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An international comparison

Valks, Bart; Arkesteijn, Monique; den Heijer, Alexandra

Publication date
2018

Document Version
Final published version

Citation (APA)
Valks, B., Arkesteijn, M., & den Heijer, A. (2018). *Smart campus tools 2.0: An international comparison*. Delft University of Technology.

Smart campus tools 2.0

An international comparison

Bart Valks
Monique Arkesteijn
Alexandra den Heijer

Colophon

This research has been carried out in assignment of fourteen Dutch universities by a research team of TU Delft, from April 2017 to March 2018.

Research team:

Bart Valks	Main researcher and Ph.D. candidate
Monique Arkesteijn	Daily supervisor, Assistant professor Real Estate Management
Alexandra den Heijer	Promotor, Professor of Public Real Estate

All researchers are employed by the department of Management in the Built Environment, Faculty of Architecture, TU Delft.

Cover Design:	Bart Valks (based on design by Flavia Curvelo Magdaniel)
Lay-out:	Bart Valks (based on design by Flavia Curvelo Magdaniel)

Published by TU Delft, Faculty of Architecture, dept. Management in the Built Environment
ISBN 978-94-6366-026-6

Table of Contents

Preface

Since the inception of our research on campus management, knowing how space use is actually used on campus – in contrast to the scheduled use via timetables or calendars – is an often discussed topic. The match between the demands of the organisation and its users and the supply in buildings can be made a lot more precisely, many think. Advances in technology continue to make it easier to measure how facilities on campus are used and/or how people make use of them.

In October 2015 this was the cause for the Dutch universities and their directors of facility services (united in the DFB network) to commission the research project on Smart campus tools. This book reports the results of the second year of the project –hence the title 'Smart campus tools 2.0'. In the Smart campus 2.0 project the objective was to explore the use of Smart tools outside of the context of Dutch universities, and to compare the results to those found at the Dutch universities.

We owe a great debt of gratitude to all the participants for making this report possible, by spending their time and effort to participate in interviews, collect data and provide feedback, and to the members of the DFB for their continued support and inspiration. Also a special thank you to my colleague Catelijne Elissen for helping to organise the joint meeting with the Dutch universities and for very helpful suggestions on universities to contact for the research.

I would also personally like to thank you all for your enthusiasm in our meetings – whether via Skype or in person- it has really inspired me. This year was a great adventure and learning experience which I can only hope to keep up in the future.

Bart Valks
On behalf of the Campus Research Team

Department of Management in the Built Environment
Faculty of Architecture, TU Delft
March 2018

Executive Summary

"Everything is booked, but many rooms and seats are empty". This problem was the basis of the 'Smart campus tools' research and is familiar to both users and campus managers alike. On today's university campus - with an increasing amount of students, part-time researchers, guest professors and other visitors - many users are looking for a place to study, to work or to have a meeting on a daily basis, but often all the space on campus seems to be in use: education spaces are booked for lectures and desks are claimed by books on the table or a coat on the chair. However, for large parts of the day they are not in active use.

This "reserved but not used" problem resembles a top-10 annoyance on vacation: sunbeds by the poolside at holiday resorts are claimed with towels, without actual people using them. This analogy with the 'towel problem' points out two important issues: when space is scarce people start claiming their territory "in advance" and this annoys all other potential users, with a negative effect on satisfaction rates. This leads to a paradox: while the campus community perceives scarcity of space, campus managers know that the available spaces are not used to their full capacity. Smart tools were envisioned as a possible solution for this problem.

Figure 0.1 - 'Reserved but not used' as a problem statement, smart tools as a possible solution

Previous research: Smart campus tools (2015-2016)

In the previous research project – smart campus tools, part 1 in 2015/2016 - a literature search, interviews with Dutch universities and interviews with other organisations were used to explore the subject of smart tools. The following definition for smart tools was formulated:

"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."

A smart tool is described in three components:
1. Why this tool? - objectives - the reasons why the smart tool is implemented
2. What does this tool measure? - space use information - the type(s) of data collected
3. How does this tool measure? - measurement methods - the sensor, system or method used to determine space use

The report identifies the smart tools in use at all Dutch universities, their current and future demands and explores the use of smart tools at a few other organisations. Based on the conclusions of the previous research the demand arose to compare the results from universities in the Netherlands to international universities and more organisations, leading to the 'Smart campus tools 2.0' research.

Smart campus tools 2.0 (2017-2018)

In smart campus tools 2.0 the use of smart tools is elaborated upon by interviewing practitioners and delivering case materials in a standardised way. These results are compared to the progress at Dutch universities over the past year. Figure 0.2 shows the three major components of the research. The main research question is:

"What smart campus tools are available at international universities and other organisations and how do they compare to the use of smart tools at universities in the Netherlands?"

Smart campus tools 2.0

International universities – UK, Germany, Switzerland, USA, Scandinavia, ...

Other organisations – tech organisations, stadiums, stations, ...

Update NL – Dutch universities, progress past year

Figure 0.2 - Components of the Smart campus tools 2.0 research

In the exploration at international universities and organisations over 40 parties were approached to participate in the research. Table 0.1 and 0.2 show give an overview of the parties that were interviewed or have reacted that they do not currently use any smart tools. Together with the fourteen Dutch universities a total of 35 parties were involved in the research. This has resulted in 27 cases of smart tools, all documented in a standardised way.

Country	University	Function of interviewee(s) and contacts
Denmark	Aarhus University	ICT, Campus management
United Kingdom	Oxford Said Business School	Campus management
Denmark	DTU	Library
United Kingdom	University of Glasgow	Campus management
Belgium	University of Leuven	Library
United States	Carnegie Mellon University	Academic
Switzerland	EPFL	Campus management
United Kingdom	Oxford University	Campus management
United Kingdom	Cambridge University	Library
United Kingdom	Reading University	Campus management
United Kingdom	Ulster University	Academic
Switzerland	ETH Zurich	Campus management
United Kingdom	Sheffield Hallam	Campus management

Table 0.1 – Overview of respondents at international universities

Country	Organisation	Function of interviewee(s)
Netherlands	ABN AMRO	Facilities management
United States	Microsoft	Real estate and Facilities management
Sweden	Sony Ericsson	Workplace services
Netherlands	Erasmus MC	Real estate management
Italy	Agnelli Foundation / Carlo Ratti Associati	Architect and founding partner
Netherlands	Dutch government (shared service centre ICT)	ICT
United States	Google	Real estate and workplace services
Netherlands	OVG	Chief technology officer

Table 0.2 – Overview of respondents at organisations

Results

In each chapter - (3) international universities, (4) other organisations and (5) Dutch universities - an analysis across the collected cases is done to conclude what type of smart tools are prevalent. Figure 0.3, 0.4 and 0.5 give an overview of the smart tools found in the study.

In the cross-case analysis of each chapter the different aspects that are documented in the cases, such as objectives, space use measurement, measurement method, etc. are compared across the different cases.

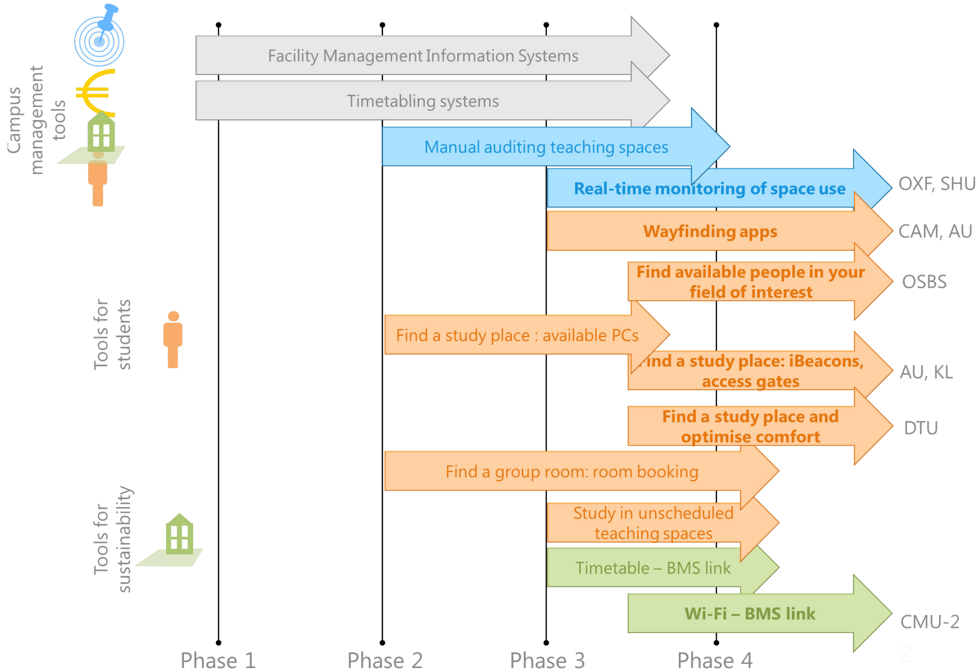


Figure 0.3 – Overview of available smart tools at international universities. Phase 1: no smart tools; phase 2: prevalent smart tools in 2016; phase 3: new smart tools in 2016; phase 4: ongoing smart tools in 2017. Arrows with bold text represent smart tools found in this study.

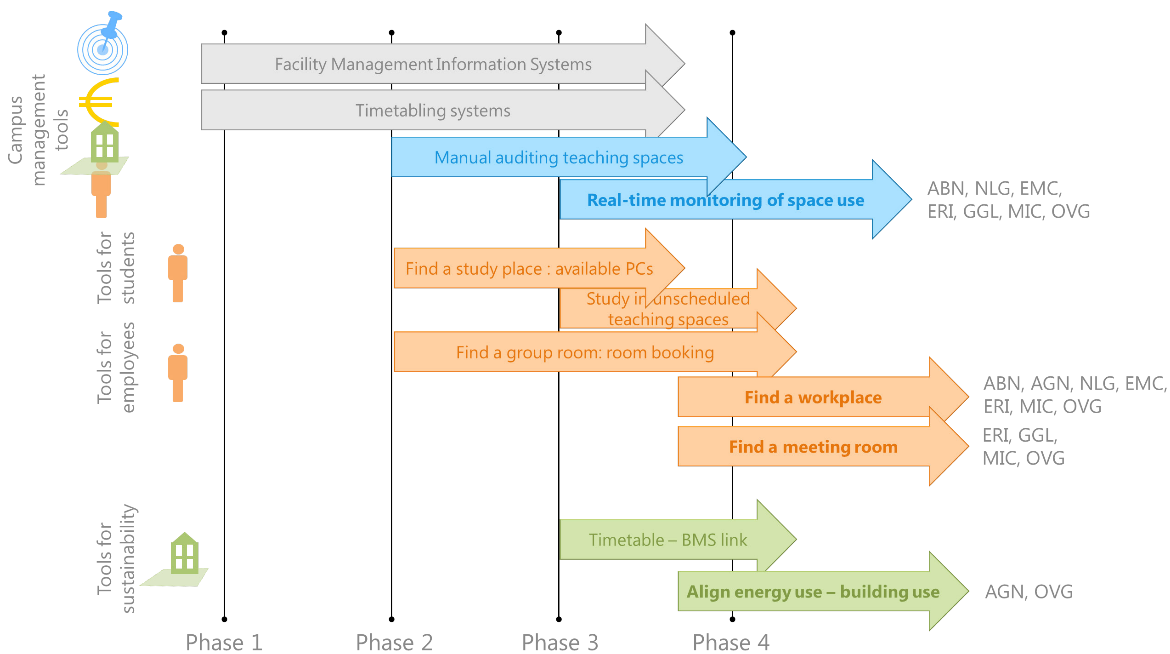


Figure 0.4 – Overview of available smart tools at organisations. Phase 1: no smart tools; phase 2: prevalent smart tools in 2016; phase 3: new smart tools in 2016; phase 4: ongoing smart tools in 2017. Arrows with bold text represent smart tools found in this study.

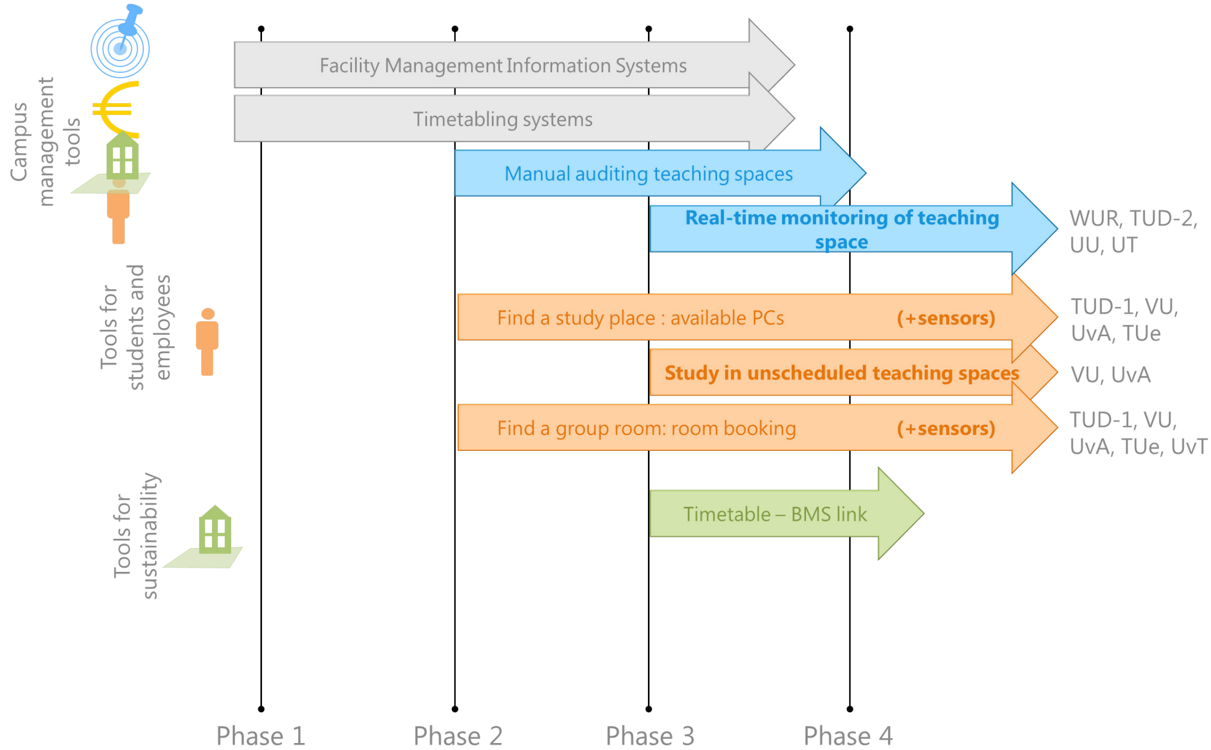


Figure 0.5 – Overview of available smart tools at Dutch universities. Phase 1: no smart tools; phase 2: prevalent smart tools in 2016; phase 3: new smart tools in 2016; phase 4: ongoing smart tools in 2017. Arrows with bold text represent smart tools found in this study.

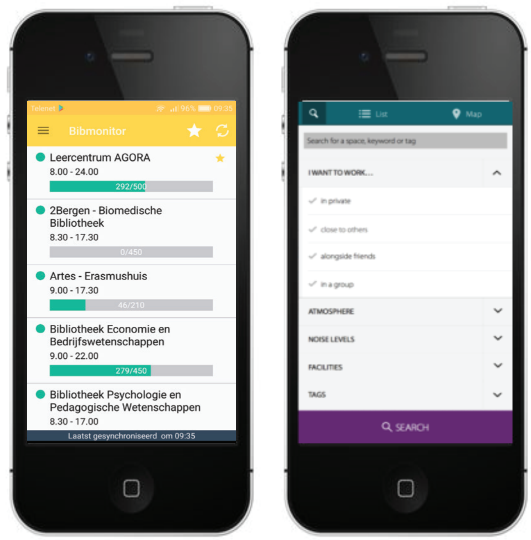
In chapter 6 a practical guide to the subject of smart tools is given based on all cases and collected information. A framework is designed to help practitioners assess the difficulty of implementing different smart tools. Furthermore, data to support cost-benefit analyses is given. Then, generalised descriptions of types of cases are made to help practitioners find the cases that meet their demands. For each type of case, main references are suggested based largely on the same criteria: the size and duration of the implementation and its ability to report on the benefits that are achieved with the smart tool.

- Smart tools to find available study places – University of Leuven
- Smart tools to optimise teaching space use – Wageningen University
- Smart tools to share teaching space for studying – University of Amsterdam
- Smart tools to find shared workplaces – ABN AMRO
- Smart tools to improve user comfort - OVG
- Smart tools to improve meeting room use – Google and Microsoft

Conclusions

At international universities two implemented user apps are found and one pilot project to optimise teaching space. The other six cases are in a pilot stage or design brief, revealing that many universities are busy with the subject. New smart tools are being considered, researched, developed and tested to support students and employees, optimise space use and save energy.

Figure 0.6 - Implemented smart tools at international universities



KU LEUVEN

UNIVERSITY OF CAMBRIDGE

At other organisations most cases reveal that organisations are working on smart tools that both monitor their space use and help their employees find available workplaces and/or meeting rooms; and in two cases also to align energy use to building use. Most smart tools are in the implementation phase and have been implemented since a few years. Organisations are generally further along than universities with their implementations. Multiple cases are found that use multiple types of sensors in their smart tools.

Figure 0.7 – Aligning building use and energy use, at organisations

OVG

Fondazione Giovanni Agnelli

At Dutch universities smart tools are aimed at either real-time monitoring of teaching space or on smart tools that support students, in which multiple functions are brought together.

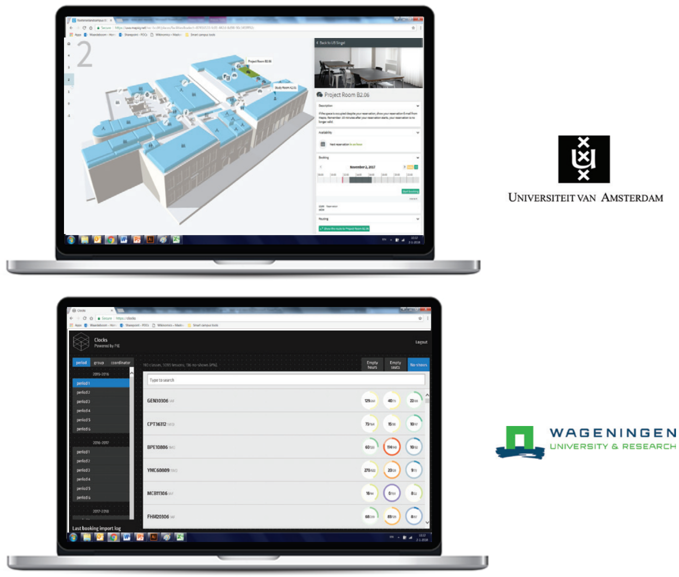


Figure 0.8 – a smart tool that support students (UvA) and a smart tool that monitors teaching space (WUR) at Dutch universities

Previous research concluded that by looking at all available smart tools –which includes more room booking apps and available PC apps- the focus of smart tools was for the largest part to add value by supporting students. The cases at Dutch universities are generally further along than those at international universities in terms of their implementation (time and amount of m2).

