead to 10% energy savings / a user satisfaction of 9 out of 10 / an occupancy rate of 75%. Since the implementation of the tool we have achieved ...
	12	**User information**
vraag		Could you indicate what information is available to the user and how the tool works?
explanation		
answer		
	13	**Management information**
vraag		Could you indicate what information is available to the campus manager and how the tool works?
explanation		
answer		
	14a	**Why: Objectives**
vraag		Could you indicate to which goals the smart tool contributes?
options		Multiple options are possible: Strategic-> Stimulating innovation, stimulating collaboration, supporting image, supporting culture, improving quality of place Functional -> Supporting users, increasing user satisfaction, increasing flexibility Financial -> Increasing profits, reducing costs, reducing risks Physical -> Optimising m2, reducing CO2 emissions, Enhancing safety
answer		
	14b	**Why: Objectives**
vraag		Which goals have priority? How are they achieved?
answer		
	15a	**What: Measurement**
vraag		How is space use measured with the smart tool?
options		Multiple options are possible: Frequency - is a space in use, yes/no Occupancy - x amount of users in a space Identity - who are the people in the space Activity - what are the people in the space doing / how do they move
answer		
	15b	**What: Measurement**
vraag		What exactly is measured? How is privacy addressed?
answer		
	16a	**How: measurement method**
vraag		Which measurement method(s) is/are used?
options		Manual - manual counts are used Booking - booking systems or scheduling data is used Sensors - sensor data is used Indicate which sensors are used: e.g. Wi-Fi, infrared, CO2, Bluetooth, ...
answer		
	16b	**How: measurement method**
vraag		How does the measurement method work?
explanation		E.g. Wi-Fi registers the amount of connected users to the network, or: an iBeacon is placed in each room and users in that room make a connection with the iBeacon via Bluetooth.
answer		
	16c	**Actuality of the information**
vraag		How up-to-date is the information reported in the smart tool?
explanation		This can be different for different functions in the smart tool. Options are: near real time, in minutes, and hourly or more
answer		
	16d	**Actuality of the information**
vraag		Could you further specify how up-to-date the information in the smart tool is? Are there differences between functions?
answer		
	17a	**Access levels**
vraag		Who has access to the smart tool?
options		managers, support, users, open access.
answer		
	17b	**Access levels**
vraag		Who has access to which function of the smart tool?
answer		
	18	**Side notes**
vraag		Could you share some of the experiences with the smart tool, or other information which you think could be of interest for stadium managers?
options		
answer		
	19	**Images**
vraag		Could you send a number of images of the smart tool? 1 general image, 2 user information, 3 management information
answer		

Interviews are held with the following market specialists:

- Willem Hegen, Manager Crowd Services Johan Cruijff ArenA
- Maurits van Hövell, Mobility Consultant Johan Cruijff ArenA
- Chelsea Disseldorp, Senior Consultant Sports Analytics, KPMG
- Noud Zootjes, Data Engineer Johan Cruijff ArenA
- Huib Pasman, Technology Strateeg
- Sander van Stiphout, Director International Johan Cruijff ArenA
- Simone Jeurissen, Senior Consultant Date & Analytics, KPMG

Visualization of the smart tool during the interviews:



Interviewprotocol Edge Olympics

Casus: EDGE Olympic
Datum: -
Geïnterviewde: X, EDGE technologies

Korte introductie:

Voor mijn afstudeeronderzoek, welke onderdeel is van de MSc Management in the Built Environment, doe ik onderzoek naar de integratie van slimme technologieën in vastgoed, met als specifieke vastgoed type stadions.

Als case study heb ik de Johan Cruijff ArenA geanalyseerd, waarbij onder andere twee conclusies waren:

- Historische data kan worden gebruikt om operaties te voorspellen en zo kosten te reduceren.
- De verschillende slimme systemen kunnen aan elkaar gelinkt worden om meer waarde toe te voegen.

Aangezien veel van de slimme technologieën zeer recent zijn geïntegreerd, is het interessant om te kijken naar vastgoedtype dat al voor een langere periode slimme technologieën heeft geïmplementeerd, en daardoor historische data bezit. Vandaar dat de Edge Olympic is geselecteerd.

Historische data inzetten:

1. Voor welke toepassingen binnen de Edge Olympic wordt er data opgeslagen?
   Bijvoorbeeld technisch onderhoud, catering, schoonmaakwerkzaamheden, energieverbruik etc.

2. Wordt er op basis van de historische data andere beslissingen genomen?

3. Zo ja, kan je dit toelichten per toepassing?

4. Zijn er directe gevolgen zichtbaar doordat historische data is opgeslagen en hierop ingespeeld wordt?

5. Zo ja, wat zijn de effecten hierdoor?
   *Bijvoorbeeld kosten reductie van ** %*

6. Wat zijn de *lessons learned* voor het gebruik van historische data?

Linken van slimme systemen aan elkaar:

7. Zijn er verschillende toepassingen binnen de Edge Olympic aan elkaar gelinkt?
   Bijvoorbeeld schoonmaakwerkzaamheden aan ruimtegebruik

8. Zo ja, is dit in de loop der tijd gebeurd?

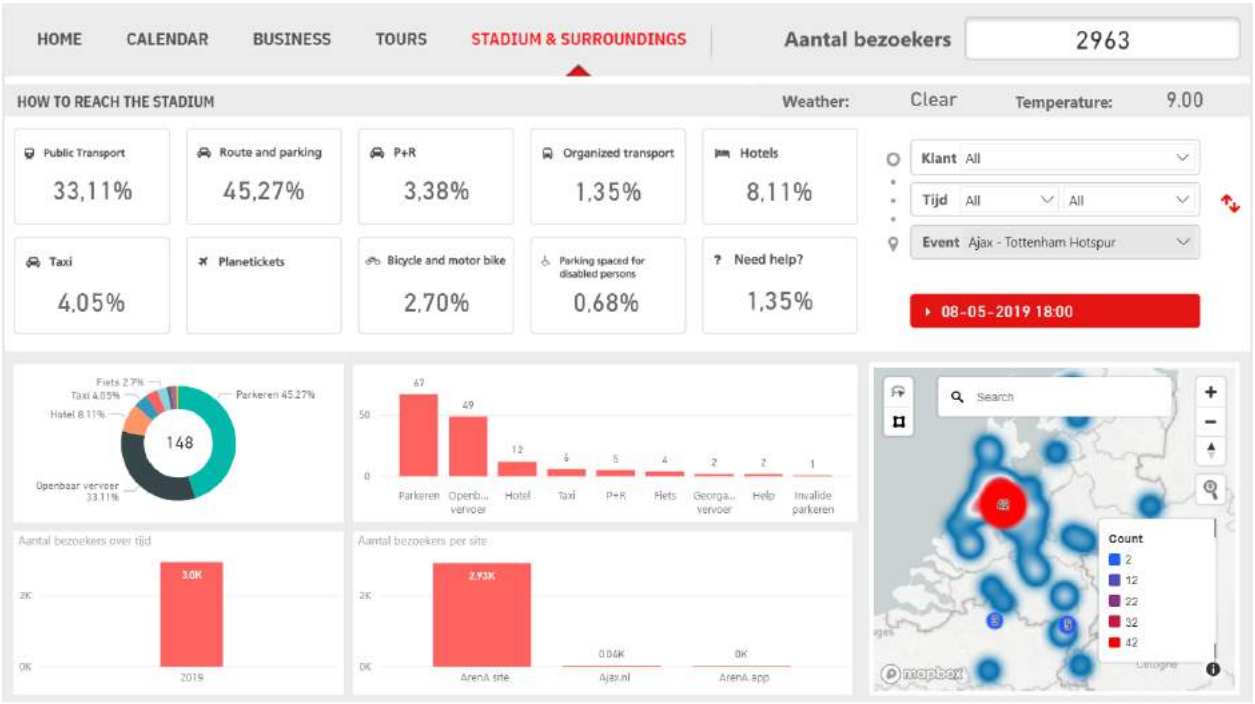
9. Heeft dit tot extra positieve gevolgen geleid?

Appendix B

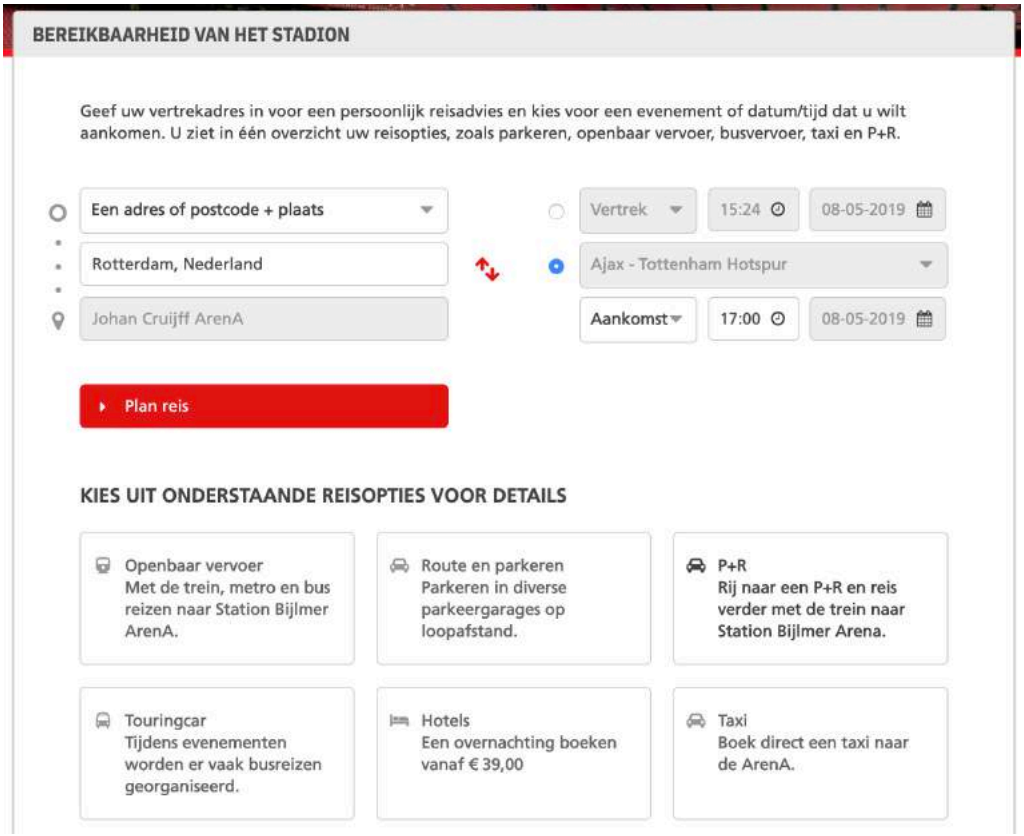
Images of the smart tools:

1. Mobility Portal
2. Smart Turf Monitoring System
3. Edge Olympic

1. Mobility Portal:



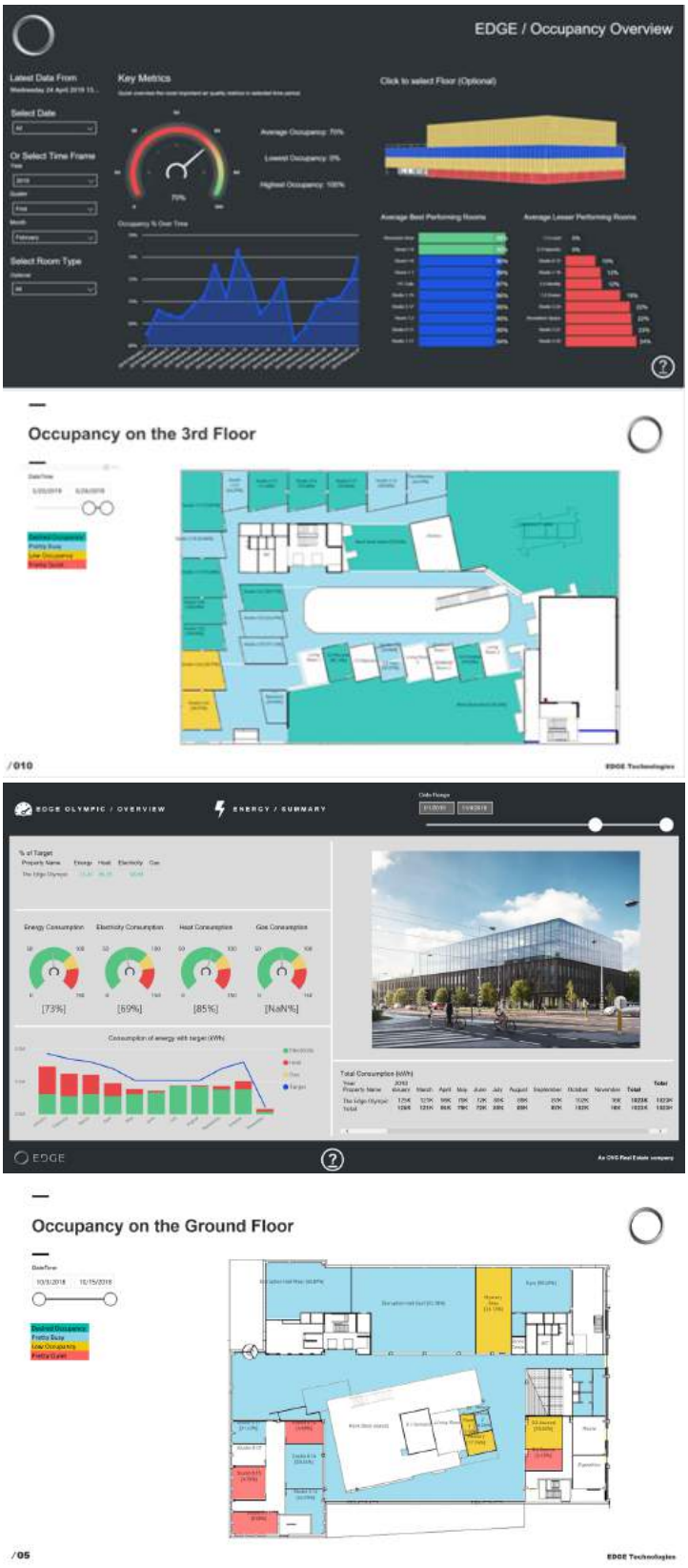
Management Dashboard Mobility Portal



User Interface Mobility Portal

Smart turf monitoring system:

Poster with explanation and user interface of the tool

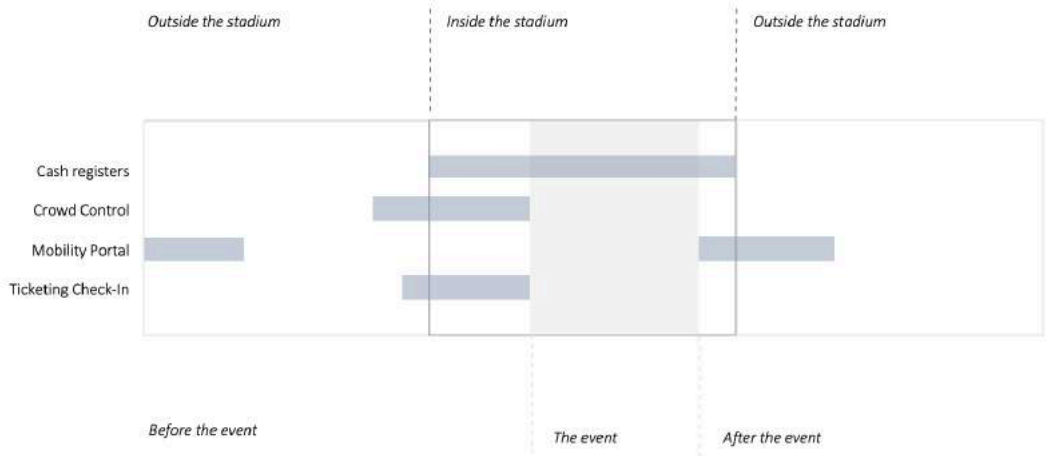


Interfaces smart tools Edge Olympic

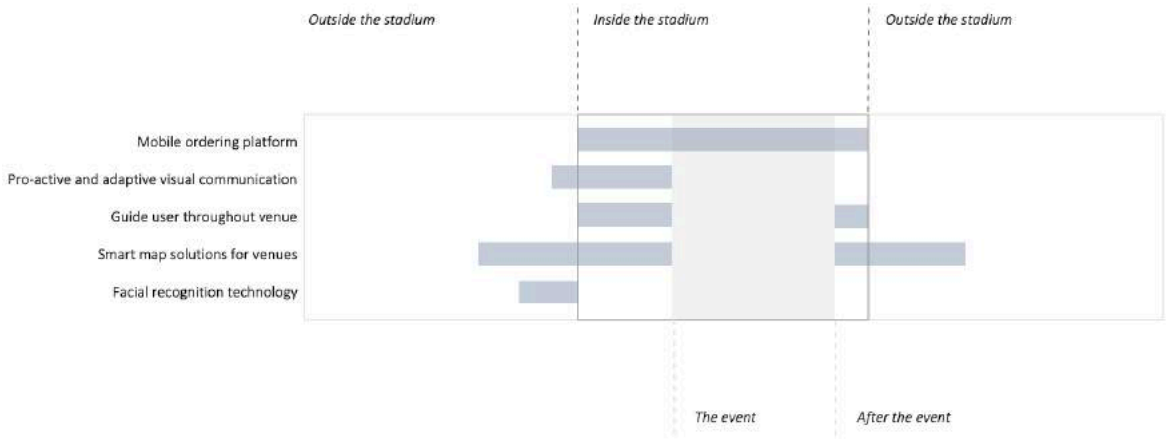
Appendix C

The different smart tools that are integrated in the Johan Cruijff ArenA are plotted on the customer journey and in the stadium:

Touch points tools in stadium environment



Current tools used during events



New potential tools

Appendix D

1. 24/7 Software

24/7 Software is a leading provider of operations management software solutions for operations centers including, commercial and residential properties, corporate, sports, and public entertainment venues.

2. AVEX b.v.

Our solution helps to unlock the data from the Arena into visual feedback for visitors. Informing visitors is done by showing relevant information on the screens in- and outside the Arena. Nowadays many of the content is scheduled and non-responsive to changing situation. The information on the screens can be optimized for visitors when information changes. Smart combination of data can stimulate decision making of visitors in the Arena.

3. Bitz

Bitz is an easy to use mobile ordering platform that lets customers place their orders and pick-up by themselves, saving time, optimizing staff costs and improving the guest experience.

4. Coca-Cola European Partners

Garbage can become resources for circular application. All drinking cups and plastic bottles used in the stadium will be made from PET and rPET as of this summer, allowing for 100% circular usage. PET is the only plastic in line with Food Safety regulations to reuse in cups/ bottles into new ones, hence circular recycled. All other plastics can only be 'down-cycled' into a new application.

5. COMPO Software

We, COMPO Software, cooperate with 20face to create a variety of solutions with privacy-proof Biometric Recognition Systems in Ticketing, Customer Experience and HR applications. 20face focusses on entry management solutions via facial identification.

6. DFFRNT Media

The Augmented Stadium experience directly starts when you arrive at (outside of) the stadium. The large banners (of Johan Cruijff/performing artists) invite you to take part in the augmented stadium experience (by downloading app or through third party app like Snapchat). Through mobile AR, different key points in the stadium are scannable markers that activate an AR experience.