Chapter 1
Introducing smart campus tools

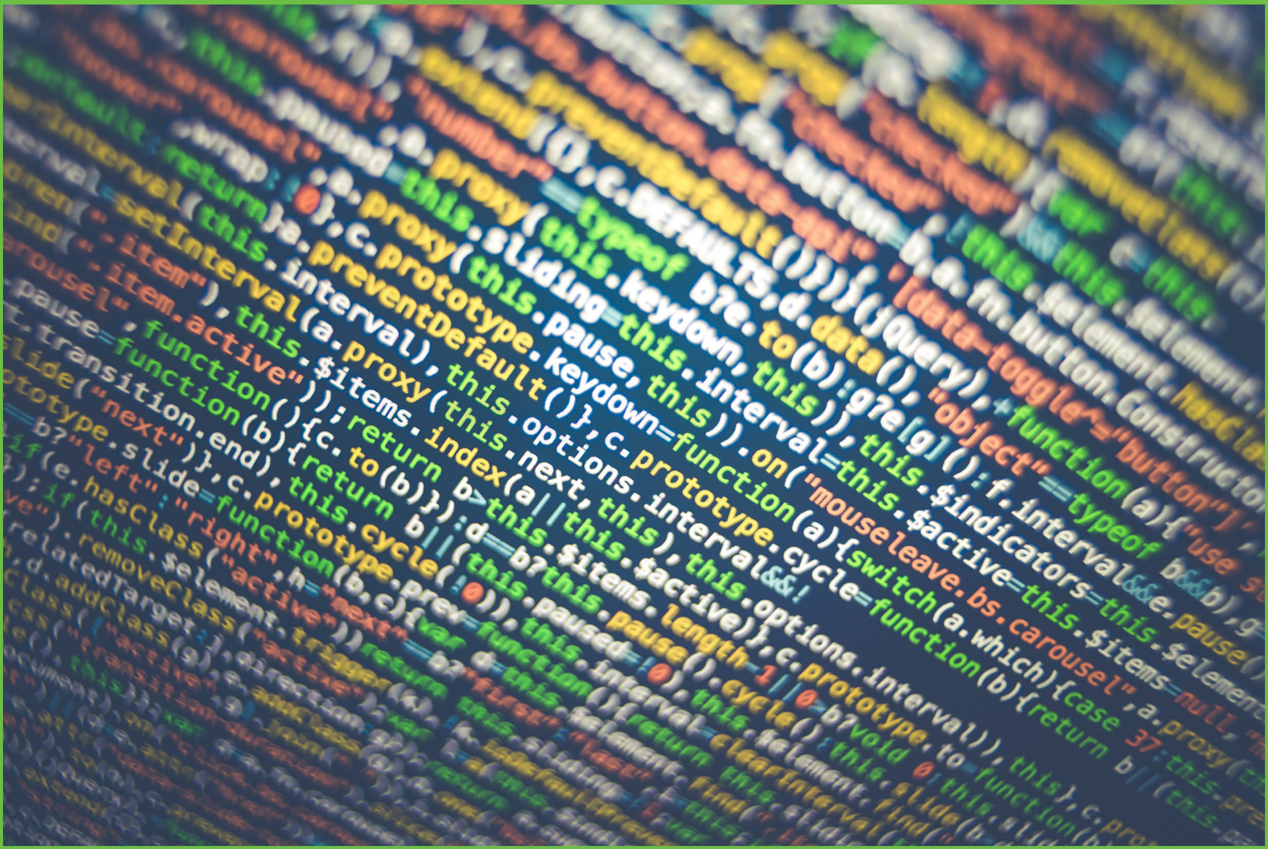


Photo: Markus Spiske via Unsplash

1. Introducing smart campus tools

Anno 2017 it seems that everywhere you go, things are being advertised as 'smart.' In order for something to be smart, it needs to be able to sense or collect information and make decisions in order to adapt accordingly. Smart systems (or tools) address environmental, economic and societal challenges, or simply help to make life easier. Take for example the transportation sector: many vehicles are already equipped with navigation systems to help you reach your destination, and self-driving vehicles are in full development. Not only do these systems help to make life easier, they also improve road safety. In this research we examine tools that make the university campus smarter. This immediately prompts the question: why does the university campus need to be any smarter? The first reason is the environment. Buildings account for a significant amount of our energy consumption as a society – 35-40 percent of CO_2 emissions (European Commission, 2017; U.S. Green Building Council, 2016). The second reason is societal. Especially academics, but also students have to deal with increasing expectations and workloads. The third reason is economical. Universities are public institutions that spend government money, in part on large and ageing real estate portfolios.

Smart tools can help to address these issues. If a building knows where its users are, it can attune the delivery of heating or ventilation accordingly and save energy. Information on the availability of workplaces and their properties (e.g. noise levels, lighting and temperature) can help academics and students find workplaces that suit their preferences. Information on the frequency and occupancy rates of buildings can help campus managers to make better decisions on real estate investments, or to lower operating costs.

The promise of smart tools to address numerous issues in campus management led to the commissioning of a research project in 2015 by the directors of the facilities management departments of the fourteen Dutch universities. In 2016 this resulted in a first publication – in Dutch – exploring the use of smart tools at Dutch universities and a number of other organisations. The content of this book builds upon the results presented in the previous one.

Figure 1.1 – Cover of the first Smart campus tools report

1.1. Research outline

In the research outline the most important components of the research design are discussed briefly.

Problem statement

The common problem on university campuses is that so often, users complain that there is a lack of space while universities think they are providing sufficient space. There are two reasons why this paradox occurs:

- Spaces on campus are claimed but not in use – e.g. an office is assigned to an individual who does not work on campus full-time or a meeting room is reserved for meetings which do not occur 20% of the time.
- During specific times specific locations are overcrowded, although there is room elsewhere – e.g. during exam weeks the library is full with students, but in a number of faculties there are unused study spaces

This presents a challenge for universities. In a time where university resources are under pressure, how can we maximise the effective use of the existing space? And: when we invest in new or renovated buildings, how do we prevent that the provided space is used just as ineffectively and inefficiently?

Hypothesis

Our hypothesis is that measuring space use real-time can contribute to solving the problem of inefficient and ineffective space use. Real-time information can help users to find spaces to work and study that suit their needs, and by increasing transparency reduce the amount of space that is claimed but not in use. It can also help campus managers to gain more insight into the use of space, which helps them to make decisions on the future campus or to optimise operations – facility management, maintenance works and energy consumption.

Research questions

The main research question answered in this book is:
What smart campus tools are available at universities and other organisations and how do they compare to the use of smart tools at universities in the Netherlands?

The sub research questions are:

- What smart tools are available at international universities?
- What smart tools are available at other organisations?
- What development have the Dutch universities made in comparison to the previous findings?

Research methods

In order to answer the aforementioned research questions a number of research methods were used:

- data collection of the applications of smart campus tools universities and organisations, yielding standardised information on the use of smart tools at different organisations
- semi-structured interviews were conducted, yielding additional case-specific information
- literature study to provide more depth on topics related to the ongoing development in smart tools - privacy, data security and stimulating innovation
- a brainstorm session with policy makers from the Dutch universities to collect extra input on the research results.

History of campus research

Since 1999 the TU Delft has done research on the management of university campuses, with the support of directors of accommodation, real estate or facilities of the Dutch universities. This research has led to a range of tools (i.e. benchmarking, building database, management models) and publications, culminating in a dissertation on 'Managing the University Campus'. Since 2011 research has moved from this dissertation forward both by broadening the scope – applying the same tools at a European level or updating the Dutch situation – and by deepening knowledge on specific aspects of campus management such as sustainability, technology campuses and smart campus tools.

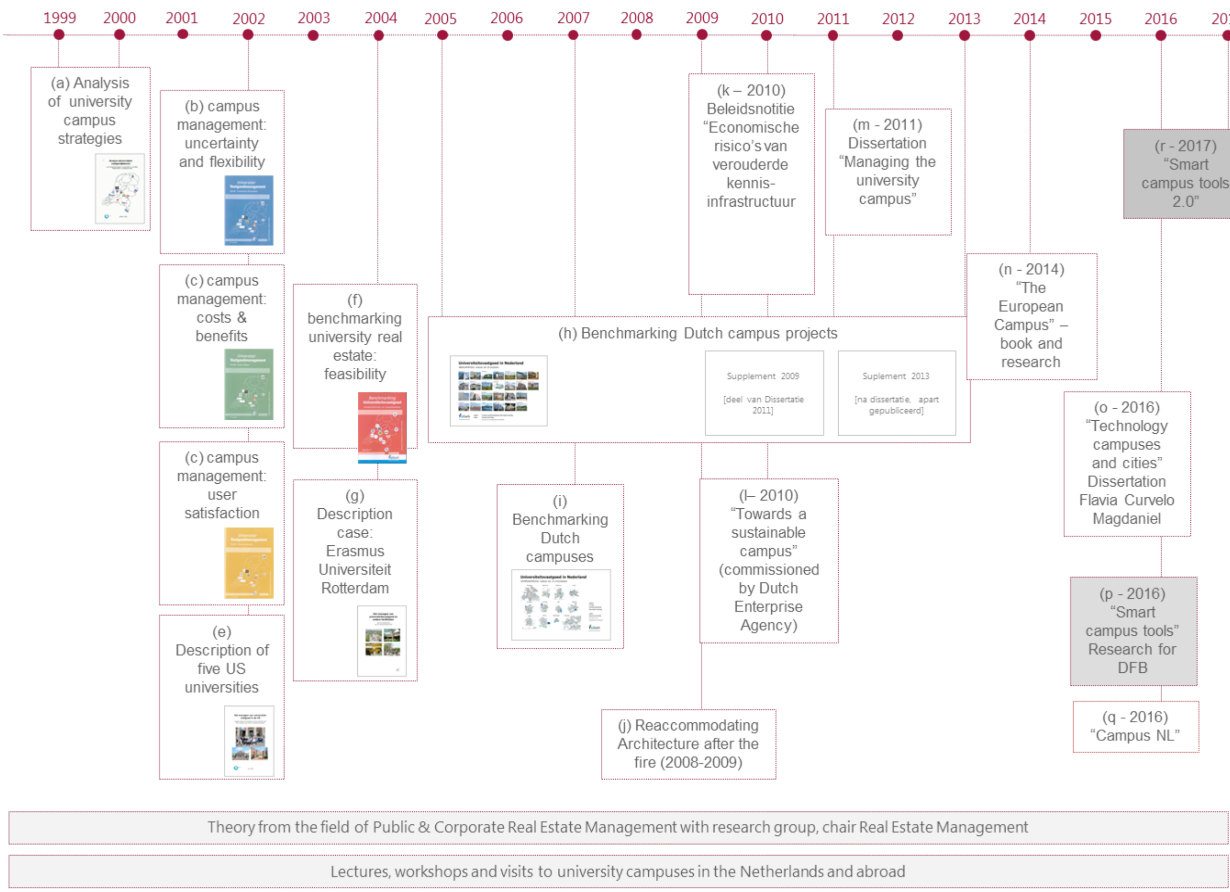


Figure 1.2 - Overview of campus research and publications: 1999-present (TU Delft, 2016)

This book builds on the foundations of the previous publications on the management of university campuses. A wide range of topics and developments that have been identified and described can be connected to the smart campus tools research. The need for information and tools to support management tasks and involve, inform or convince stakeholders is still very topical anno 2018. Furthermore, the collected data on ambition levels, student numbers, state of the campus and financial KPIs provide important evidence to show why universities are considering smart campus tools. Finally, many conceptual frameworks developed in previous research are used to position the findings of the smart campus tools research.

Researching smart campus tools

The smart campus tools research project was initiated in October 2015 by the fourteen Dutch universities to research how technology could be used to better understand how spaces on campus are actually used. The hypothesis was the same back then as it is now: that by measuring space use real-time can lead to a more effective and efficient use of space.

In the first year of research (Oct. 2015-Sept. 2016), which was published in a Dutch report, the subject was explored from different perspectives. First, a literature study was done to better define the term 'smart campus tools' and to explore what types of smart tools were reported in scientific literature. Then, policy officers and campus managers of Dutch universities were interviewed to identify what their demands with regard to smart campus tools were and what solutions were currently in place at their university. Finally, interviews were done with various other organisations –to learn from smart tools implemented in their context- and with suppliers to gain more knowledge about the market and the types of sensors implemented.

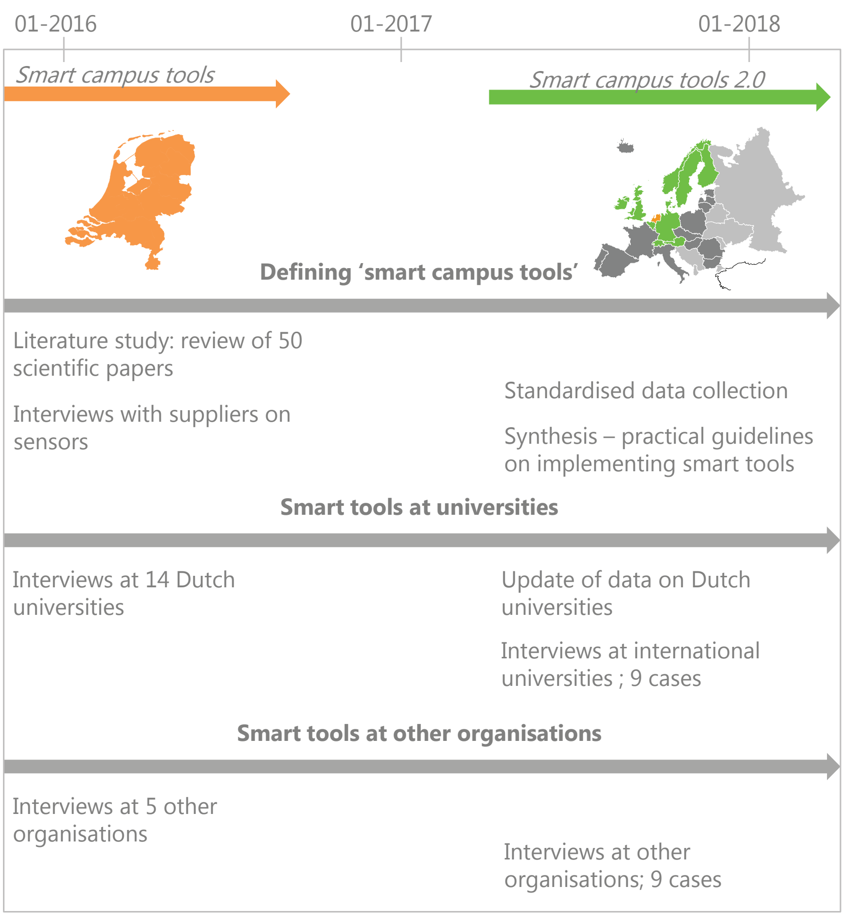


Figure 1.3 - Timeline of Smart campus tools research and content

In 2017 a second phase of the smart campus tools research was initiated (2017-18), again funded by the Dutch universities. In this phase the focus was on broadening the exploration of smart campus tools at both universities and other organisations and comparing the results to the smart tools at Dutch universities. The high response rate (around 50 percent) to the enquiry shows how topical the subject is and how interested organisations are in learning from each other. More than 20 interviews were conducted and 27 cases of smart campus tools were documented in a standardised way.

The research on smart campus tools will continue in the form of Bart Valks' Ph.D. research. After finishing the first research project, various presentations have been given to both national and international audiences on the subject. The first journal paper on the results is expected to be published this year and the first book has already sold over 90 copies.

1.2. Definitions and concepts

In this chapter the most important definitions and concepts used at the outset of this research are discussed.

Campus

In our research team we refer to the "campus" as all the land and buildings that are in use by university functions or functions related to the campus, whether leased or owned by the university, and not bound to a single location. A "campus" can thus also refer to a collection of buildings that are scattered across a city, and is not limited to isolated areas. This definition reveals two problems, being the ownership of the buildings and the functions contained in them. Today's campus is becoming harder to define, as the ownership models become more diverse and hybrid and the amount of related functions on campus increase – residential, retail and leisure, related businesses and infrastructure.

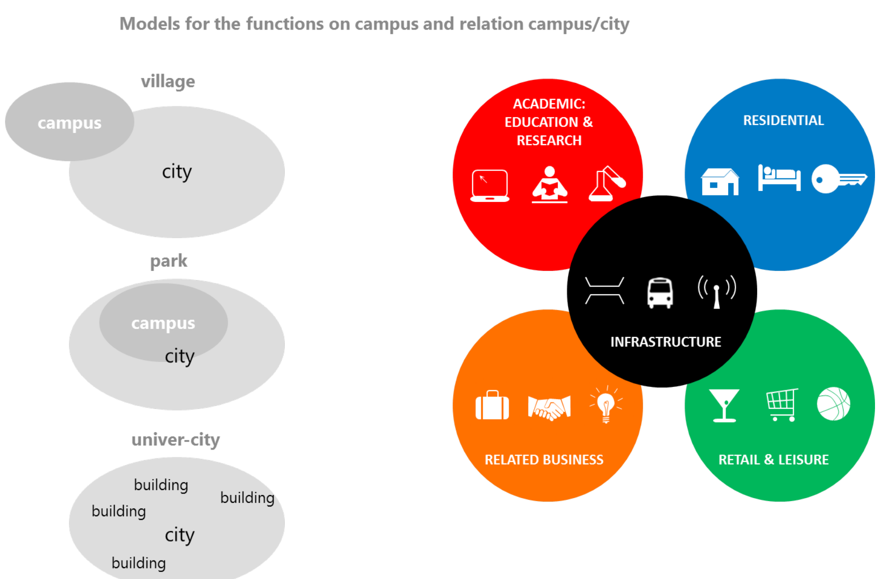


Figure 1.4 - Campus typologies (left) and functions on campus (right) (Den Heijer, 2011)

Campus management

Campus management is defined as the process of attuning the campus on the changing context of the university, the demands of the different stakeholder groups and contributing to the performance of the university. The campus manager – being in charge of facilities management and/or estates management is responsible for this process.

For the process of campus management the framework below is used to structure data. This framework describes campus management as a repetitive process of four steps: assessing the current campus, exploring changing demand, generating models for the future campus and defining projects to transform the campus.

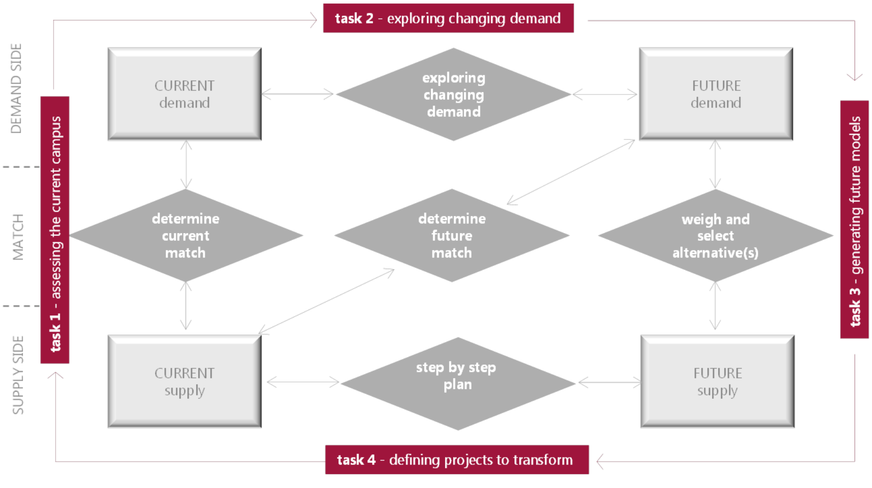


Figure 1.5 - Process framework for campus management: designing an accommodation strategy (Den Heijer, 2011); adapted from De Jonge et al. (2009)

Task 1: Assessing the current campus to determine the current match, from the perspectives of the university's stakeholders and demand derived from the changing primary processes – education and research.
Task 2: Exploring changing demand and determining the future match between the current campus and future demand, derived from the changing primary processes – education and research – based on the changing context and the changing goals of the university's stakeholders.
Task 3: Generating future models and designing alternatives for the campus of the future, based on assumptions in changing demand; evaluating these alternatives from different perspectives.
Task 4: Defining projects to transform the current campus into (selected alternative for) campus of the future, in a step-by-step plan.

In addition figure 1.6 identifies the four stakeholder perspectives to include in each of the steps during the process: the strategic, functional, financial and physical perspective. For each perspective the model also identifies which variables to measure, objectives of each stakeholder, etc. In the figure below the objectives are displayed per perspective in which the campus adds value to the university.

Figure 1.6 - Four perspectives to consider in campus management and objectives per perspective (Den Heijer, 2011); adapted figure

Smart campus tools

A smart campus tool is defined as 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. During the previous research project, this definition has been elaborated upon, describing the why, how and what of smart campus tools: its objective, the type of space use data it collects and the measurement method used to collect real-time data.

Why - The objectives are based on the model introduced in figure 1.6. Thirteen objectives through which the campus adds value to the university are introduced.

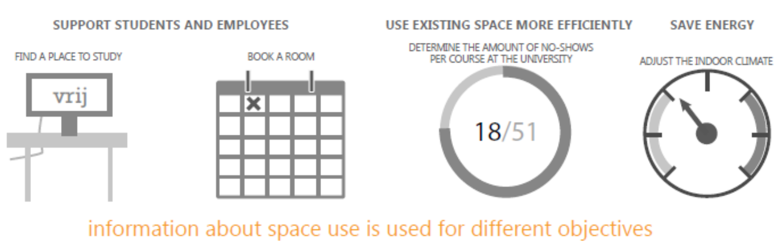


Figure 1.7 – examples of objectives of smart tools, based on the first smart campus tools project

How - With regard to the type of space use data collected, a framework by Christensen, Melfi, Nordman, Rosenblum, and Viera (2014) is used. They determine four levels in which the use of a space can be measured. Each of these levels can be aggregated in space and time. The four levels are described with four terms and questions they answer:

- Frequency: (when) is there at least one person in a zone?
- Occupancy: how many people are in the zone?
- Identity: who are the people in the zone
- Activity: what are the people doing in the zone

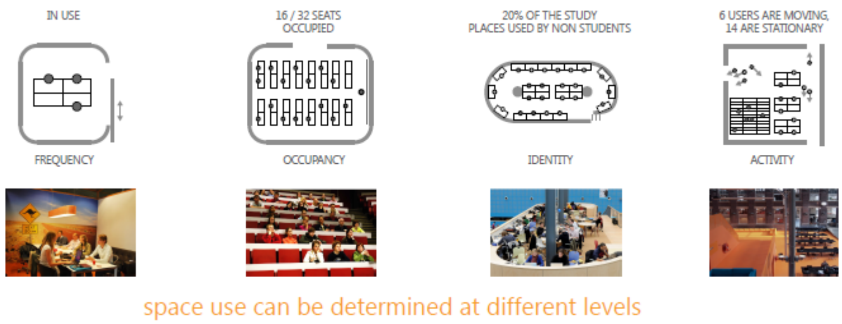


Figure 1.8 – ways to measure space use, based on the first smart campus tools project

What - Finally, the measurement methods used to collect real-time data are based on a survey on indoor positioning methods done by Mautz (2012), a white paper on utilisation collection technologies by Serraview (2015) and the findings of the research. Examples of sensors identified are: Wi-Fi, Bluetooth, RFID, camera's, infrared, PC login, wearables and CO_2 measurements.