7. Eyecandylab

With eyecandylab's mobile AR technology, users can enjoy live games with an interactive AR layer - The augmen.tv „AR Sports Interface". Simply by pointing their smartphone or tablet towards a live broadcasted game, sports fans will access a real-time AR Sports Interface with key game stats, player profiles and tracking data in an interactive and visually enhancing way.

8. Foot Analytics

Foot Analytics uses wifi tracking technology to locate devices and by extension people carrying them. This data is used to analyse the people traffic, visitor behaviour, dwell time, recurrences, real-time occupancy, customer journeys and many other kpis which can also be tailored to a specific scenario.

9. Forward Game UG

A week ago we have launched a game that implements the solutions for location based and Augmented Reality gamification of the arena with Schalke 04 team. The game transforms the area around the arena into a quest. We use location based game objects that need to be discovered on the map, inside them there are quiz questions and additional challenges. Users collect team player cards and can swap the cards between each other.

10. Game On

Our purpose is to provide athletes, coaches and sports organisations with the most advanced and easy-to-use video technology through our continuous focus on innovation and our passion for sports and technologies.

11. GEENEE

Geenee bridges the physical and digital world through lightweight and robust image and video recognition technology. Geenee has developed a platform to deliver a web-based API that can turn any website into an immersive camera that is spatially aware and capable of providing deeper context and/or experiences to the IRL images, videos and objects in the environment around the user.

12. Hawk-Eye Innovations

With the implementation of VAR (video assistant referee) technology in the Eredivisie, there is a growing need for transparency about decision making from the refereeing team and VARs. As a company, we have created two solutions to share more information with the spectators in the stadium.

13. Hey Digital Ventures Lda

X-PLORA is an app-based solution that guides users throughout a venue in a totally interactive and immersive way. As the visitors move around a venue, the app provides customized information/content, determined by the user's exact location, profile, interests and moment in time (e.g. content triggered during an event can be different from content triggered during a stadium tour).

14. HIGGS Live

We help sport clubs to level up their fan engagement especially for younger people by creating live game shows.

15. Hikvision

VIP fast entrance stadium based on face recognition. Hikvision has embedded Deep-Learning algorithms into its face recognition terminals, providing fewer transmission delays and a reduced load on backend components. As a result, the terminals have a high success rate – the face-capture rate can hit 99% accuracy at less than 0.5 seconds.

16. Immersiv

ARISE is an in-stadium experience for spectators, which allows them to visualize live data directly overlaid on top of the pitch and even on top of the players. Indeed, using Augmented Reality technology we can give the fans access to all the information they want, without ever looking away from the action.

17. Inmotio Object Tracking BV

Creating personalized video streams of artists, players and athletes by combining real time position tracking technology and high resolution streaming video. ArenA visitors will be enabled to zoom in on their favorite artists/players/athletes creating a close up and ultimate experience. In addition by applying virtual director technology (TNO), an automated registration of an event such as a football match will be generated.

18. iXpole

This is where iXpole pops up. iXpole automates ALL operational aspects, from contract management, over stock management, resource management, over ticketing, automated communication to automated invoicing, surveying etc. More importantly: iXpole centers around the VIP customer journey. Every VIP gets access to an online portal/app to personalise his experience, manage his invitations, tickets and even administration. This gives you VIPs total digital freedom

19. Jalu.tv

On www.jalu.tv anyone can become a sports commentator. That way we want to enable a big pool of different styles of commentation for sport events.

This provides further insights for viewers who are not in the stadium and they can watch a commentator standing right in the stands of the stadium. Viewers in the stadium could enjoy an individual commentation of the event to get further info and improve the experience in the stadium.

20. Keyper GmbH

Whether it is music, sports or cultural events - keyper is the easiest way for organizers to send mobile tickets, reach all your visitors and generate more sales. We provide white labeled technology for easy and secure sharing and selling of tickets by connecting the existing ticketing solutions with mobile platforms. Enabling sport clubs to solve the “No-Show” problem, connect to all attendees, gain more relevant data and increase overall revenue.

21. LiveArena Broadcast AB

LiveArena provides radically simple, innovative, and cost-effective solutions to produce, create and deliver live and on-demand streaming for online TV channels to any device, anywhere at any time. Our revolutionary production automation turns every event into a live event.

22. LiveTube Ltd.

LiveTube - The World's First And Only Live Platform With Professional Curation. You can find many other live platforms e.g. Consumer - Facebook Live, Periscope, Twitch etc or LiveU. Bambuser etc. (B2B). None of these offers a global cloud based newsroom with real-time curation and a safe environment for advertisers, companies, content licensees/ copyright holders and users. LiveTube also fully integrates with media outlets around the world for real-time content licensing.

23. Netco Sports

Thanks to the Live Stadium feature, users will have an interactive experience inside their venue app that enable them to rewatch the best moments from different cameras. The Live Stadium gives user a premium way to see the game and increase their engagement.