Figure 1.9 – measurement methods used to collect real-time data, based on the first smart campus tools project

1.3 Reader's guide

The report is structured as follows. Chapter 2 provides a short recap of last year's research and the 'knowledge basis' that is built on this year. Chapter 3, 4 and 5 each describe one of the main steps of the research. Chapter 6 is provided as a practical guide to the contents of the report. Chapter 7 provides the conclusion with regard to the research questions. Chapter 8 introduces additional insights to the topic of smart campus tools. Figure 1.10 shows how to read the report for academics and practitioners:

- A (academic): Use when wanting a full picture of the research. Read the knowledge basis, the whole chapter (3, 4 or 5), followed by the main conclusion and if desired further insights.
- B (practitioner): Use when requiring information on a specific smart tool and practical guidelines. Start at chapter 6. Read chapter 6.1 and 6.2 and choose the type of smart tool about which you want more information. Then skip through the relevant cases in chapters 3, 4 and 5 and read the conclusions.

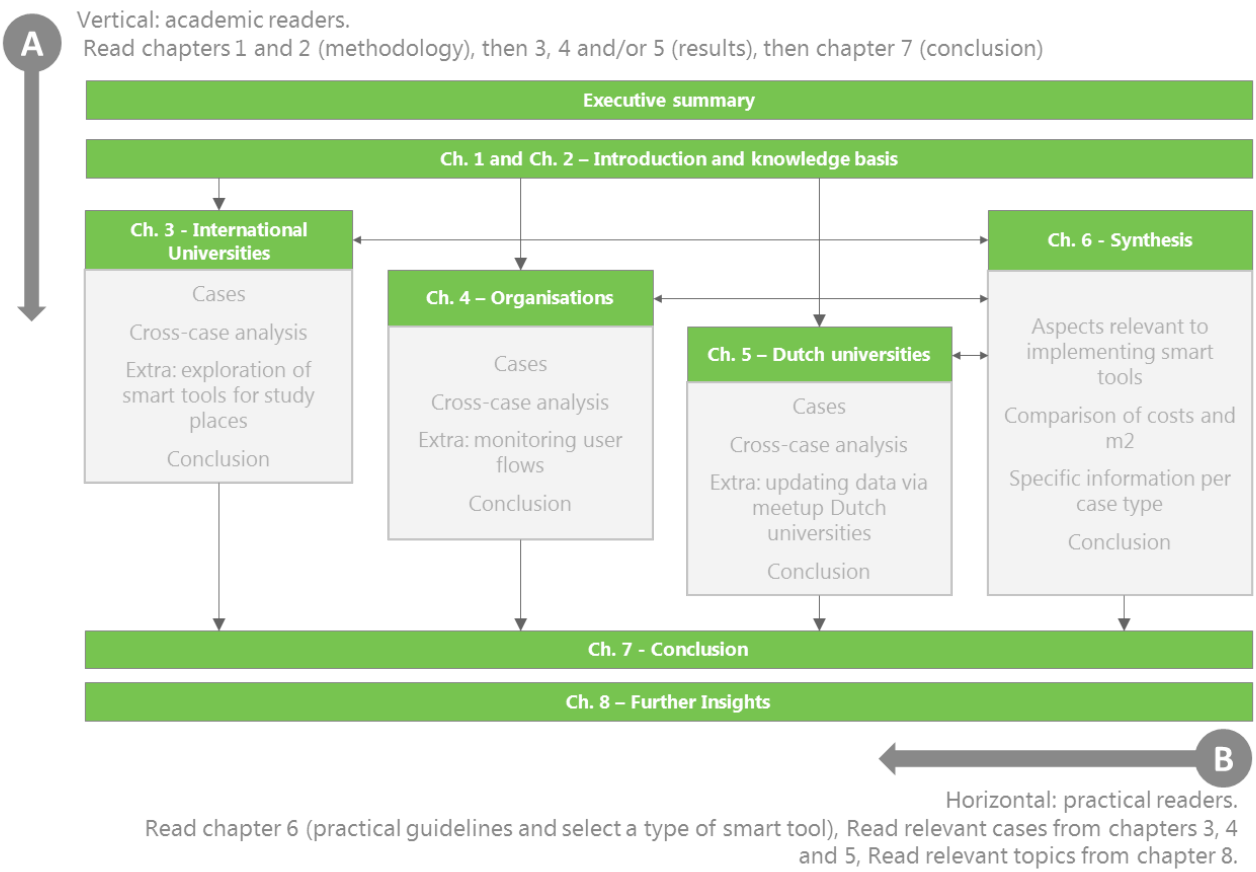


Figure 1.10 - Reader's guide

Chapter 2
Knowledge basis

Photo by Rob Bye via Unsplash.com

2. Knowledge basis

This chapter describes the point of departure for the exploration of smart tools. It summarises the challenges universities are facing in general. Then it discusses the smart campus tools that Dutch universities are using to use their space more effectively and efficiently, the smart tools found at other organisations and their recommendations for the next steps in smart tools at universities.

2.1. Organisational context – pressure on resources

Across most developed countries universities are dealing with similar problems. Many universities have to accommodate increasing numbers of students, whilst simultaneously receiving less public funding per student. Reports from the United States and Europe reveal the possible results – rising tuition fees, reducing the size of the teaching staff, and not investing in infrastructure (European University Association, 2016; Mitchell, Leachman, & Masterson, 2016). At the same time universities are more in competition with each other and consistent pressure is applied to both students and academics to improve their performance.

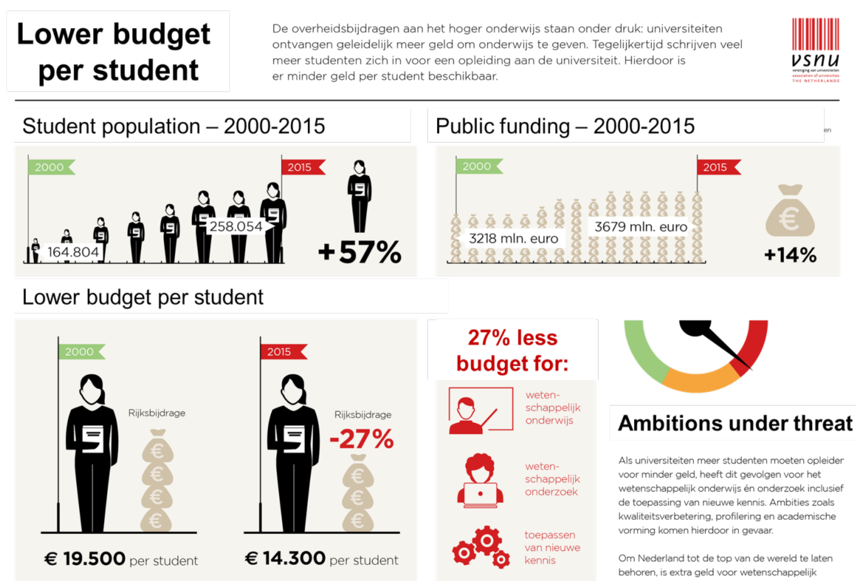


Figure 2.1 - Development of public funding, student numbers and budget per student in the Netherlands (VSNU 2016)

The development at universities to do 'more with relatively less' does not only result in pressure on education and research, but also on the supporting infrastructure. Research by Den Heijer and Tzovlas (2014) and Kadamus (2013) shows that European and American universities are dealing with large and ageing real estate portfolios with backlog maintenance, which require large-scale reinvestment. Furthermore, the requirements set for new buildings have increased over the years – and are still increasing due to sustainability requirements – leading to an increase of investment costs per square meter.

Therefore most universities are looking to implement an estates strategy that accommodates a growing population and that reduces the backlog maintenance whilst keeping the total costs of ownership of the estate portfolio at the same level. The primary result of this strategy is to reduce the amount of square meters per user.

2.2. Different states of space types – solid, liquid and gas

University campuses are characterised by a large amount of buildings that consist of multiple space types: offices, meeting rooms, lecture halls, classrooms, study places, laboratories, etc. Each space type has its own dynamic in terms of how space is used and assigned. These dynamics can be described as chemical states – solid, liquid and gas.

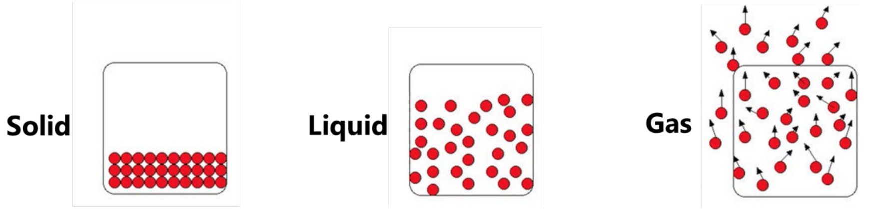


Figure 2.2 - Physical states as a metaphor for the provision and use of space (Den Heijer, 2017)

Offices and laboratories are largely assigned to individuals or departments and used only by the employees of these organisational units. The provision and use of these spaces can thus be characterised as 'solid'. With regard to the academic office a large debate is taking place with regard to the benefits and drawbacks of sharing offices. Examples exist where this has been brought into practice, although they are still very uncommon. At the same time, the academic population consists more and more of part-time researchers and researchers that work at multiple locations.

At many universities lecture halls, classrooms and meeting rooms are being shared between faculties in order to better match the available spaces to group sizes. Especially in education spaces, the pressure on resources together with the growth in students has led universities to start sharing spaces on a campus level in order to use the space as effectively and efficiently as possible. For meeting rooms this is true to a lesser extent. The provision and use of these spaces can be characterised as 'liquid'. The movement to improve the use of these facilities is expected to continue: although spaces are shared more, research and evidence from practice suggest space utilisation rates can still be improved further.

Finally, study places are to the largest extent shared on campus. According to TU Delft (2016) the past ten years has seen an enormous growth of studying on campus, evidenced by the transformation of libraries to learning centres and the creation of study places in hallways and atriums. In some cases these spaces attract other user groups, such as high school students studying for exams or students from other universities. In addition students do not only use learning spaces to study, they also use cafes and restaurant spaces. The provision and use of study spaces can be characterised as 'gas': students study at spaces both on and off campus (at home or in city centres) and study spaces are used by many different user groups.

2.3. Space use data and smart tools at universities

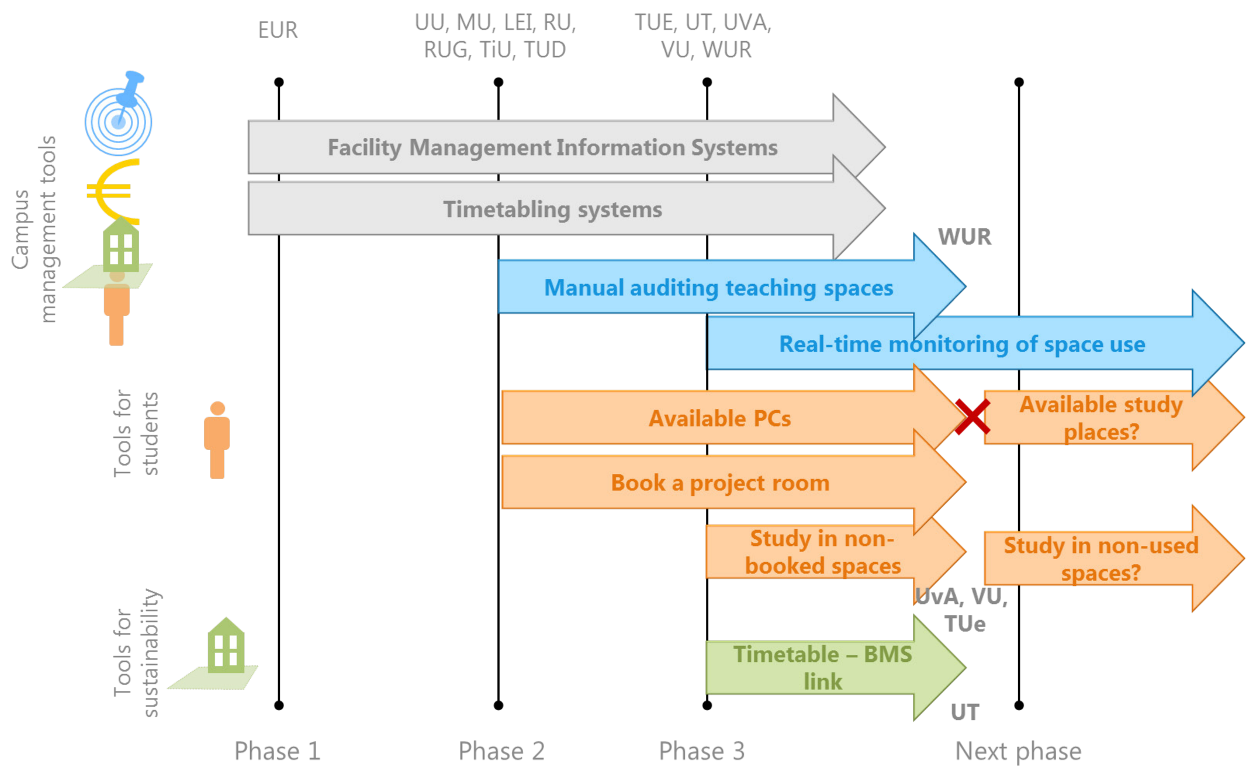
Previous research on the Dutch university campus (Valks, Arkesteijn, Den Heijer, & Vande Putte, 2016) shows that the use of space use data and smart tools is to a large extent related to the solid, liquid and gas states. In offices and laboratories data on the occupancy of workplaces is hardly ever collected. Data is usually only collected once an office needs to be renovated or reaccommodated in order to draw up the design brief. This reflects the solid state of the offices and laboratories.

For education spaces most universities periodically monitor the frequency and occupancy rates, caused by their decision to start sharing these spaces on a campus level – and moving from a solid to a liquid state. This is done by using the timetable to indicate the 'predicted' use and comparing the timetable with a sample of manual counts to reveal the actual use. These measurements are done manually, with one exception of a university who determines the frequency and occupancy rates via Wi-Fi measurements. An additional benefit of this smart tool is that it enables the university to assess and improve the timetabling process and product based on the results of the timetable of the previous year.

For study spaces most universities do not monitor the occupancy rates. Instead they have provided students with tools to book available rooms and find available desktop PCs, reflecting the growing demand for study spaces on campus in the past years. More recently some universities have started to give students access to non-booked classrooms and even meeting rooms to study, thereby making other spaces available for studying.

Figure 2.3 - Current state and next steps from the university campus management perspective (Valks et al., 2016)

Phase 1: no smart tools; phase 2: prevalent smart tools in 2016; phase 3: new smart tools in 2016



In figure 2.3 these smart tools have been mapped in different evolutionary stages. Phase 1 shows the tools and systems in use at all universities, Phase 2 shows the tools and systems in use at most universities and Phase 3 shows the tools and systems in use at a few universities. The colors of the arrows indicate the purpose of the tools / systems. Grey arrows indicate tools and systems for general use; blue arrows indicate tools and systems with a strategic objective; orange arrows indicate tools and systems with a functional objective; and green arrows indicate tools and systems with a physical objective.

Based on these applications a number of next steps can be foreseen. There is a development on campus that the amount of desktop PCs is reducing, because more and more students use laptops on campus. Because of this, the applications relying on availability based on desktop PCs are becoming obsolete and the question is if these applications should be replaced by applications that show the availability of study places without PCs.

Furthermore, the applications that enable the use of education spaces for studying currently rely on booking information. This means that users can see if a room is unscheduled, but not how many people are currently in the room. The question with these applications is if the applications should also include information on the amount of occupants. The same is the case with the systems that link the building management systems to timetabling information.

2.4. The why, how and what of current smart tools

In terms of objectives supporting students has been the largest driver to implement smart tools on campus. Of all the smart tools identified in the research, functional and strategic objectives were named most as objectives supported by these smart tools. Therefore the conclusion is that smart tools at the university are currently aimed at using space on campus more effectively – helping the right user to find the right space at the right time – than at efficiency.

The type of space use data collected in the existing smart tools is in all cases on the levels of frequency (is a space in use or not) and occupancy (by how many people is the space used). In none of the examples space use data is collected in which identity or activity are registered. For a large number of tools space use is determined based on booking systems rather than real-time data. The extent to which this reflects the actual use of space is determined by the time between the moment which a booking is made and the time of the booking itself: the shorter this time, the better the booking system reflects actual use. For example, a booking system that only allows one to book one day in advance better reflects actual use than a booking system that allows one to book a week in advance.

With regard to data collection the most used data sources to measure actual use are self-booking systems and login data of desktop PCs. In some examples other sensors are used, such as Wi-Fi, cameras and infrared sensors.

2.5. Exploring use of smart tools at other organisations

In the interviews a number of end users were interviewed: two Universities of Applied Sciences (UAS), two organisations with office portfolios and the Netherlands railways.

The first interviews held in this series of interviews were at the Universities of Applied Sciences. The first UAS is currently developing a room booking tool that allows a user to book only when he/she is nearby the room. This is done to solve the problem that rooms on campus are booked, but not in use. By only allowing bookings based on proximity, the user is more often able to find a nearby room and the demand for space is not influenced by unused bookings. The location of the user is determined via the Wi-Fi network. By positioning the user the app is able to determine if the user is nearby and if he/she can book the room. The second UAS is in the process of implementing a smart tool which is used both for room booking and monitoring of space use based on real-time measurements. The main objective of the tool is to close the planning and evaluation cycle of the timetabling process at the university. With the tool the university is able to determine to what extent the timetable is actually used in practice: not only in terms of frequency and occupancy, but also if a booking is used by the right group of students. By doing so the UAS hopes to minimise the gap between predicted (timetabled) use and actual use. This is done via iBeacons that are placed in each room. The students and employees connect to these iBeacons via the Bluetooth connection of their smartphones. This is enabled via an app, which users can install to book rooms and find study places on campus.

The other two applications of smart tools, at the office user and Netherlands Railways, are both tools which collect real-time information on the building in order to inform real estate managers and/or operations. At Netherlands Railways the number of smart tools are compiled in a programme called smart stations. These smart tools measure how large numbers of users use the train stations in the Netherlands: via Wi-Fi, Bluetooth, cameras and smart card data movements are analysed to determine where congestion occurs. The objectives of Netherlands Railways are not only to make better decisions on investment in stations, but also to monitor if safety regulations in station areas are met. However, Netherlands Railways defines the performance of stations in terms of their value towards the user – therefore supporting the user is mentioned as primary objective (van den Heuvel & Hoogenraad, 2014, p. 643). Adjustments are made if necessary – e.g. changing train stopping positions can help to reduce congestion on platforms. Netherlands Railways also determines occupancy on a high level (activity), and has set very high requirements to ensure the privacy of the users tracked. The organisation with a large portfolio of offices monitors the use of these office buildings by combining multiple data sources: the data of access gates and pc login, combined with data on the amount of employees registered per location are used to determine which buildings are used efficiently and which are not.

The interviews with end users in other industries show that the implemented smart tools are directed more towards informing management – to improve the efficiency of operations and/or the efficiency of the real estate portfolio – than towards supporting users, which is more common at universities.

2.6. Translation to use of smart tools at universities

The interviews with other parties in the market resulted in a number of recommendations for universities when considering their next step in the development of smart tools.

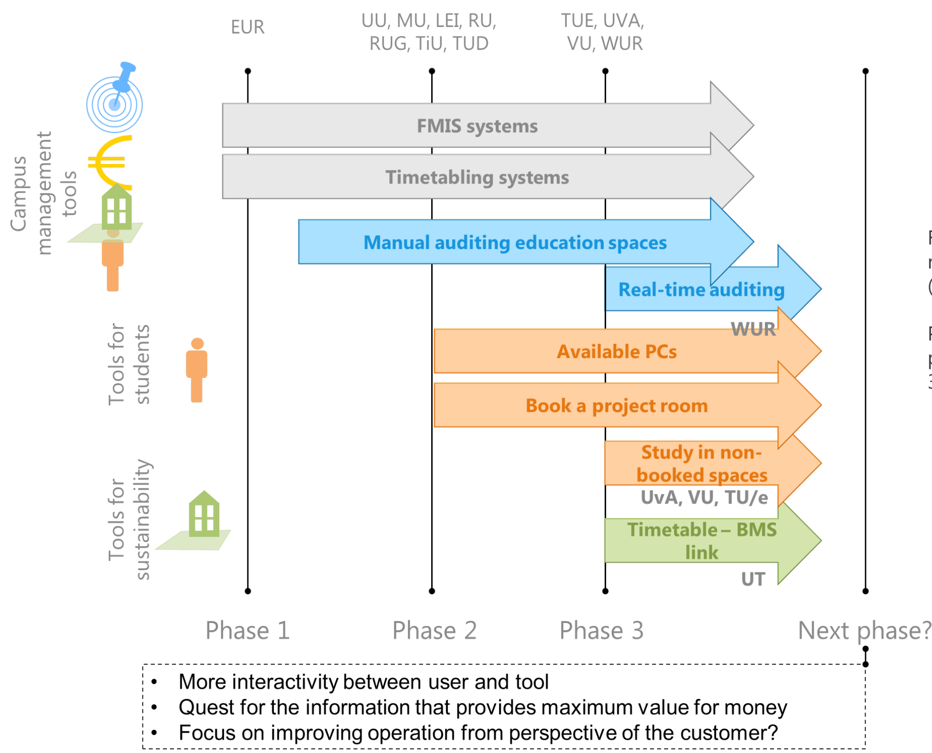


Figure 2.4 - Next steps from the other real estate management perspectives (Valks et al., 2016)

Phase 1: no smart tools; phase 2: prevalent smart tools in 2016; phase 3: new smart tools in 2016

An increase of interactivity between the tools and the user. This is based on the development of an application by this organisation that enables users to book a meeting room based on their proximity to the room. The underlying idea is in order to improve space use on campus the behaviour of the users needs to improve. For example: if you want to reduce the overbooking of rooms, you can use an app that identifies overbooking and penalizes or rewards users for good behaviour. Similar apps exist where users are stimulated to be healthier by taking the stairs instead of the elevator, by having an app that puts them in competition with their colleagues and that can determine if they use the stairs or not.

The use of multiple sensors / data sources is an efficient way to gain more insight into space use. This is also supported by the white paper of Serraview (2015), in which the use of multiple collection technologies is foreseen. At one of the interviewed organisations a smart tool was seen that integrated data on the amount of employees and contractors registered in a building with the access gate data of the building and the amount of connected laptops in the building.

One interviewee at Dutch Railways indicated that the implementation of smart tools at their organisation was a process in which insight was gained into the information that provided maximum value for money by focusing on what delivers the most improvement to the customer. Rather than delivering detailed, expensive information on the availability of seating in trains Dutch Railways chose to provide cheaper information of the stopping positions of trains at the platform. This information reduces the time needed to board the train, resulting in less delays, which are the primary dissatisfier for customers.

2.7. To summarise

The most important (theoretical) conclusions based on the contents of this chapter are:

- Many universities in the United States and Europe are dealing with similar problems, which lead them to pursue (estates) strategies of resource efficiency, reducing the amount of m2 per user.
- University buildings have many different space types in their real estate portfolios, which are provided and used in different ways. An analogy of solid, liquid and gas states is used to explain the differences in space use.
- If and how space use data is collected is related to the way spaces are provided and used at the university. Offices and laboratories are hardly monitored; for education spaces almost all universities monitor their space use (manually); for study spaces most universities provide tools to support their users without monitoring space use.
- At the moment universities focus mostly on improving effective use of space over the efficient use of space. Real-time data is not used in many applications, though examples exist where Wi-Fi, infrared or cameras are used.
- The exploration at other organisations show that the implemented smart tools are directed more towards informing management – to improve the efficiency of operations and/or the efficiency of the real estate portfolio.
- The interviewees of other organisations suggest a number of directions for further development of smart tools at universities: improving interactivity between the user and the tool, combining multiple sensor technologies and viewing the development of smart tools as a process of finding the information that provides optimum value for the end user.

These conclusions summarise the findings of the previous smart campus tools research (2015-2016) and are the point of departure for the data collection in the chapters 3, 4 and 5.

Chapter 3
Smart tools at international universities

This chapter is aimed at the first component of the research project, which is to explore the uptake and use of smart tools at international universities. The following research question is answered:

What smart tools are available at international universities?

First, the chapter discusses the process of selecting cases and provides a short description of each case. Then the collected data in the templates is displayed. Based on these templates the properties of the cases are analysed before concluding the chapter.

Photo: Presenting the research project at Aarhus University

3. Smart tools at international universities

3.1. Cases

This chapter reports the way in which cases were selected, provides a description of the cases and the templates of the cases that included smart tools.

Case selection

A number of steps were followed in the selection of cases. First a sample was selected of universities in Scandinavia, the UK, Germany, Switzerland, Austria and the USA, as these were the countries where the use of smart tools was expected. Based on a survey of smart tools on study places a number of universities were approached. Furthermore, numerous universities were approached based on suggestions by Dutch practitioners and by 'snowballing' – asking interviewees which other universities to contact. In total more than 25 universities have been contacted to participate. The map below gives an overview of the universities approached and the cases provided in this research. The cases labelled 'cases in progress' are in different stages of progress, and it is uncertain if they will lead to actual cases. In addition colleague researchers are mapping the use of smart tools in Finland.

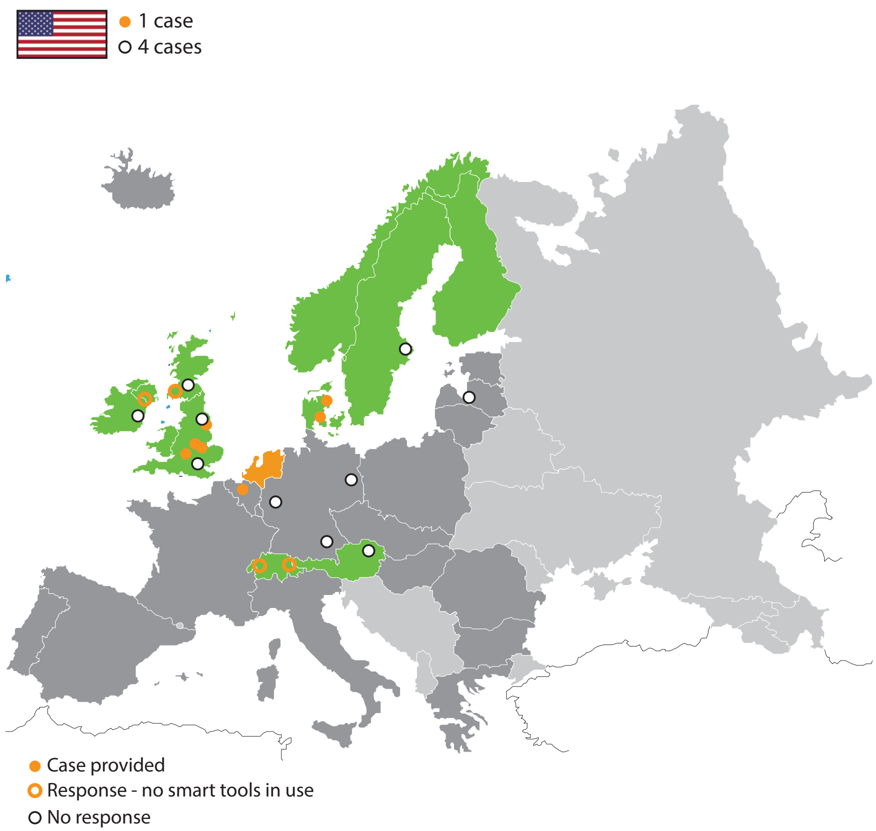


Figure 3.1 - Map including all the cases at universities

Affluences

The French app Affluences displays information on the opening hours of many university libraries, museums, student restaurants etc. The app shows locations in France as well as some in Switzerland and Belgium.

Furthermore, it provides forecasts for the occupancy of these facilities. The occupancy data is mostly provided by the users of the app.

Source (see also): https://www.affluences.com

In about 50 percent the universities approached responded and generally speaking they were very positive about participating in the research. Of course this did not lead to cases in all examples, as there were universities that did not have smart tools implemented or in development. In the interviews different people within the organisations were interviewed – librarians, campus managers, facility managers, ICT specialists and academics. The table on the next page displays the interviewed organisations in chronological order.

Country	University	Function of interviewee(s) and contacts
Denmark	Aarhus University	ICT, Campus management
United Kingdom	Oxford Said Business School	Campus management
Denmark	DTU	Library
United Kingdom	University of Glasgow	Campus management
Belgium	University of Leuven	Library
United States	Carnegie Mellon University	Academic
Switzerland	EPFL	Campus management
United Kingdom	Oxford University	Campus management
United Kingdom	Cambridge University	Library
United Kingdom	Reading University	Campus management
United Kingdom	Ulster University	Academic
Switzerland	ETH Zurich	Campus management
United Kingdom	Sheffield Hallam	Campus management

Table 3.1 – Overview of respondents at international universities

Case description

The cases provided in this research display a wide variety in terms of the context in which the development of smart tools takes place.

At Aarhus University, the university is going to implement a very ambitious Estate Strategy in which it will transform a complex of former hospital buildings for various university functions. The university is also scattered across multiple campuses. Therefore, the university wants to implement a basic system for indoor navigation first, and then it will look to supplement this system with real-time information on available study places.

At Oxford Said Business School the university is in the process of realising a building called the Oxford Foundry, which will be a space for all students, staff and alumni of Oxford University and the Business School with entrepreneurial ambitions. In order to maximally support their users, the campus managers are thinking of implementing a solution that shows the entrepreneurs who is currently in the building and what their field of interest is.

At DTU the university has initiated a smart building project with the renovation of its Library, because of the user comfort problems experienced in the existing building. The university expects a significant growth of students, therefore it wants to experiment in the Library first and translate the findings to make the entire campus a Smart campus.

At University of Glasgow the university has recently acquired a piece of land of an old hospital that adjoins the existing campus. Incorporating and redeveloping this plot requires considerable investment. The university has identified this as an opportunity to realise a smart campus. At the moment no smart tools have been implemented, although the university will start a number of research initiatives in the next few months.

At University of Leuven the university has gradually developed into a place of social learning with increasing numbers of students coming to the campus to study. In order to meet the increasing demand for study places the university developed an application with real-time information on the available study places across the campus.

Study Spots

The app Study Spots displays information on the opening hours and the occupancy of some university buildings in Germany and the UK.

The occupancy data is mostly provided by users of the app. However, it seems that the information on occupancy is no longer displayed in the app.

Source (see also):
https://www.study-spots.com

Smart Labs @ UC Irvine

In 2013, UC Irvine reported the results of a project to reduce the energy consumption of their laboratory facilities.

By adjusting the ventilation (air changes per hour) to the occupancy of the laboratory -fully occupied, partly or unoccupied- they were able to achieve a 50 percent energy savings.

Source (see also): https://www.ehs.uci.edu/programs/energy/

At Carnegie Mellon University the university has decided to use its campus as a living laboratory for Internet of Things applications, with a special focus on privacy and security in the development of these applications. This IoT expedition is being funded by Google. Two research projects have been provided as examples; the basis for the materials of this case are the research papers on Sentinel (Balaji, Xu, Nwokafor, Gupta, & Agarwal, 2013) and Genie (Balaji, Koh, Weibel, & Agarwal, 2016).

At Oxford University the university has formulated the ambition to use space more efficiently and share research and teaching space. Therefore the Space and Asset Management department determines when investment in the Estates is appropriate, in which it has to deal with competing demands. The university is thinking to invest in a moveable sensor infrastructure which can be used to conduct occasional space utilisation measurements in order to evaluate demands for additional space.

At Cambridge University the University Library conducted research among students and concluded that students had trouble to navigate their way across the many university buildings and library facilities during the initial stages of their studies. In order to help solve this problem the Library has developed Spacefinder to help students find a place to study. See also the publication of Spacefinder by Priestner, Marshall, and Modern Human (2016).

At Sheffield Hallam University the university is looking to move buildings from its campus just outside the city centre to the campus inside the city centre. It is piloting an application to monitor teaching space on campus, in order to inform decision-making on its Estates masterplan and to use it in discussions with faculties and improve the timetable.

At EFPL, ETH Zurich, Reading University and Ulster University there is no current use or development of smart campus tools to measure space utilisation.

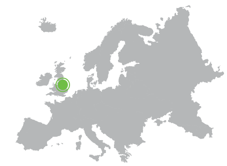
3.2. Templates

For each of the cases the smart tool templates were filled in – either during the interviews as far as possible or afterwards by the interviewee. In some cases the template could not be filled in entirely, either because the project was still in development or because the data needed to be delivered by another person.

The templates are provided in order of their phase. First, the implementations are displayed, following by pilots, design briefs and finally research projects.

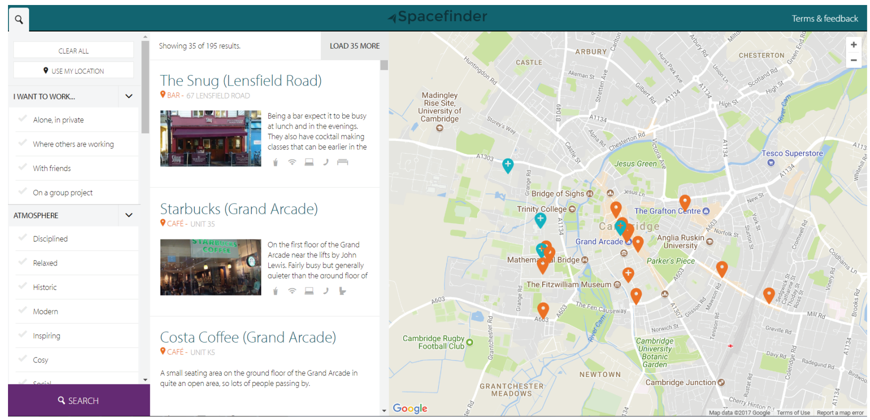
CAM — Cambridge University — Spacefinder

phase **Implementation** — scale **206 spaces** — duration **2015 - present**



Project description

The problem at Cambridge University is that the University has an abundance of libraries across the city of Cambridge, that each have their own study facilities. There are a lot of facilities and a lot of different ones, and the problem for students is to find the facilities that suit their needs. In previous research the University Library identified that there were different needs among students. Spacefinder was developed as a solution to match these differing needs and differing facilities.



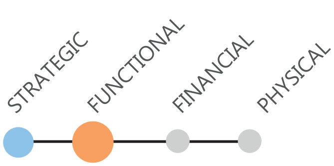
User interface via https://spacefinder.lib.cam.ac.uk/

Foreseen developments

Spacefinder was adapted in June 2016 where a number of features were added in collaboration with the Student Union, such as gender-neutral toilets, disability access etc. The most important thing for a next step would be to be able to filter on opening hours (e.g. open on Sundays and during evenings).

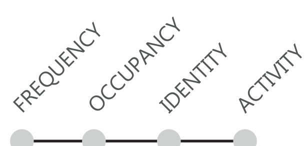
Profile

Why: Objectives



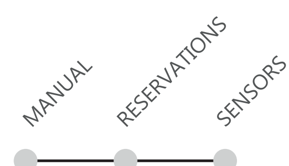
Supporting user activities
Increasing user satisfaction
Increasing flexibility
Stimulating collaboration

What: Measurement



Not applicable - no space use measurement.

How: Measurement method



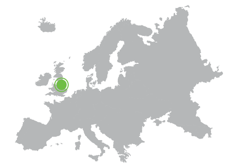
Not applicable - no space use measurement.

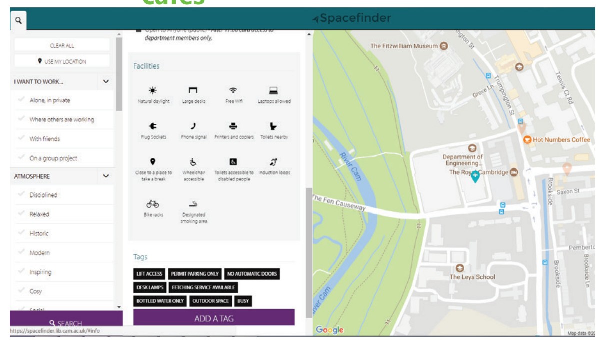
The tool is often used when people begin their studies at Cambridge and are looking for a suitable workspace. It also experiences high levels of traffic during other peak periods such as exam time when students are looking for a change of scenery, or a new place to study. Repeat visits are relatively low as students and other users seem to use the service to find their ideal space, rather than revisiting to vary their workspace.

CAM — **Cambridge University** — **Spacefinder**

functionalities
Find a workplace

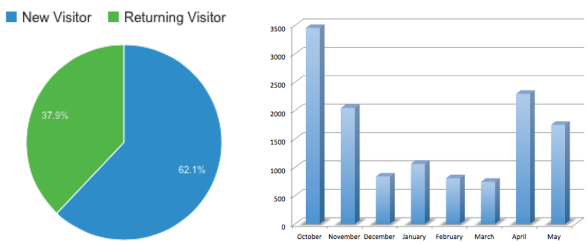
space types
Study places, project rooms, cafes





User information

The user accesses an interace that shows a map of Cambridge with all the possible study locations on it, as well as a column with search options on it. As the user applies different preferences such as type of lighting, atmosphere etc. the amount of locations lighting up on the map are adjusted to indicate which study spaces comply, thereby helping the student to find a suitable study place. For each study space a description, photo, list of facilities and tags are given.

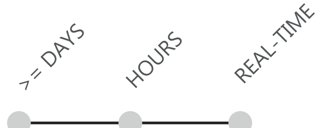


Examples of usage statistics, obtained via Spacefinder report

Management information

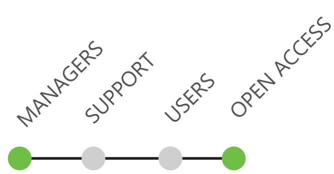
The types of information available from the back end are shown in the report as well, which include data on the amount of visits per month, unique visitors vs. recurring visitors and the device used to access Spacefinder.

Actuality of the information



Not applicable - no space use measurement

Access levels



Everyone can access the webpage.

The back-end of Spacefinder is accessible to the programme manager, which can be used to generate various reports

Benefits

The objective of the project was to cater to students' needs in the best way possible. Evaluating whether this was the case was done mainly through qualitative data (ethnographic) - being conversations with students, and through the continuous involvement of users throughout the design and development process.

Side notes

Through the analytics it was discovered that most users were using Spacefinder via a desktop or laptop rather than a mobile device (smartphone or tablet) and that there were more unique visitors than recurring visitors. This suggested that people usually use Spacefinder to deliberately plan where to study and that once they find a place that suits their needs, they don't often need to return to Spacefinder again. This was corroborated by qualitative data gathered during interviews with students.

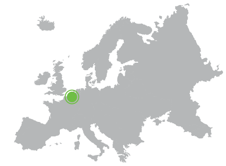
Cambridge used a human centred design process. This process involves designing a prototype version of a product, testing it on users, and then iterating on the prototype based on user behaviours and approaches, as well as feedback received. This process continues until a product is arrived at which fulfils the majority, but crucially not all, of people’s needs. The goal is a ‘minimum viable product’ (MVP for short): a product that has enough features gathered via research to ensure its deployment and use, ahead of continued development and updates.

KL — **University of Leuven** — **Blokken in Leuven**

phase
Implementation

scale
28.785 m2
10 buildings

duration
2013 - present

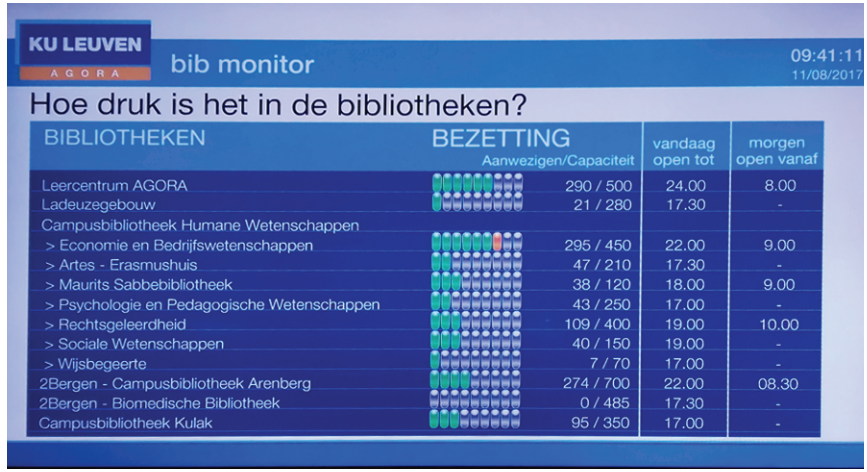


Project description

The initiative of this smart tool was taken as one of the measures to enable the increasing demand for social learning on campus. Blokken in Leuven was introduced to give students insight into the distribution of students across campus. The data and infrastructure was already in place; access control systems had been in the Library for quite a while and the data was already being used to determine the # of study places and opening hours of Library locations.