24. Nmodes

A chatbot (or voice bot) allows visitors to personalize their experience based on their individual interests and desires. The chatbot is powered by AI and therefore can be trained to deal with any conversational topic. It can listen to user's requests, understand them and reply accordingly (for example, with interesting info on user’s favorite player) or can be proactive, for example letting a user know if his favorite player is giving a post-match interview and maybe even asking this player a question via the same chatbot.

Names

25. NODALBLOCK S.L

Next generation ticketing experience with blockchain. Nodalblock’s ticketing distribution system is fully production ready. It is intended to be integrated with authorized online sales channels, not to replace them. The system digitizes each ticket as a unique, interactive asset managed by a private blockchain, and delivers it securely to the end-user.

26. Orwell VR

Over the last 12 months, Virtual Soccer Zone has been developed and customised for AS Roma and Genoa CFC using our videogame in the stadium as entertainment for fans before and after the football match.

27. Oveit

Our vendor ecosystem technology works great for organizations that need to tap into new revenue and data streams, as well as audience engagement tools. We use a private local blockchain that allows the ArenA to extend its closed loop economy outside the stadium walls. Visitors would subscribe to the Johan Cruijff ArenA, get access to curated places and events, pay using the local payment card issued by the Johan Cruijff ArenA and fans can use the same card to access fan-only locations and products throughout Amsterdam, all the while extending the brand recognition.

28. SciSports

SciSports uses data intelligence to understand football with the goal of improving the game on the pitch and enriching the experience of billions of fans around the globe. SciSports created an index (SciSkill Index) to determine the quality and potential of over 200,000 players around the globe. SciSports' platform Insight provides access to data sources as well as reports offering novel insights in player performances and team tactics.

29. Snaptivity (Snapify Ltd.)

Snaptivity - award-winning Smart Stadium tech that enhances the live event experience by using IoT sensors & AI to understand & predict crowd emotions and robotic cameras to capture the best moments for every fan.

30. Stayfilm

Stayfilm is an automatic film producer that transforms your photos and videos into films with fantastic visual effects and outstanding cinema-like quality. Use the content from your social networks, smartphone and in one instant your film is ready to be shared. It's fast, automatic and free!

31. Synchronicity Productions Foundation

Can you imagine a big crowd in a stadium performing a moving animation without any rehearsal? We make it happen. Our animations touch the heart of your fans and maximise engagement & experience. Not only is it fun to do, it also connects the fans, making it a show of strength and unity. Whether it is to salute the players, pay tribute to a special person, or celebrate a victory.

32. Texel, Inc.

Visitors will get 3D avatars and make 3D-photos with panoramic stadium background. It takes only 30 seconds to make a scan and 1 minute to build up a 3D-image on a big screen. 3D-photos are sent to all visitors who scanned automatically.

33. Tiledmedia

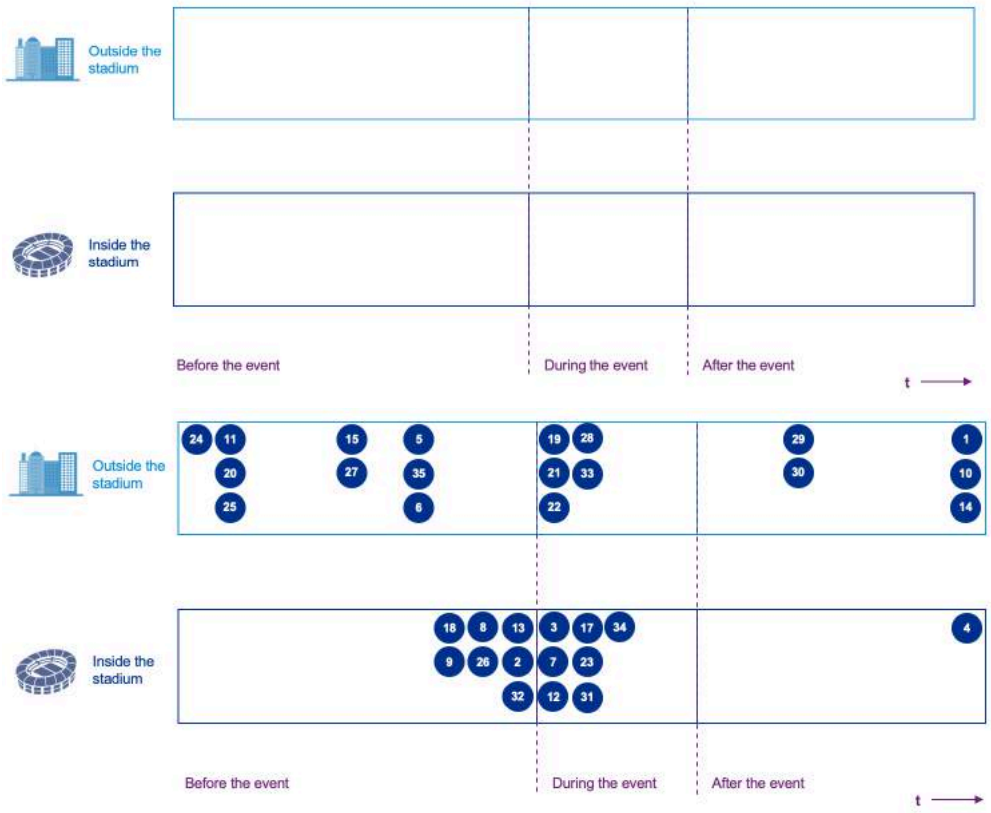
Tiledmedia proposes to bring the fans from outside the stadium into the stadium through their connected devices. Building on proven technology and experience with customers live streaming Budesliga Basketball, UEFA Football and live music concerts, we offer to provide the Johan Cruijff ArenA with its own 360 degrees stereoscopic live experiences delivered to fans anywhere in and outside the stadium via the apps of the Johan Cruijff ArenA and/or their partners. With a stereoscopic experience, the fans will feel even closer to the action. Our technology provides the ability to instantly switch between different cameras and viewpoints, giving full control to the end-user.