Foreseen developments

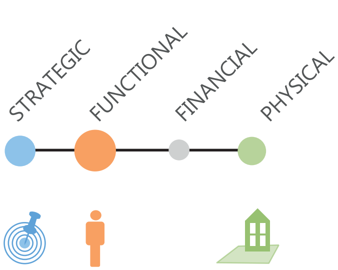
It is a wish to make a distinction between the occupancy of study places and project rooms, but that is still in an exploratory phase. Also the data of the access control is being used to do (anonymised) research on the relation between the time that a student studies in the library and his/her study results - Learning Analytics.



User interface on digital signage in the Library

Profile

Why: Objectives

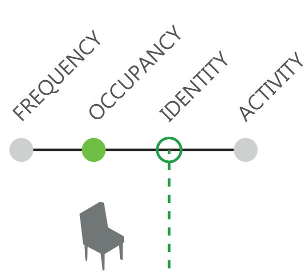


Supporting user activities
Increasing user satisfaction
Stimulating collaboration
Supporting image
Optimising m2 footprint

Also mentioned: increasing flexibility, supporting culture, improving quality of place

Supporting users has the highest priority; this is achieved by providing a supply that fits the needs of our users

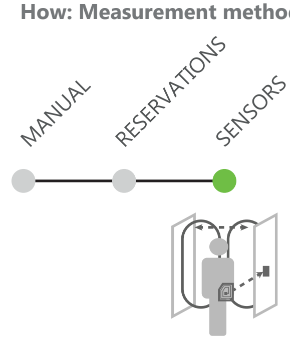
What: Measurement



The data is anonymised, but perhaps the method which is currently used needs to be revised to comply with new EU regulations

The amount of registered users present at a location is measured, resulting in an occupancy number per library.

How: Measurement method



Access control (campus card)

Access to each Library is granted via access control systems. These systems allow users entry based on the privileges on their campus card. Each user is counted individually, therefore the users in the building at a given time can be monitored.

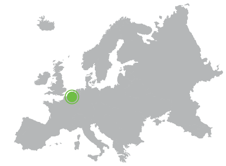
KL

University of Leuven

Blokken in Leuven

functionalities
Find a workplace, Monitor space use

space types
Study places, project rooms



User information (open access)

The user can see an overview of the Library locations on campus and the occupancy of each of these locations (building level). The interface also shows the opening hours and provides links to the website of each library, the location in Google Maps and the Facebook page. The information is also displayed on other media, such as the student app Quivr.

Home › Toegang en gebruik › Studeren in de bibliotheek › Blokken in Leuven

BLOKKEN IN LEUVEN

Locatie	Openingstijden	Bezetting
2Bergen - Biomedische Bibliotheek	8.30 - 17.30	30 / 450
2Bergen - Campusbibliotheek Arenberg	08.30 - 22.00	197 / 700
Alma 2	gesloten	0 / 300
Leercentrum AGORA	8.00 - 24.00	152 / 500
Leercentrum FEB Leuven	9.00 - 22.00	138 / 450

De volgende studieplaatsen worden aangeboden in bibliotheken, waar collectiegebruikers voorrang hebben op blokkende studenten. De beschikbaarheid die in deze bezettingsgraadmeter wordt aangegeven is met andere woorden niet gegarandeerd.

Management information

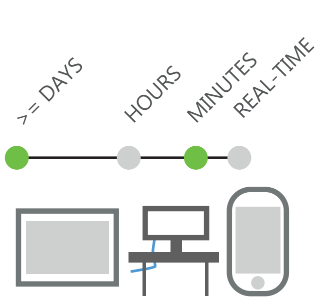
A report of the informatics department. Analytics: amount of unique visitors per year/month, amount of visitors per year/month, occupancy per hour.

Bezetting van de bibliotheek

Maand	All
Week	All
Bibliotheek	AGORA

Sum of Bezet	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2/01/2017	23	291	316	339	300	179	322	372	355	360	293	167	259	283	216	106	-3
3/01/2017	29	378	409	428	342	176	370	436	424	420	310	183	297	340	232	108	-13
4/01/2017	0	371	387	410	329	204	371	421	426	420	295	223	322	362	269	122	0
5/01/2017	26	376	397	422	351	208	365	437	431	424	312	207	334	342	267	126	-8

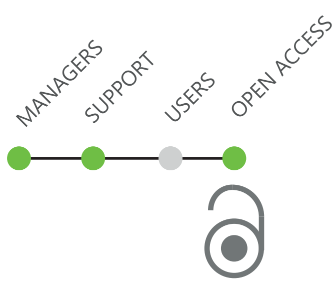
Actuality of the information



The information displayed on digital signage, the app and the webpage has a refresh rate of a few minutes.

The data used in reporting is aggregated data over a monthly or yearly period.

Access levels



Everyone can access the webpage.

Reports are accessible to the persons responsible for each Library desk and to the coordinator (Peter). Libraries can specify the reports to their own locations.

Benefits

Prior to the implementation the objective was to spread the business of the inner city locations to the Heverlee campus (Arenberg and Gasthuisberg). The occupancy rates per location are compared - to each other and to the previous periods - to see if this achieved.

Side notes

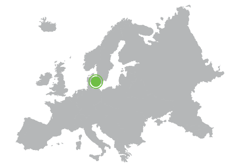
The interface of Blokken in Leuven is not a goal in itself, but providing the data that is displayed there is. What is important is that the data can be communicated to different systems and applications that have a use for the data.

DTU — Technical University of Denmark — Smart Library

phase: **Living Lab**

scale: **35.000 m2, 1 building**

duration: **Expected Oct. 2017**

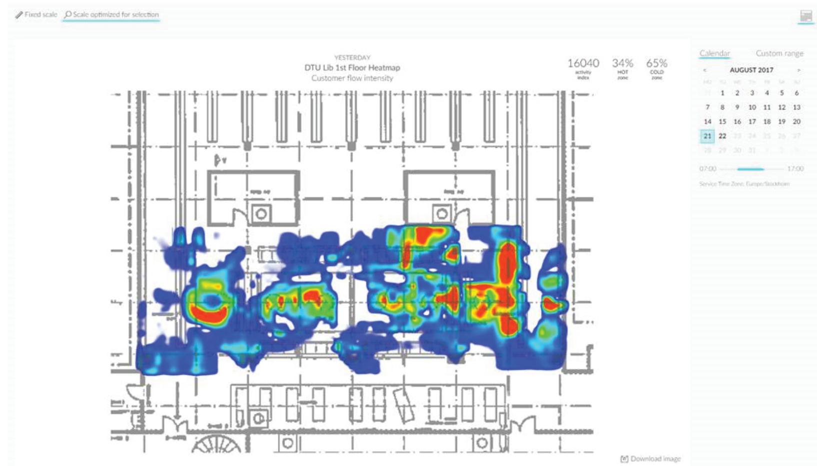


Project description

The initiative was started because of the ageing Library building. The building was built 50 years ago for books and not for people. Now it has almost 2500 visitors per day and is open 24/7. Because of this there are issues with the indoor climate and lighting. We also wanted to improve our services for students. Therefore we chose a solution that helps students to find a place that fits their needs and in which they are able to adjust the lighting. The building is now being renovated and the Smart Library is part of the renovation project.

Foreseen developments

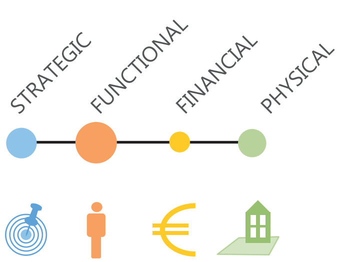
Smart Library is a pilot for the Smart Campus. We want to experiment here in order to find out what works and apply that to the whole DTU campus. We hope that in the future research projects will take place in our Living Lab and that these projects add more sensors and data to the Smart Library.



Heatmap of the Library, based on Wi-Fi measurements

Profile

Why: Objectives

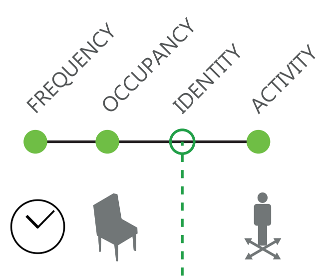


Supporting user activities
Increasing user satisfaction
Stimulating innovation
Reducing costs
Optimising m2 footprint

Also mentioned: stimulating collaboration, supporting image, supporting culture, improving quality of place, increasing flexibility, reducing CO2 footprint.

The comfort of our users has the highest priority for the Library. Comfort has a huge impact on the ability to learn something, so personal comfort is the main goal. Besides that it is working with data, making data open.

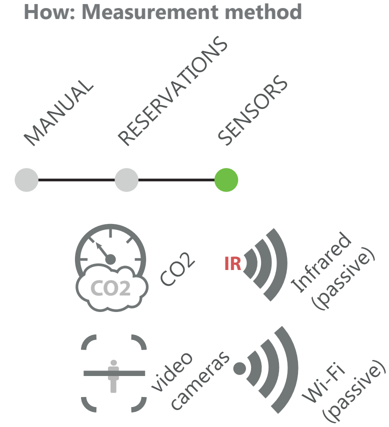
What: Measurement



First we want to make sure all the other aspects are in place and that we comply to privacy laws. Later on we want to offer users to share their identity for additional services such as finding their friends.

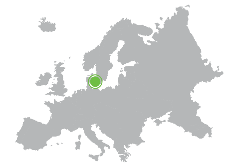
Frequency and occupancy are measured by counting the amount of people in a zone. Movement is measured by registering how the people move between zones.

How: Measurement method



The Sensortags are placed underneath each chair and they measure movement, temperature, humidity etc. The cameras in place create a panorama as they each measure the amount of users in a predefined square and communicate with each other to see movements across squares.

DTU — Technical University of Denmark — Smart Library



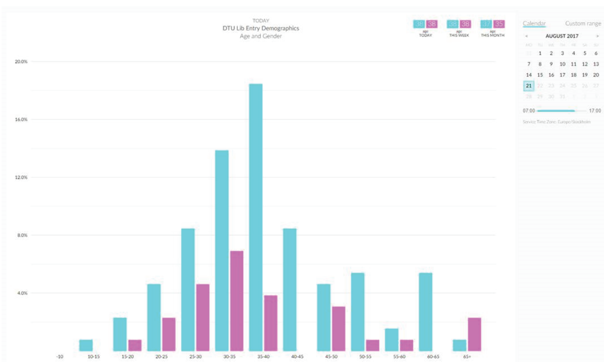
functionalities
Find a workplace, Optimising workplace comfort, Monitoring space use

space types
Study places, project rooms

User information (employees)

The users will be able to access a webpage that gives them information about the available seats in the Library, as well as the temperature, humidity and lighting in different zones. They will also be able to modify the lighting settings (LED lights)

In a next phase the Library will release an app which will also include features such as wayfinding and room booking.

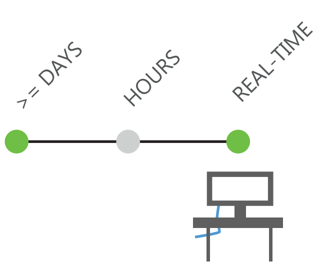


Management information

We will be able to see what kind of chairs to our users like, what services they use, what the preferred temperature and lighting settings are. Also, what are the frequency and occupancy rates of the library. In the future we hope via iBeacons to see how much people attend events and to get feedback from them via the iBeacons.

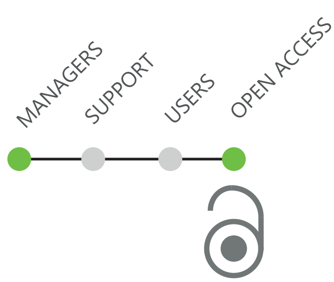
The visual on the left is an example, showing the age and gender of the visitors of the Library.

Actuality of the information



The information displayed on the webpage is real-time.

Access levels



Everyone can access the webpage and the open data.

Benefits

Unknown

The data used in reporting goes from real-time to as far back as possible.

The reporting will be internal in the initial stages.

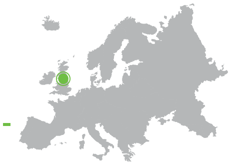
Side notes

There are plenty of things that we are trying out in the near future. Because we are not done yet we're not sure what is going to work. We're trying out different types of cameras.

The Sensetag seems to be a very good solution to make something on your own very quickly.

SHU-1 — Sheffield Hallam University — Clocks (Lone Rooftop)

phase **pilot** — scale **? m2, 5 buildings** — duration **nov. 2017 - present**

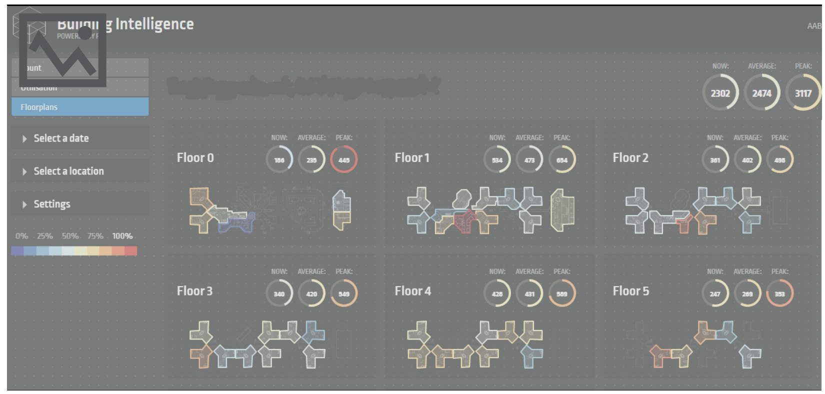


Project description

The initiative was taken because of two reasons. The primary reason is that the academics at the university tend to overbook space. The university shares space across departments and has a high scheduled frequency rate: 70%, which means that there is pressure to use the scarce amount of space efficiently. We are looking at ways to penalise when bookings are not used. The second reason is the Estates masterplan, to inform their development projects as they progress. Lone Rooftop was selected to deliver concrete data to support this.

Foreseen developments

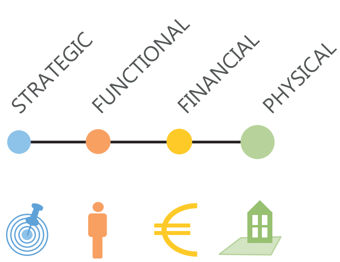
To expand the use of Lone Rooftop to our whole portfolio (58 buildings) and possibly to look at other modules such as PIE.



Images not yet available; image from another case with Lone Rooftop (ABN AMRO)

Profile

Why: Objectives

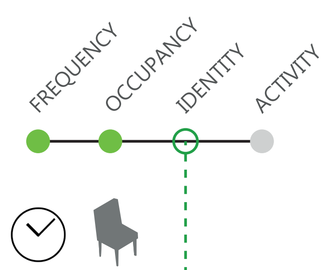


Reducing m2 footprint
Reducing costs
Increasing flexibility
Stimulating innovation

Also mentioned: reducing risks, increasing revenues, supporting users, increasing user satisfaction, supporting culture, supporting image, improving quality of place, stimulating collaboration

Definitely optimising m2. This is achieved by confirming no-shows and sharing the data with faculties, and planning with them how to improve next year's timetable.

What: Measurement



Privacy is addressed by working together with a compliance officer - at the moment looking at the GDPR.

An indication of the occupancy is given for a predetermined zone. The size of this zone is aligned to the accuracy of the measurement.

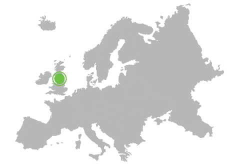
How: Measurement method

The amount of people is measured. First, the devices are counted, both actively via connections and passively via connection attempts, on a certain time in a certain place. This measurement is processed by an algorithm that pairs devices that belong to one person.

SHU-1 — Sheffield Hallam University — Clocks (Lone Rooftop)

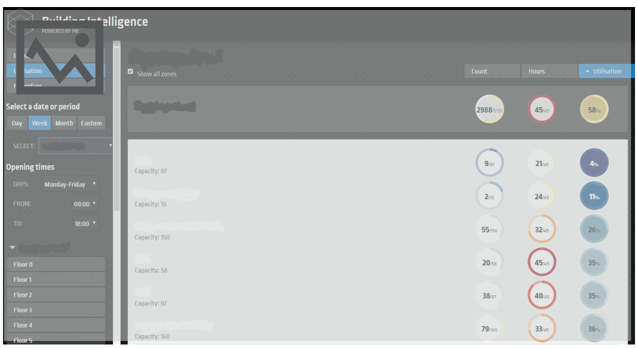
functionalities
Monitoring space use

space types
Education spaces



User information
Users do not receive any information from the dashboard. Based on the results reported in Clocks, workshops are scheduled with departments in order to improve next year's schedule.

Management information
The management information is the Clocks module, which compares the scheduled use and actual use for each course. Per module a figure is shown for the amount of no-shows, amount of empty hours and amount of empty seats.



Images not yet available; image from another case with Lone Rooftop (ABN AMRO)

Actuality of the information

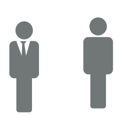
>= DAYS — HOURS — REAL-TIME

The information displayed in Clocks is near-real time.

The data used in reporting goes from real-time to as far back as possible.

Access levels

MANAGERS — SUPPORT — USERS — OPEN ACCESS



The dashboard and reporting functions are available to the space resource manager and the management information officer.

Benefits
to be filled in...

Side notes

When piloting/implementing Wi-Fi, a lot of attention needs to be given to details - for example the location of the access points, linking Syllabus to Lone Rooftop. Also the start of the pilot was delayed because Cisco's MSE went down, which was something that we didn't anticipate.

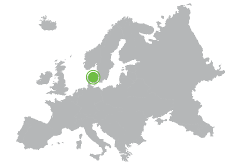
The reporting function in Clocks surprised us - I would prefer having a view per classroom instead of per module.

AU — **Aarhus University** — **design brief**

phase
Design brief

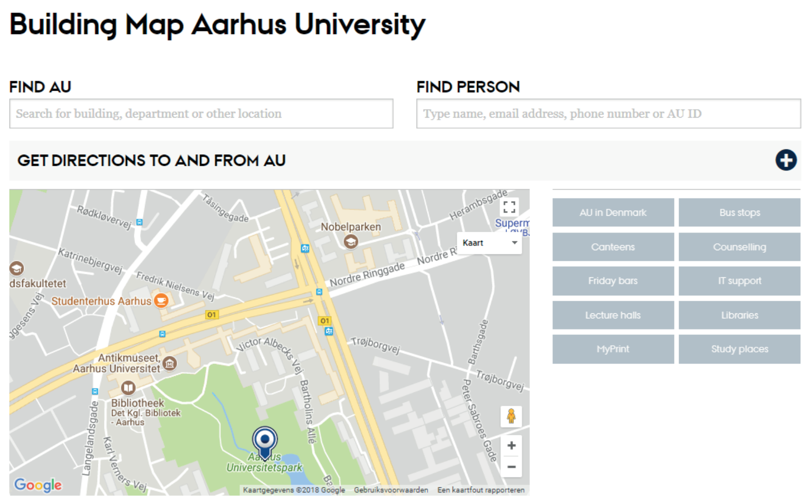
scale
16 buildings
40.000 m2

duration
t.b.d.



Project description

The project was started to make it easier for visitors to navigate on campus. In the conceptual stages it was also identified that monitoring study places could be interesting: we believe that there is a great potential in giving the students a real time overview of available study spaces on campus in order to reduce the wasted time looking for places to study. Using iBeacons looks like the best solution, because the study places at AU are scattered across the campus in many different buildings. Currently the project is only aimed at AU's Business and Social Sciences School (AU BSS).

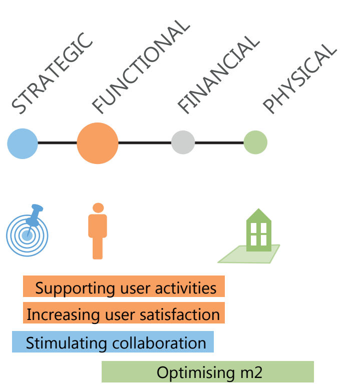


Foreseen developments

In further stages of the project the use of Location-based services (LBS) are foreseen. In a '2.0' version push services for activities on campus could be included, and in a '3.0 or 4.0' version push services based on the needs of the users

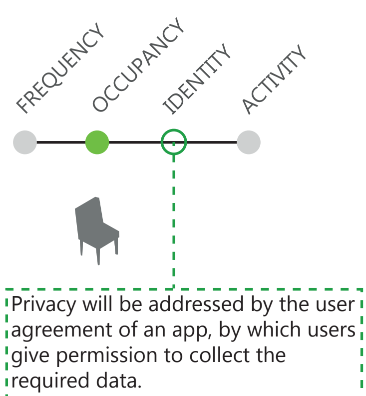
Profile

Why: Objectives



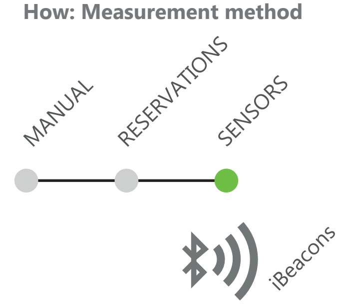
Functional goals have priority.

What: Measurement



The amount of devices connected via Bluetooth to an iBeacon.

How: Measurement method

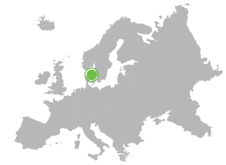


iBeacons measure the amount of occupants by letting devices connect to the iBeacon via Bluetooth. Bluetooth is switched on via an app

AU **Aarhus University** **design brief**

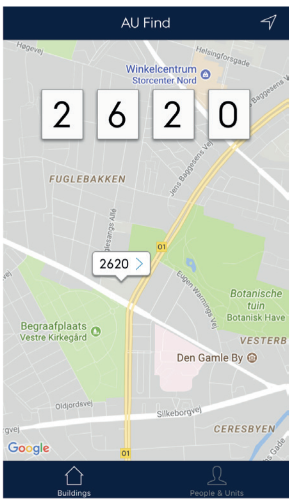
functionalities
Wayfinding,
(Find a study place)

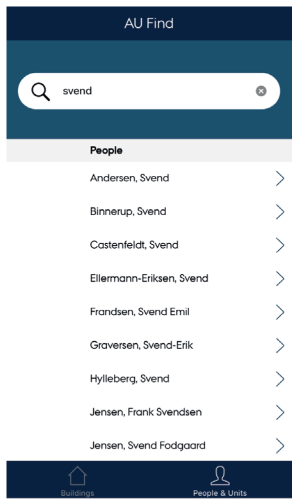
space types
Whole buildings
(study places)



User information

The user will be able to review his/her own location and his/her new location to find their way on the campus. Real-time availability will be given on a room level or floor level to search for available spaces.

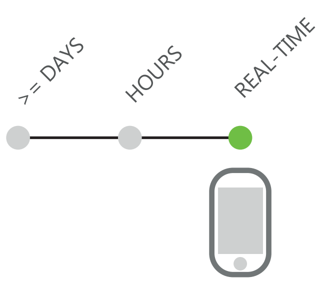




Management information

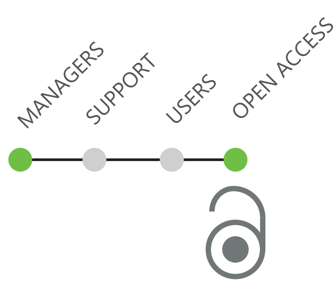
Aside from the information on users, managers will be able to retrieve information over a longer period on a specific building or space type. This gives the opportunity to provide the preferred spaces in the future by knowing what needs to be enlarged or what is not used. It helps to make space use more effective.

Actuality of the information



The information on available study places will be updated in near real time.

Access levels



Everyone can access the wayfinding application via a smartphone app.

Campus management has access to the reporting tool.

Benefits

The main objective is user satisfaction. So far this has not been translated into any metrics. By measuring the usage, different spaces can be assigned to the users that need it. This will result in more effective space use.

Side notes

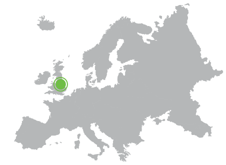
The images on this template show the current version of the smart tool. The web-based version offers additional information on the position of different facilities on campus.

OSBS **Oxford Said Business School** **design brief**

phase
Future implementation

scale
1 building
840 m2

duration
expected
2017



Project description

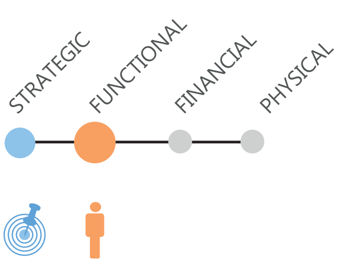
The development of the solution was initiated because the university wants to support the users of the coworking space to find people based on their field of interest. The idea of the Foundry is that users across the whole university can apply and start using the building, but there has to be some way for them to connect to each other. This solution (self-developed) will help them to do that.

Foreseen developments

It would be interesting to see if the data can be correlated to data from the success of start-ups, i.e. if amount of visits and stay duration influence success. This is not foreseen, though.

Profile

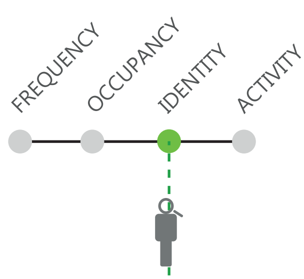
Why: Objectives



Supporting user activities
Stimulating collaboration
Stimulating innovation

Supporting users has the highest priority, this tool helps them by supporting them to find meaningful collaborations

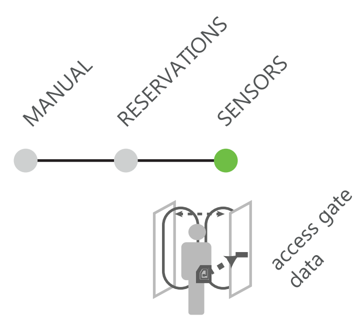
What: Measurement



Privacy will be addressed by allowing people to enable and disable the service.

The people that are in the building at any given time.

How: Measurement method

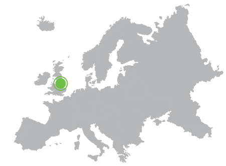


When a user uses the access gate, the gate collects data of the user that has entered the building (who is it, from which faculty and with which field of interest.). The access gates also record departure.

OSBS **Oxford Said Business School** **design brief**

functionalities
People finding

space types
Whole buildings (offices, informal places)



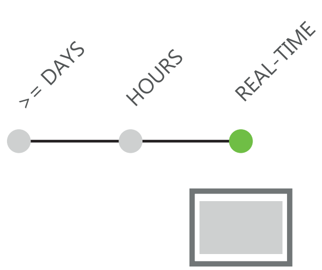
User information

There will be a display in the building on which users can see profiles of who is currently present in the building and what their field of interest is.

Management information

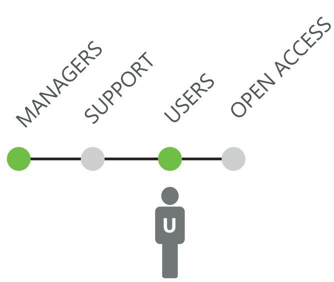
Management will get information on the amount of visits and stay duration of individuals.

Actuality of the information



User information is real-time, management information unknown

Access levels



The user information can only be accessed on site, locally.

The reporting functions can be accessed by the department director only.

Benefits

The project is being financed by donations so there is not much pressure on monitoring the use. Probably we will report on the amount of start-ups that translate into businesses through the Oxford foundry as a metric for success.

Side notes

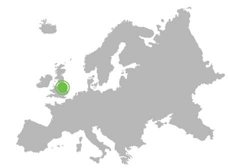
We're still working out if we want the user information loaded into the access card data - which would make the link to the display easy - or if the access card data is linked to a database which would interface with the display. We know that the first option is feasible, the access card system supplier can provide enough fields in the system to satisfy our current demands.

OXF — **Oxford University** — **design brief**

phase
Design brief

scale
1 building
? m2

duration
t.b.d.



Project description

The problem of the university faces is that the amount of development locations in Oxford is finite and so the university needs to decide (1) if demands for new buildings are necessary and (2) if they are necessary, what the amount of realised space should be.

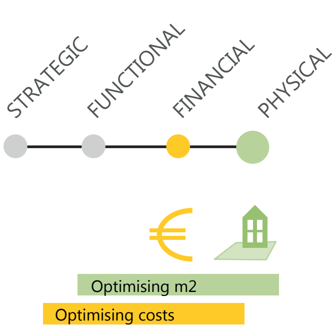
Currently Oxford is looking at a solution that can be easily installed and moved in order to record space utilisation for a finite period at a location in order to make these decisions. In addition, the size of the estate has being growing steadily and is one of the largest financial impacts to the University, there is an increased emphasis on using utilisation methods to combat unnecessary growth.

Foreseen developments

We are still developing a briefing note on new sensor technology, which will need to be signed off by the University before we can start using it.

Profile

Why: Objectives

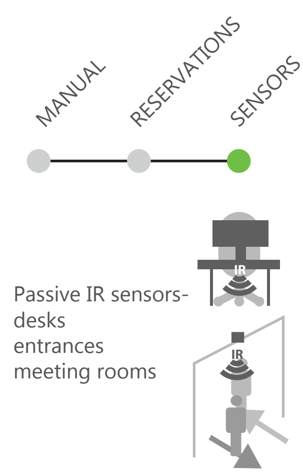


The primary objective is to optimise the use of space on campus as this is becoming more and more a scarce commodity.

What: Measurement

In teaching space the amount of in- and outgoing people are measured. In offices the usage of each desk is measured. In meeting rooms the use (yes/no) of the room is measured.

How: Measurement method

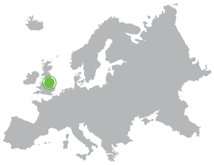


In teaching space the infrared beam registers when a user passes through it. For desks and meeting rooms similar concepts apply

OXF **Oxford University** **design brief**

functionalities
Monitoring space use

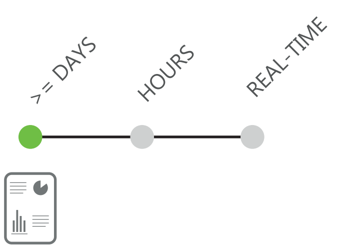
space types
Education spaces, offices, meeting rooms, (potentially research space)



User information
Not known if users receive information.

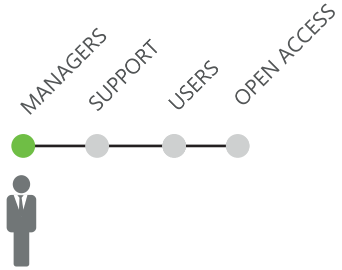
Management information
The management information is space utilisation rates for the teaching spaces in the building, the individual office spaces and meeting rooms.

Actuality of the information



Reporting based on real-time information is done over an entire period (probably two weeks or a month)

Access levels



Managers will have access to the utilisation reports that are used to determine what intervention is appropriate.

Benefits
Unknown.

Side notes

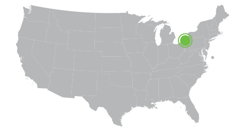
The energy department has a different interest in selecting sensors. We want a solution that is flexible and movable, they want to use another type of sensor (not known which) to link to energy systems in order to reduce energy use.

CMU-1 | **Carnegie Mellon University** | **Sentinel**

phase: **Research**

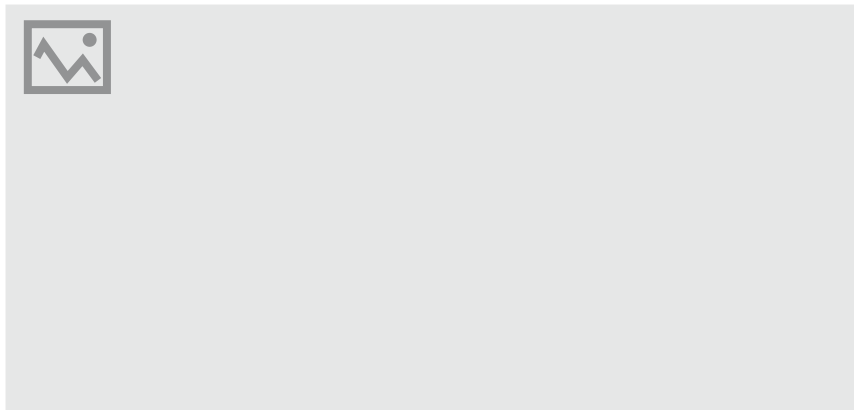
scale: **13.470 m2**
1 building

duration: **2013**



Project description

In general, commercial buildings are a large contributor to primary energy consumption (19%), of which HVAC systems contribute 39,6%. HVAC systems commonly use static schedules to condition modern buildings, which leads to considerable waste of energy. Sentinel was started to research the use of Wi-Fi to collect occupancy information, because (1) existing methods require new infrastructure and thus high investment costs and (2) existing solutions with Wi-Fi encounter limitations.

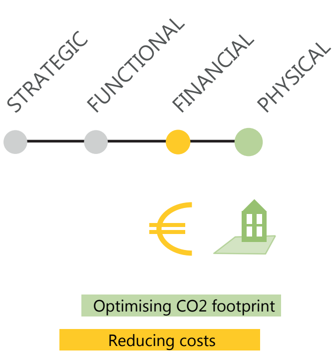


Foreseen developments

To explore the use of occupancy-based HVAC control in shared spaces, to further explore infrastructure based localisation techniques

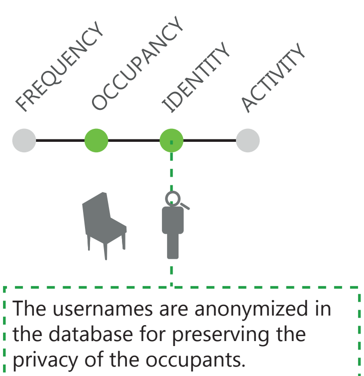
Profile

Why: Objectives



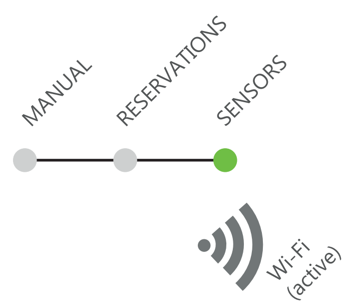
Reducing CO2 emissions is the main objective. Reducing costs is a secondary objective and a reason to research the use of Wi-Fi instead of other methods.

What: Measurement



For individual offices Sentinel measures if the user of the office is present in the office. Therefore Sentinel requires data on which office belongs to whom, therefore it also requires user data (identity)

How: Measurement method

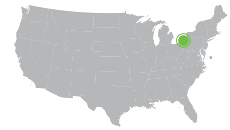


Wi-Fi is used to map a specific user to a specific location. Each access point covers a number of zones. If a user is in the same zone as his/her office, he occupies his office according to Sentinel. Access, Authentication and Accounting logs are used.

CMU-1 **Carnegie Mellon University** **Sentinel**

functionalities
Linking systems

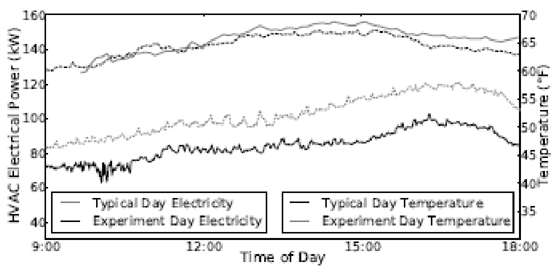
space types
Individual offices



User information (system)

Not applicable - the users do not receive any information in this case.

The system receives information about the use of the offices in the building by their occupants. If the office's user is in the neighbourhood of his/her office the system classifies the room as 'occupied' and the HVAC system conditions the space.

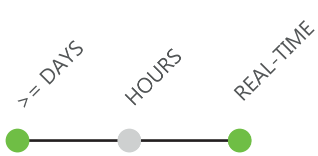


Management information (research output)

Data is provided on the occupancy levels of the offices in the building and the power consumption levels of the HVAC system, enabling the comparison of the two. Furthermore the amount of energy savings can be calculated by comparing days with the same temperature and their energy consumption with Sentinel and without Sentinel.

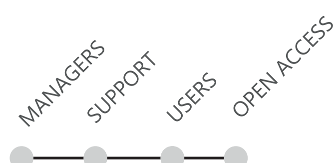
The diagram to the left shows the typical day temperature and electricity use versus the experiment day with Sentinel.

Actuality of the information



The information used by the system is real-time.

Access levels



not applicable.

Benefits

Energy savings; the achieved energy savings during the project were 17,8%.

Side notes

The researchers find that it is possible to infer occupancy of individual offices based on coarse-grained Wi-Fi data (active over passive)

A drawback of using Wi-Fi data in this system is that it assumes that a device is continuously connected to the network. This is not always the case because some smartphones disconnect from networks in sleep mode. In order to address this issue the researchers have asked users to automatically refresh their e-mail every 15 minutes in order to avoid disconnecting.

The measured energy savings of 17,8% could be higher if the Wi-Fi data is more fine-grained, or if the HVAC system can control smaller zones

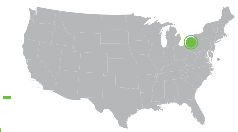
The data used in the analysis goes from real-time to as far back as possible.

CMU-2 **Carnegie Mellon University** **GENIE**

phase **Research**

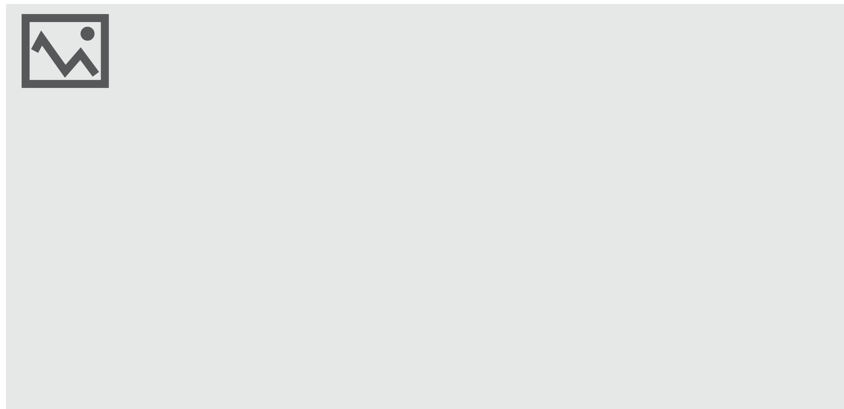
scale **1 building 14.000 m2**

duration **Oct. 2013- Jun. 2015**



Project description

The initiative for this tool was taken to provide users with more information about room temperature to enlarge their wellbeing. To bring this information, software thermostats were user rather than modern thermostats, as software thermostats cost only a fraction of the price of modern thermostats and there was not much research about the effectiveness of these software thermostats in real settings.



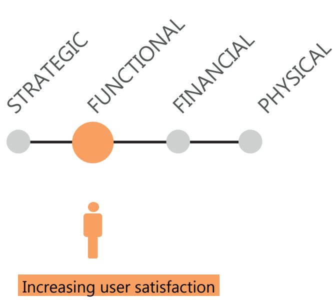
images not yet available

Foreseen developments

More research is needed to verify the findings across different thermostat types, cultures and climate zones

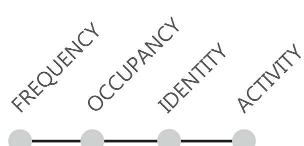
Profile

Why: Objectives



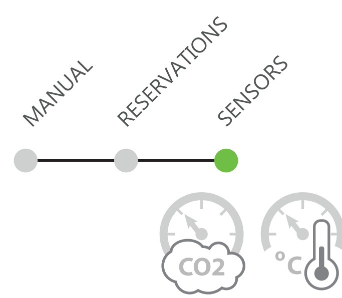
Our goal is to provide transparent access to HVAC information to avoid user misconceptions. Occupants should be able to control the temperature as needed and send feedback about their comfort.

What: Measurement



Not applicable; no occupancy measurement used.

How: Measurement method

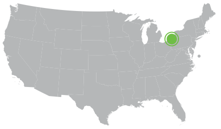


The thermostat measures CO_2 and temperature per zone (a meeting room or a few small offices). This data is collected via the BMS and displayed in an app.

CMU-2 **Carnegie Mellon University** **GENIE**

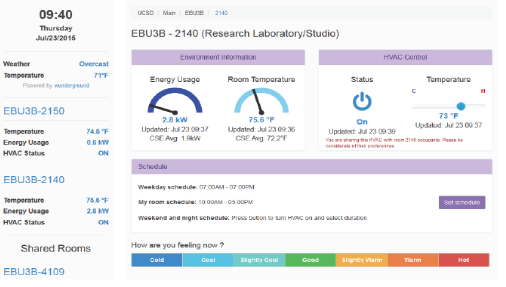
functionalities
Optimising workplace comfort

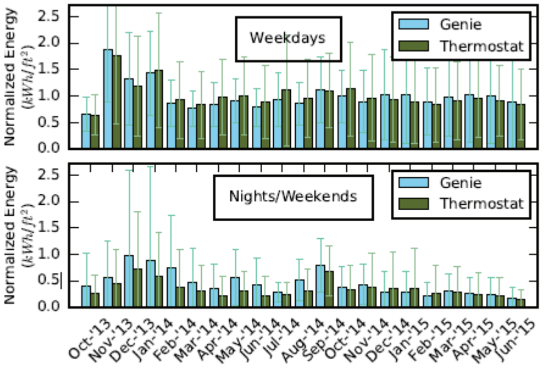
space types
Small offices



User information

The tool gives personalized energy feedback to its users and a possibility to give feedback on the comfort of the room by scoring on a 7 point scale and report in free tekst.