34. VOGO

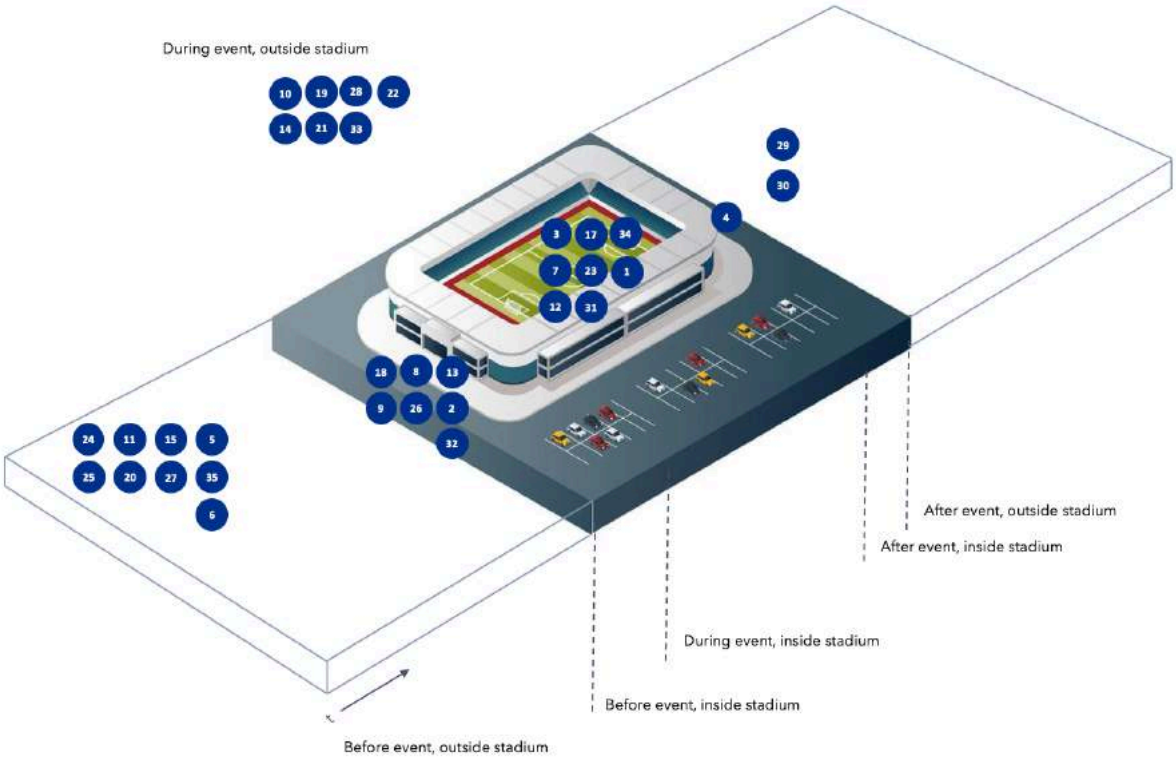
With VOGO SPORT application, we give access for spectators attending the match in the stadium, to the live feeds from the TV cameras filming the match, through their smartphones. Through VOGO SPORT, they have several angles of view on the match (ex: close camera, camera behind the goal,...). On every angle of view, they can instantly, and at any time, rewind to replay an action, in normal speed or in slow motion. They can also zoom or pause to get a closer view on a detailed action. Actually, every spectator becomes his/her own produce, and becomes actor of what he/she watches

35. Wizzymaps

We make the best of every event minute by providing a smart web based map for the venue and venue area. On the spot information where and when you need it. Are you hungry and looking for a burger, just type 'burger' and you know where to go. Do you have seat for a match with the Dutch football team? Just type your seat number and you'll be guided to the correct entrance. Try it yourself! You are looking for seat number 415.



Used model with the 35 plotted innovations



Visual plot of the 35 innovations from the challenge in relation to the 5 phases (see customer journey)

Appendix E

As seen in the customer journey of the stadium management, there are a lot of daily operations that are not linked to the organization of an event. For these daily operations, which does not touch the visitors' experience, measuring could add value. Information of space-use can be used to optimize the staffing. Secondly, the information of space use can be used for cleaning scheduling. Also, the use of spaces can be related to maintenance and construction work. Lastly, the space use can be related to the energy consumption in the stadium. See the customer journey of the stadium management on the right side.

CUSTOMER JOURNEY STADIUM MANAGEMENT.

	BEFORE THE EVENT				STADIUM IS OPEN FOR SPECTATOR		LIVE EVENT	AFTER THE EVENT	
	Announcement of event	Ticket sell	Preparing the stadium	Spectator is heading to the event	Check-in stadium	Before the event	During live event	Event ended: spectators leave	After event: prepare for next event
ACTIVITIES	The stadium management discusses and negotiates with an external organization or clubs to see if the event is possible to be organized. Meeting with different stakeholders.	This is the responsibility for the organisation that leases the stadium. However the stadium has interests in the ticketing, the more tickets there are sold, the better for the stadium image.	Stadium will be cleaned and prepared for the event (facility management). Supply of F&B for during the event (operational). Personnel will be booked in order to meet safety standards (security, safety and hospitality).	Prioritize transportation methods for spectators in order to reduce nuisance for key stakeholders and to make sure that spectators will be as early as possible within the stadium.	Open and operate ticket check ins. Make sure that check-in desks are regulated. Security check the spectators.	Make sure that spectators can use toilet, food and beverages facilities. Guide the spectators to their seat safely. Make sure that the crowd is distributed due to safety and sales. Supply of the facilities. Hospitality services.	Monitor the crowd and control them. Monitor the safety and security of the spectator. Supply the F&B facilities.	Open the gates and make sure spectators can leave the stadium efficient. Distribution of the crowd.	Stadium will be cleaned and prepared for the event (facility management). Waste management. Re-pair the pitch. Facilities have to be prepared for the next match. Evaluating.
MOTIVATIONS	Organizing an event will generate income for the stadium.	The more visitors, the more income can be generated by F&B services. Also, it's better for the atmosphere during a live event.	Make sure that the stadium can fulfil the expectation of the spectator, the event organizer, and other stakeholders. Reduce the costs of the preparation activities in order to optimize profit.	Keep a good relationship with external stakeholders. Good accessible stadium is positive for the image. The earlier spectators are in the stadium, the more they can spend.	Make sure that only people who bought a ticket can entry the stadium. Limit the waiting lines in order to reduce nuisance for spectators and extend the duration time of spectators in the stadium.	Optimize the sales of F&B and merchandise. Improve the visitor experience and guarantee the safety of visitors.	Create a safe environment for both players and spectators within a stadium.	Make sure that the spectators can be guided home safely. Try to keep the spectator as long as possible within the stadium.	Prepare the stadium for next events. Evaluate to improve. Reduction of costs.
QUESTIONS	When is the event? Is the stadium available? Do the stakeholders agree?	Where to buy the tickets, are there enough tickets and how expensive are the tickets?	What needs to be cleaned and prepared? Which rooms are booked? How much spectators are expected? What is the risk level of the event?	Are there incidents that can harm the accessibility of the stadium? Where is enough capacity to transport the spectators?	How busy will the event be? Are the check-in desks all working? How is the flow through?	What are opportunities to generate more sales? Which area's are too crowded? Is there enough supply left?	Is there enough supply left? How is the match influencing safety and security? How is the crowd behaving?	How does the match result impact the behaviour of spectators? Are there any barriers for leaving the stadium? Are there incidents that can harm the transportation services?	Which areas have to be cleaned? Which ones have priority? What can be improved next time?
BARRIERS	The stadium is already booked. Key stakeholders do not agree with the event. The event organizer does not agree with the price.	What are barriers for visitors to buy a ticket and visit the event of the stadium? How many tickets are sold? What does this mean for the operation of the stadium?	Not enough personnel available. Problems with the pitch condition.	Incidents that can impact the accessibility of the event.	Technical problems with the check-in desks. Not enough personnel to conduct a security check.	Long waiting lines for the different facilities. Problems with the supply of products. Signals and wayfinding are not clear.	Incidents during the match can impact the behaviour of crowds.	Crowded area's. Problems with the transportation services. No supply of products left. Match result impacts the behaviour of the spectator.	Unknown which areas are used? Period of time till the next event.
TOUCH POINTS	Collaboration with main stakeholders. Event management.	Online platform for ticket sell (and ticket resell), ticket shop, marketing.	Facility services, operational services	Transportation services and transportation infrastructure	Ticketing check in, queue management	Ticketing, facility management, operational management, hospitality services.	Live experience, crowd control, safety management.	Crowd control, transportation services., safety management.	Facility management, operational management, property management.

This research is conducted in partial fulfilment of the requirements for the degree of Master in Science at the Delft University of Technology in combination with a graduation internship at KPMG The Netherlands.