Comparison of energy consumption: GENIE vs. regular thermostats.

Management information

The campus manager is able to compare the adaptions made by users on both the genie tool and the traditional thermostat. The user satisfaction is measured and textual feedback is send to the campus manager. Besides that, also insights are given into energy usage.

Actuality of the information

>= DAYS HOURS REAL-TIME

The tool shows measurements like room temperature and energy usage. Depending on the moment it refreshes, it shows the actual temperature and energy usage.

The data used in reporting goes from real-time to as far back as possible.

Access levels

MANAGERS SUPPORT USERS OPEN ACCESS

When someone has specific access to a room they can request the data for this room. These requests are processed manually.

Benefits

Improved occupant experience and energy savings; the results report an improved occupant experience and no significant impact on HVAC energy savings

Side notes

Giving users the ability to adapt the temperature enlarges their comfort and lowers complaints. Lowering complaints results in less work for the Facility services. The FM department would like to deploy Genie in all university buildings. It is not indicated if a follow-up to the project is foreseen.

3.3. Cross-case analysis

In this chapter a number of insights are drawn up based on the data collected in the cases, which are shown in chapter 3.2.

Numerous problems, different solutions

The first thing that stands out from the cases is their diversity in the problems that they are facing (or rather focusing on) and the intended or implemented solutions. Even for similar problems the surveyed universities tend to develop different solutions. The nine cases displayed in chapter 3.2 tackle six different problems and lead to nine different solutions.

Problems / Solutions	High occupancy of the (main) Library building	Difficulty in finding facilities on campus	Inefficient space use on campus	How to find people that can further your idea for a new business	Low user comfort levels	High energy consumption of HVAC systems
Smart tool that shows real time availability of study places at all major study locations	University of Leuven					
Smart tool that shows real-time availability, temperature and lighting of study places in the Library	DTU					
Smart tool that shows where study places are on campus and what their properties are		Cambridge University				
Smart tool that shows the location of buildings on campus, their facilities and in the future the availability of study places		Aarhus University				
Smart tool that monitors the use of teaching space compared to the timetable			Sheffield Hallam University			
Smart tool that can be moved from location to location to assess space demands			Oxford University			
Smart tool that shows the people present in a building that work or study in your field of interest				Oxford Said Business School		
Smart tool that allows users to set temperature via their smartphone (software thermostat)					Carnegie Mellon University	
Smart tool that adjusts the HVAC system based on real-time occupancy of spaces						Carnegie Mellon University

Table 3.2 – Different problem-solution relationships across cases

University of Leuven and DTU describe a similar problem as driver for their solution, being the increasing demand for learning activities in the library. However, University of Leuven is focused more specifically on making sure that study places across campus are used equally well (rather than all students studying in the same place), whereas DTU is focused on something entirely different: the application of sensors and IoT-technology and looking how that can be applied further on its campus. Therefore the chosen solution is very different. University of Leuven has developed a system that provides real-time insight into the availability of study spaces at Libraries, whilst DTU will also provide students with data on the temperature, lighting and CO2 levels once the solution is implemented. In addition they will use these sensors and future sensors to make their library building a living lab.

A similar observation can be made when comparing Cambridge University and Aarhus University. On first sight they are similar in the sense that they have developed or are developing a tool that combines wayfinding functionalities with finding study places. However, Cambridge University looks specifically at helping students find the facilities that suit their needs in the initial stages of their studies (from a Library perspective) whereas Aarhus University is more aimed at helping students, employees and visitors with general navigation on campus, because they are planning a major redevelopment of the campus. Therefore the chosen solution is again very different: Cambridge University provides a wayfinding tool specifically for study places with very elaborate information on the properties of each study place. Aarhus University is looking at a wayfinding application that informs users of the location of all facilities, and in later stages will look at providing students with real-time information on the location of its scattered study places across campus.

A comparison between Sheffield Hallam University and Oxford University shows the same pattern. Both are looking at or testing a solution that helps them optimise space use on campus. However, Oxford University is primarily concerned with assessing space demands by departments or colleges whereas Sheffield Hallam University is focused on optimising the use of its teaching space in general. Therefore Sheffield Hallam University is piloting a smart tool that helps them to consistently monitor the use of its teaching space on campus whilst Oxford University is looking for a solution that can be moved around, and can be used to conduct a utilisation survey in different space types during a short time period.

Finally, the remaining cases in the survey are using the different smart tools to solve their specific problems:

- Oxford Said Business School has just realised a building called the Oxford Foundry: a co-working space in which all people at the business school and Oxford University can work on start-up initiatives. They are developing a solution that helps users to find people based on their field of interest.
- The GENIE project at Carnegie Mellon was undertaken to improve the comfort of users in offices by providing them information about the room temperature.
- The Sentinel project at Carnegie Mellon was undertaken to address the problem of energy consumption of HVAC systems.

Project status shows actuality of the subject matter

The actuality of the subject matter is revealed by the fact that all surveyed smart tools – or developments have taken place in the past four years. In fact, a timeline of the smart tools shows that the majority of interviewed universities are in the process of developing, testing and implementing solutions, rather than having smart tools already in use.

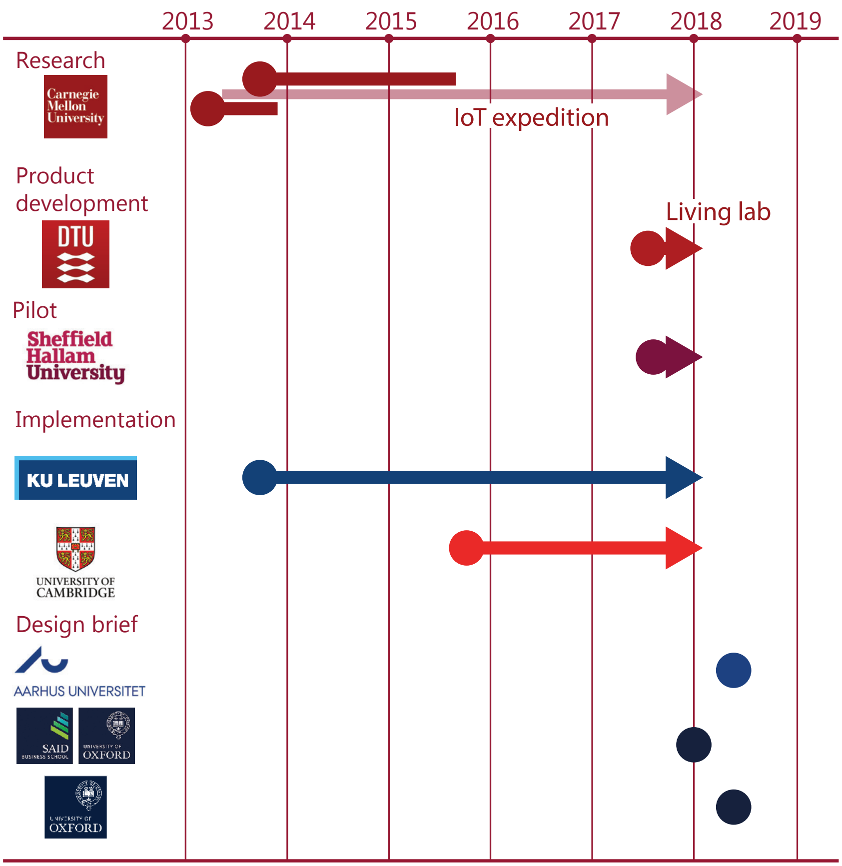


Figure 3.2 – Timeline of smart tools

The next few months will be interesting as a number of parties have indicated that they expect to start implementing a smart tool during that time frame. These smart tools are displayed as circles only. The lines without arrows reflect research projects that have a certain duration.

Foreseen developments – expansion and data analysis

Further reflecting the actuality of the subject matter is that almost all cases mention foreseen developments for their smart tools. The further development of smart tools focuses on a number of different aspects. Sheffield Hallam University and DTU both mention expanding the use of their smart tool to a larger part of the campus. Another aspect is adding additional information to the smart tool: University of Leuven mentions that it is thinking about adding information on the availability of study rooms, whilst

Cambridge would look at filtering study locations on opening hours in a next step. Finally, some universities consider analysing the data in relation to user performance. University of Leuven is currently using its data to research the relation between study time in the Library and study success. Oxford Said Business School has also expressed an interest in the use of data for analysis, being correlation of presence in the Foundry to start-up success.

Finally, a special mention is given to Cambridge University with regard to foreseen developments as the researchers wanted to know if they intend to use space use measurements in Spacefinder in the future. The interviewee indicated that this development is not foreseen and that it also does not fit the use of Spacefinder:. Spacefinder was specifically designed to help students find the ideal study place based on needs and preferences, a problem which they face especially in the initial stages of their studies. Information on availability is not necessary to solve this problem: that information is needed when there is a perceived shortage of study places.

Costs – difficulty to obtain comparative data

With regard to investment and operating costs it was not possible to gain data in all available cases. Because of this and the request of some cases to treat the information anonymously, the information has been omitted from the case data reported in the previous chapter. Instead, an anonymised comparison is given across all cases (chapter 3, 4 and 5) in chapter 6.

Benefits – both qualitative and quantitative

During the data collection process it was decided to add a question to the templates, being: “What objectives are defined to be achieved with the tool, and what is the progress on these objectives since implementing the tool?” This question was added to gain insight into the key metric(s) which universities report on in order to assess to what extent their smart tools are successful.

Because the question was added later and a lot of the projects are in the process of implementation, data was collected for only 6 out of 9 cases.

At Aarhus University and DTU no data is collected with regard to this question. In the development of the Foundry at Oxford Said Business School there is no pressure on monitoring space use as the project is funded through donations, therefore no objective is stated.

University of Leuven and Cambridge have both defined an objective prior to the start of the project. Cambridge has stated that the objective was to cater to students’ needs in the best way possible. By means of feedback, qualitative interviews and anecdotal evidence it has determined that the implementation of Spacefinder is successful, as well as what can be improved. University of Leuven wanted to achieve a better spread of students studying across campus: resulting in students studying more at the Heverlee campus and not only in the inner city. Based on occupancy data per location and a comparison to the previous period(s) it is concluded that this is working well at one of the two buildings at Heverlee, but not yet at the other building.

The research projects at Carnegie Mellon also state an objective and conclusions with regard to those objectives. The software thermostat GENIE was developed to improve user comfort. The researchers report an improvement on user experience and no significant energy savings. The user experience is observed through user interaction data, a survey, and a number of interviews. In the Sentinel project, which is aimed at improving HVAC systems, the objective is energy savings. The paper reports energy savings of 17,8 percent.

Thus it can be concluded that in most cases there is a stated objective and some form of evaluation. This evaluation is quantitative when it concerns space use or energy savings, and qualitative when it concerns supporting user activities.

Objectives are primarily functional

The interviewees were asked to state to which objectives their smart tools or intended smart tools contributed. For this question the framework developed by Den Heijer et al. (see chapter 1) was used: this framework states the objectives through which the campus adds value to the university. The results are displayed in figure 3.3.

The documented smart tools are mostly aimed at adding value through functional objectives such as supporting user activities and increasing user satisfaction. These objectives are also mentioned in most cases as the objectives that have priority. Furthermore one or more strategic objectives are usually mentioned when functional objectives are supported – especially stimulating innovation and stimulating collaboration.

In addition there are examples available where physical and financial objectives have priority, such as optimising $m^{2,}$ reducing costs and saving energy.

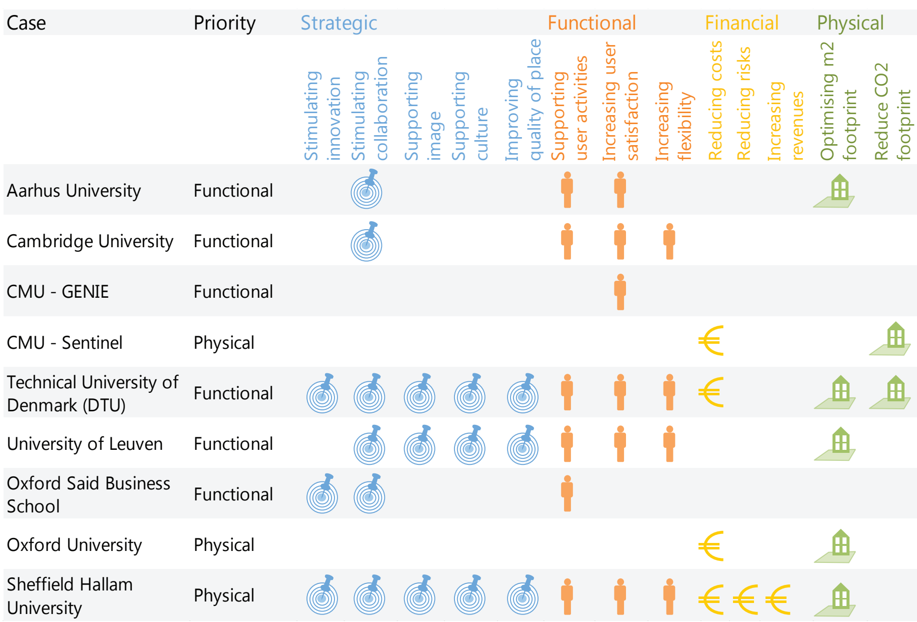


Figure 3.3 – Cases and the objectives they contribute to per category.

Space use is measured in different ways

There is quite a lot of diversity in the type of space use measurements that are used in the documented smart tools. Most of the smart tools use data on occupancy (the amount of people in a space), but there are also examples where smart tools measure space use on the levels of frequency, identity and activity. In addition there are a few examples of tools that do not make use of space use data at all.

Case	Privacy	Frequency	Occupancy	Identity	Activity
Aarhus University	Via the user agreement of the app		●		
Cambridge University	Not applicable	no space use measurements			
CMU - GENIE	Not applicable	no space use measurements			
CMU - Sentinel	Usernames are anonymised in the database		●	●	
Technical University of Denmark (DTU)	Users will be able to share their identity for additional services	●	●		●
University of Leuven	The data is anonymised, but perhaps the method needs to be reviewed to comply with EU regulations.		●		
Oxford Said Business School	Users will be able to enable and disable the service			●	
Oxford University	Sensing methods will be applied that register people anonymously.	●	●		
Sheffield Hallam University	Wi-Fi data is anonymised on-site. Anonymisation is done differently each day. Privacy is addressed together with a compliance officer. At the moment the GDPR is being looked at.	●	●		

Figure 3.4 – Cases and the ways in which they measure space use. If applicable, privacy issues are mentioned.

Privacy is dealt with in different ways:

- The opt-in principle, where users agree to share their data in order to make use of the service (see Aarhus and Oxford SBS)
- Direct anonymization, where the university anonymises the data after collection and prior to analysing the data (see University of Leuven, Sheffield Hallam University and CMU-Sentinel)
- Anonymous data collection, when a sensing technology is chosen that cannot register individuals. (see Oxford University)

DTU is a special case in this respect, as it intends to make its datasets accessible to a larger public (similar to using books, you would also be able to use datasets). With regard to privacy the interviewee has stated that DTU wants to make sure to comply to privacy laws first, probably meaning that data will be anonymised after collection given their sensing methods. In a later stage they will also look to use an opt-in service.

Different measurement methods

Similar to the space use measurements different measurement methods are used: in the various cases Wi-Fi, iBeacons, access gates, and passive infrared sensors are mentioned. This is specified in figure 3.5, where the measurement method is specified in terms of what type of sensor is used and what the specific application is. Furthermore sensors that do not measure space use have been identified, such as temperature and CO_2 sensors.

Figure 3.5 shows the collected data per case. Here the observation made at the start of the chapter –that there are cases with similar problems but different smart tools- is visible. Cambridge and Aarhus have a similar problem, but Aarhus intends to use iBeacons whereas Cambridge does not measure space use at all. University of Leuven and DTU have similar problems, but DTU uses multiple sensors and University of Leuven uses access gate data. Oxford University and Sheffield Hallam have a similar problem, but Oxford University intends to use infrared sensors whilst Sheffield Hallam uses Wi-Fi.

Case	Measurement method	Manual	Reservations	Sensors	Sensor application
Aarhus University	iBeacons measure the amount of occupants by letting devices connect to the iBeacon via Bluetooth. Bluetooth is switched on via an app			Bluetooth	iBeacons
Cambridge University				no space use measurements	
CMU - GENIE				no space use measurements	
CMU - Sentinel	Wi-Fi is used to map a specific user to a specific location. Access, Authentication and Accounting logs are used.			Wi-Fi	Active connections
Technical University of Denmark (DTU)	The Sensortags are placed underneath each chair and they measure movement, temperature, humidity etc. The cameras in place create a panorama as they each measure the amount of users in a predefined square and communicate with each other to see movements across squares.			Cameras, Infrared, CO2, Temperature	
University of Leuven	Access to each Library is granted via access control systems. These systems allow users entry based on the privileges on their campus card. Each user is counted individually, therefore the users in the building at a given time can be monitored.			RFID	Access gates
Oxford Said Business School	When a user uses the access gate, the gate collects data of the user that has entered the building (who is it, from which faculty and with which field of interest.). The access gates also record departure.			RFID	Access gates
Oxford University	In teaching space the infrared beam registers when a user passes through it. For desks and meeting rooms similar concepts apply			Infrared	Doorways, Desks
Sheffield Hallam University	The amount of people is measured. First, the devices are counted, both actively via connections and passively via connection attempts, on a certain time in a certain place. This measurement is processed by an algorithm that pairs devices that belong to one person.		Schedule data	Wi-Fi	Connections, connection attempts

Figure 3.5 – Cases and types of sensors they use to measure space use (or other space properties)

Actuality of information: difference in provision of user information, similar requirements for management information.

With regard to the information generated by the smart tool the actuality of the user information and management information was also one of the properties asked. Figure 3.6 shows that all cases report user information (near) real time. University of Leuven further specifies the update frequency. Noteworthy is the difference in output between the different tools – where Aarhus mentions the intended use of a smartphone app, Oxford Said Business School specifically chooses for digital signage at the location itself. University of Leuven provides multiple methods to display their user information.

The generated management information shows a more unilateral picture: most cases have reporting tools in which data can be aggregated and compared over the entire measurement period. Only Sheffield Hallam specifies having a tool for management information with both a dashboard and a reporting function.

Case	User information	Management information
Aarhus University	The information on study places will be updated near real-time	Unspecified
Cambridge University	not applicable; no use of sensor data	
CMU - GENIE	The tool shows measurements like room temperature and energy usage. Depending on the moment it refreshes, it shows the actual temperature and energy usage.	The data used in reporting goes from real-time to as far back as possible.
CMU - Sentinel	-	The data used in reporting goes from real-time to as far back as possible.
Technical University of Denmark (DTU)	The information displayed on the webpage is real-time.	The data used in reporting goes from real-time to as far back as possible.
University of Leuven	The information displayed on digital signage, the app and the webpage has a refresh rate of a few minutes.	The data used in reporting is aggregated data over a monthly or yearly period.
Oxford Said Business School	User information is real-time	Unknown
Oxford University		Reporting based on real-time information is done over an entire period (probably two weeks or a month)
Sheffield Hallam University		The information displayed in Clocks is near-real time. The data used in reporting goes from real-time to as far back as possible.

Figure 3.6 – Cases and actuality of the information reported

Access levels

Finally, the access levels within the use of the smart tools have been collected. Of course almost all tools make a distinction in access to user information and management information – however there are slight differences in how they do this. As figure 3.7 shows, some universities choose to provide the information only to their university users whereas other universities make the information open access. With regard to reporting functions most universities keep access restricted to management levels, although some also grant access to support staff. DTU is unique in this respect as their ambition is to make the reporting data available to a larger public as well.

Case	Specification	Managers	Support	Users	Open access
Aarhus University	Everyone can access the wayfinding application via a smartphone app; campus management has access to the reporting tool.	✓			✓
Cambridge University	Everyone can access the webpage. The back-end of Spacefinder is accessible to the programme manager, which can be used to generate various reports	✓			✓
CMU - GENIE	When someone has specific access to a room they can request the data for this room. These requests are processed manually.			✓	
CMU - Sentinel			not applicable.		
Technical University of Denmark (DTU)	Everyone can access the webpage and open data. The reporting will be internal in the initial stages	✓			✓
University of Leuven	Everyone can access the webpage. Reports are accessible to the persons responsible for each Library desk and to the coordinator (Peter). Libraries can specify the reports to their own locations.	✓	✓		✓
Oxford Said Business School	The user information can only be accessed on site, locally. The reporting functions can be accessed by the department director only.	✓		✓	
Oxford University	Managers will have access to the utilisation reports that are used to determine what intervention is appropriate.	✓			
Sheffield Hallam University	The dashboard and reporting functions are available to the space resource manager and the management information officer.	✓	✓		

Figure 3.7 – Cases and access levels within the smart tools.

3.4. Additional: Study places and smart tools

In addition to the data collected via the cases discussed in the previous part of this chapter, the case selection process also yielded information relevant to the research question. In order to select cases an exploration was done in order to determine where to look for innovative smart tools. This also resulted in a blog post that was shared on www.managingtheuniversitycampus.com .

In order to find out which universities might be using innovative smart tools we decided to look at the information available on finding study places at universities. Researching if there are smart tools related to study places in this stadium of the research is logical for multiple reasons. The research method used here is desk research, collecting data that is on the websites of the universities systematically. More so than other space types, universities are likely to provide information on study places on their websites. Aside from the fact that office spaces, laboratories, classrooms and meeting rooms are shared much less often between faculties, departments and/or individuals, even if this is the case this is done via internal booking and scheduling systems, thus not being publicly available information. In addition, studying on campus is a hot topic: research by the CampusNL research team showed that in the Netherlands, the past ten years the universities have seen a development in which students study more on campus and in which they have made a conscious effort to support this demand (TU Delft, 2016).

With regard to the universities our hypothesis is that universities in northern Europe and the coasts of the United States are most likely to be innovative in this area. To this end I explored the existence of smart tools for study places on campus within the 50 top ranked universities, according to the Times Higher Education rankings. The THE top 50 universities consists mostly of US universities (25), followed by universities from the UK (7), China (4), Germany (3), Canada (3), Switzerland (2), Australia (2) and universities from Belgium, Sweden, Singapore and Japan. The existence of smart tools were identified in three categories: self-booking systems, real-time availability of desktop PCs and real-time availability of study places.

The results were as follows:

- 13 out of 50 universities provides insight into availability of desktop PCs via their websites or mobile apps; when divided per region the ratios are: USA 3 out of 25, Europe 4 out of 14, rest of the world 6 out of 11.
- 44 out of 50 universities provide a self-booking service for study rooms for their students; some universities also provide services to reserve individual study places
- 2 out of 50 universities provide information on the availability of study places: KU Leuven and Ludwig Maximilians University in Munich. Furthermore the University of Edinburgh states that it is working on a space monitoring pilot on their website.

Based on this data KU Leuven, LMU Munich and the University of Edinburgh were all contacted, of which KU Leuven was added as a case. Although the other two universities were not added as a case, more information is available.

At LMU Munich the occupancy of its libraries is shown on their 'Platzfinder' website. The libraries at the university work with parking discs: students receive a parking disc upon entering the library which they must leave on their spot when they take a break. If the spot is left empty for more than one hour, the spot may be used by someone else. Librarians count the amount of parking discs they have given to (and received back from) students, information which they enter in a website and which is updated every five minutes. The source suggests that the same system is being used at other German universities as well (Witzenberger, 2017).

Aside from the information provided by the universities via their websites, another development is going on: students themselves have been working on projects to provide information on availability to their peers. At Columbia University, a student lab called ADI has developed an app called Density that estimates occupancy rates based on Wi-Fi data. At Duke University three students have built the FreeSpace app, which allows users to find Free spaces based on a sensor network using their own sensors. A quick search teaches us that this is not a particularly unique development – at UC Davis and Bryant University students are doing the same! Bryant University even uses its lighting system to show room occupancy.

See for yourself:
http://findyourfreespace.com/ - FreeSpace, Duke University
http://density.adicu.com/ - Density, Columbia University
https://study.space/ - Study Space, UC Davis
https://www.universitybusiness.com/article/app-helps-students-find-empty-study-space - RoomFinder, Bryant University

Another development that was found to be taking place is that third parties are starting to offer space to study as a pay-per-use service to students – numerous examples have been found in Singapore (Sin, 2017). A recent example has also been found in the Netherlands: a company called Timespace offers students a place to study for € 4 per day and € 20 for ten visits.

http://thestudyarea.com/ - in Singapore
https://studyonecorner.com/ - in Singapore
http://www.thestudybox.com/ - in Singapore
http://timespace.nl/ - in Utrecht, the Netherlands

These student projects and third party study places reflect the high demand in study places and potential value of providing information on available study places to students.

3.5. Conclusion

The question to be answered in this chapter is:
What smart tools are available at international universities?

To answer this question, fourteen universities were interviewed, which resulted in nine cases of smart tools.

Smart tools to find available study places

In two cases user apps are available to find study places on campus. University of Leuven offers information on the availability of study places in their Library buildings based on data from their access gate systems. It is the only case in this chapter in which real-time information is given to users.

Cambridge University offers information on the location and properties of study places across campus and in the city. The case of Cambridge University is noteworthy because the development of the app was initiated to provide students with information on study places specifically in the initial stages of their studies. Providing real-time information on the availability of those study places was considered, but found to not fit the purpose of the Spacefinder app.

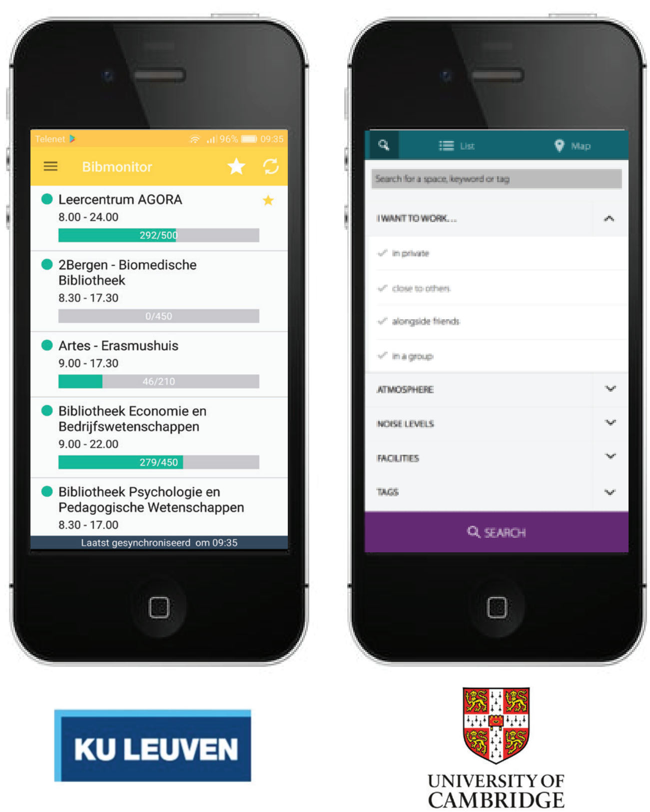
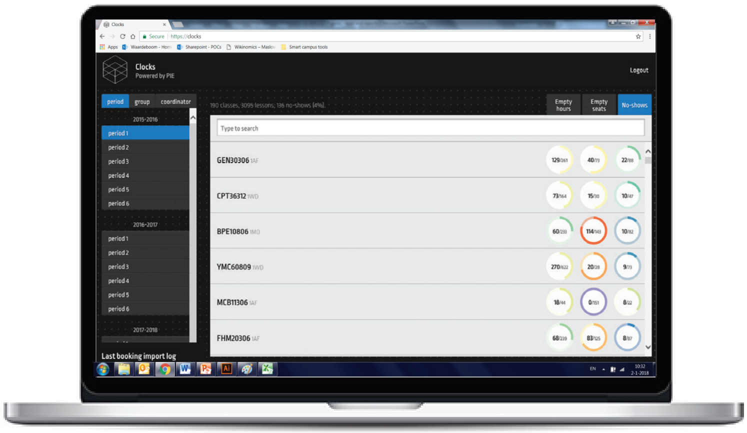


Figure 3.8 – User apps in use at University of Leuven and Cambridge University

Smart tools to optimise the use of teaching space

At Sheffield Hallam University a pilot is undertaken to monitor and improve the use of teaching space across campus. Using Wi-Fi data from the university's campus network the frequency and occupancy rates are determined per activity in the university's schedule.



Sheffield Hallam University

Figure 3.9 – Optimising the use teaching space: Sheffield Hallam University

Many developments are on their way

Although only two implemented user apps and one pilot project to optimise teaching space are found, the other six cases reveal that many universities are busy with the subject. New smart tools are being considered, researched, developed and tested to support students and employees, optimise space use and save energy.

The nine cases reveal that international universities focus on many (slightly) different problems, which lead them to develop their own specific solutions. Figure 3.10 shows an overview of what they are working on, when positioned in the current state of smart tools and next steps of the previous research – see also figure 2.3 and 2.4 in chapter 2. The international universities are working on smart tools that monitor teaching space, smart tools that monitor multiple space types, smart tools that help you find people in your field of interest, smart tools for wayfinding on campus, smart tools to help find study places on campus, smart tools to help find a study place and optimise your comfort on that study place.

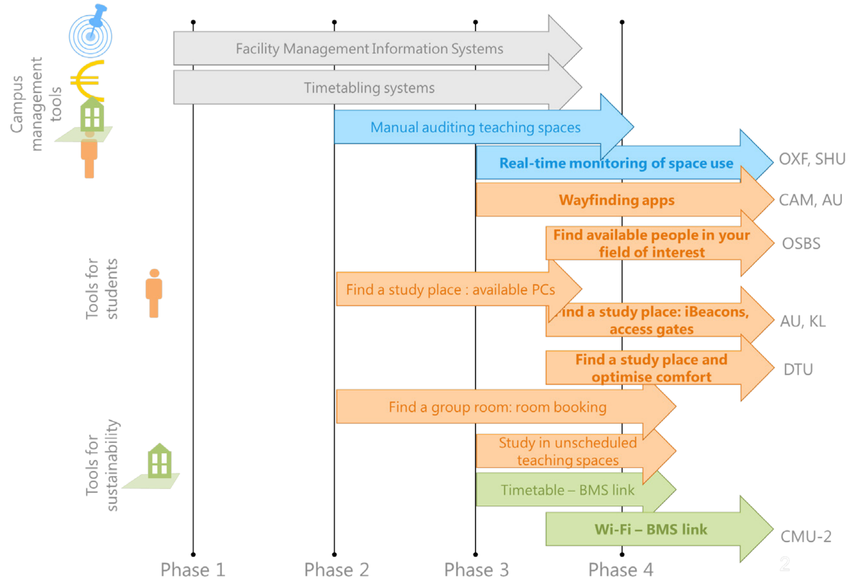
Findings from the cross-case analysis

Furthermore, the following conclusions can be drawn when comparing the nine cases: The cases focus on many (slightly) different problems, which lead them to select or develop their own specific solutions.

- Only three of these nine tools were operational at the time of the interviews – two are completed research projects and four are intended smart tools, expected to become operational within the next six months.

Figure 3.10 – Overview of available smart tools.

Phase 1: no smart tools; phase 2: prevalent smart tools in 2016; phase 3: new smart tools in 2016; phase 4: ongoing smart tools in 2017. Arrows with bold text represent smart tools found in this study.



- Foreseen developments focus on either expanding the solution to a larger part of the campus or using the data to analyse the relationship between presence and performance.
- In most cases there is a stated objective and some form of evaluation. This evaluation is quantitative when it concerns space use or energy savings, and qualitative when it concerns supporting user activities. For many cases there is no information available yet on the results, as the smart tools have not been implemented yet.
- The cases are mostly aimed at adding value through functional objectives, i.e. supporting users, increasing user satisfaction and increasing flexibility.
- Occupancy is the level of space use that most smart tools measure on.
- The sensors used most are Wi-Fi (2 cases), Infrared (2 cases), and RFID (2 cases). Universities deal with privacy in different ways.
- Information is provided in near real-time to users, but via different output. The requirements for management information are fairly similar across cases, using reports almost exclusively as output.
- User information is in most cases open access, and in some restricted to university users. Management information is usually restricted to campus management, in some cases to support and in one case intended to be open access.

Other insights

The exploration of smart tools in use for study places (chapter 3.4) suggests that it is not at all common for universities to provide information on the availability of study places, and certainly not amongst the highest ranked universities. Also the hypothesis that European and US universities would be ahead in this respect cannot be confirmed, although the universities that do provide real-time data on availability are all European universities.

There is other evidence that does confirm the high demand for study places: at multiple universities students have taken it upon themselves to develop apps that give insight into study places. Furthermore, there are examples of entrepreneurs who are offering pay-per-use study places as an alternative form of supply.

Chapter 4
Smart tools at other organisations

This chapter is aimed at the second component of the research project, which is to explore examples of smart tools in use at other organisations. The following research question is answered:

What smart tools are available at other organisations?

First, the chapter discusses the process of selecting cases and provides a short description of each case. Then the collected data in the templates is displayed. Based on these templates the properties of the cases are analysed before concluding the chapter.

Photo: Microsoft Redmond Campus, Seattle, WA.

4. Smart tools at other organisations

4.1. Cases

This chapter reports the way in which cases were selected and provides a description of the cases.

Case selection

A number of different methods were followed in the selection of cases. First a number of companies were approached in the technology industry, as these were companies that were included in the research proposal. In order to find contemporary cases Google Alerts were used to find press releases of recent applications of smart buildings. This resulted in a number of results. Finally, a number of companies were approached based on suggestions of colleagues or interviewees, reflecting a more opportunity-driven approach. A total of 10 parties were approached. The map below gives an overview of the organisations approached and the cases provided in this research.

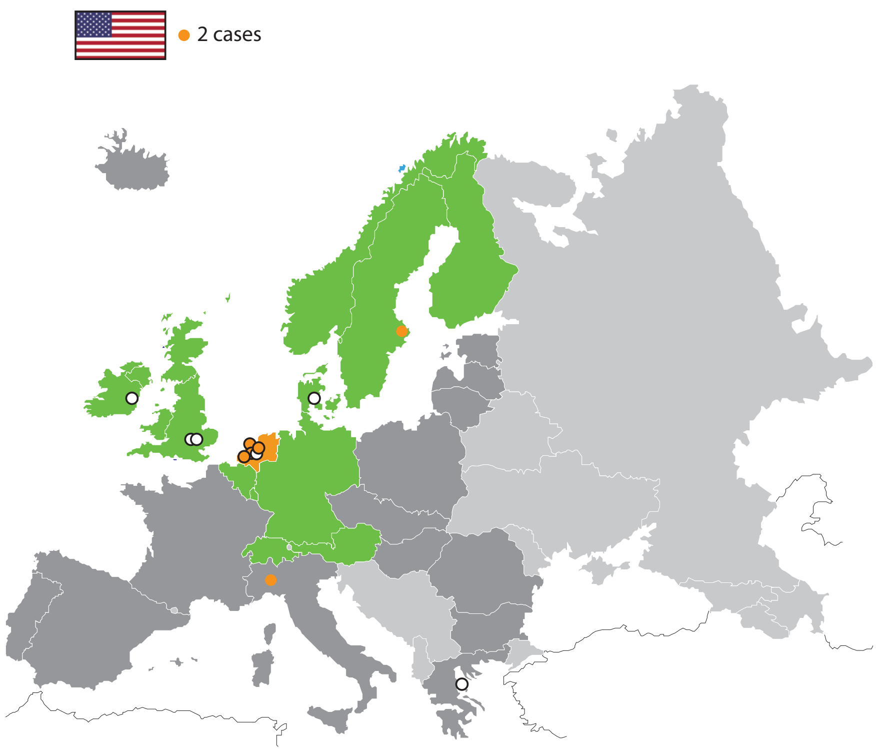


Figure 4.1 - Map including all the cases at organisations

The response rate at organisations was higher than at universities – around 65 percent. The people interviewed were also less diverse in terms of roles. The table displays the interviewed organisations in chronological order.

Country	Organisation	Function of interviewee(s)
Netherlands	ABN AMRO	Facilities management
United States	Microsoft	Real estate and Facilities management
Sweden	Sony Ericsson	Workplace services
Netherlands	Erasmus MC	Real estate management
Italy	Agnelli Foundation / Carlo Ratti Associati	Architect and founding partner
Netherlands	Dutch government (shared service centre ICT)	ICT
United States	Google	Real estate and workplace services
Netherlands	OVG	Chief technology officer

Table 4.1 – Overview of cases at organisations

Case description

Similar to the universities, the cases provided thus far display a large variety.
ABN AMRO has implemented a smart tool in order to gain insight into the hidden vacancy in its offices, and to use this information to discuss with their business lines how to optimise their accommodation. Furthermore ABN AMRO wants to increase its employee satisfaction and provide insight into where workplaces are available in buildings.

Microsoft has been working for the past few years on a change from individual offices to team-based spaces, in which it looks at the question how to design the ideal workplace. The data from the implemented tools reinforce the objective of designing the ideal workplace.

Ericsson has implemented one of its own applications in order to support its office users to find work- and meeting spaces when needed.

Erasmus MC is currently working on the redevelopment of large parts of its portfolio. In one of its office buildings it will move towards a shared desk office concept, for which it is contemplating a smart tool to support its office users. In the future it will also redevelop a high-rise containing laboratories and offices, for which smart solutions are sought that support users in their daily work whilst also helping to reduce the energy consumption of the building.

The Agnelli foundation’s new headquarters in Turin, Italy includes a system that enables the building to manage heating, lighting, space allocation and air conditioning whilst people move around in the building and enables them to book meeting rooms and shared desks. CRA practice’s vision is to realise an ‘Office 3.0’ in which the interaction between occupants and the building stimulates creativity and collaboration.

The Dutch government has been working on the development of a workplace finding application to support its strategy of optimising their real estate portfolio.

Google has a real estate portfolio that is rapidly expanding. It consists largely of office buildings with workplaces, meeting rooms and informal spaces. The workplace strategy of Google is aimed foremost at employee productivity and satisfaction and therefore provides individual workplaces rather than shared office concepts. In the meeting rooms in its portfolio Google had a specific problem: that these were being claimed too often for long periods of time. A smart tool was developed to solve this problem.

Fontys Quantified Student
(previous research project)

Fontys Hogeschool, a Dutch University of Applied Sciences (UAS), has been working on a programme called Quantified Student. In this programme the partners aim to use data to help students improve their performance.

The programme consists of multiple initiatives, which are also integrated in the education programmes of the UAS.

Source (see also):
https://quantifiedstudent.nl/

OVG has developed the Edge based on the demands of Deloitte. At the time Deloitte was making a transition as a firm from accountancy to consulting and they knew that in order to be competitive as a consultant they needed to attract and retain talent. The vision for the Edge was linked to that demand – making the office of the future by connecting all facilities in the building to the internet.

4.2. Templates

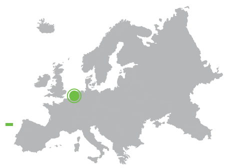
For each of the cases the smart tool templates were filled in – either during the interviews as far as possible or afterwards by the interviewee. In some cases the template could not be filled in entirely, either because the project was still in development or because the data needed to be delivered by another person. The templates are provided in order of their phase. First, the implementations are displayed, following by pilots, design briefs and finally research projects.

ABN — **ABN AMRO** — **Intelligent Building - Lone Rooftop**

phase **Implementation**

scale **232.000 m2**
11 buildings

duration **dec. 2016 - present**



Project description

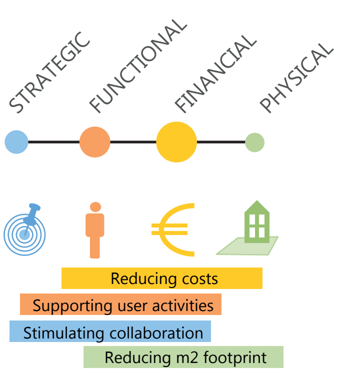
The project was initiated because we wanted to manage our scarce resources better. We wanted insight into hidden vacancy in the different buildings in order to discuss the space use with our different business lines and to optimise our services as FM. In addition we wanted to show our employees the availability of workplaces. We then started to look at options to use existing infrastructure and initiated a pilot with Lone Rooftop. The project includes three different services: the building dashboard, the SPOT app and Wally.

Foreseen developments

We want to get insight into the frequency (no-show) and occupancy (amount of persons) of meeting rooms with other sensors.

Profile

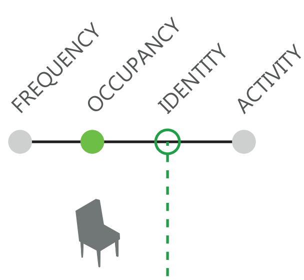
Why: Objectives



Also mentioned: increasing user satisfaction, increasing flexibility, stimulating innovation, supporting culture, improving quality of place

Cost reduction has the highest priority, followed by supporting our users. Cost reduction is achieved by discussing space use with our business lines, which will result in not having to build new buildings or disposing of existing buildings.

What: Measurement



With Wi-Fi personal data is collected. Lone Rooftop deals with this issue by anonymising its data differently every day and by anonymising it directly after data collection

An indication of the occupancy is given for a predetermined zone. The size of this zone is aligned to the accuracy of the measurement.

How: Measurement method

The amount of people is measured. First, the devices are counted, both actively via connections and passively via connection attempts, on a certain time in a certain place. This measurement is processed by an algorithm that pairs devices that belong to one person.

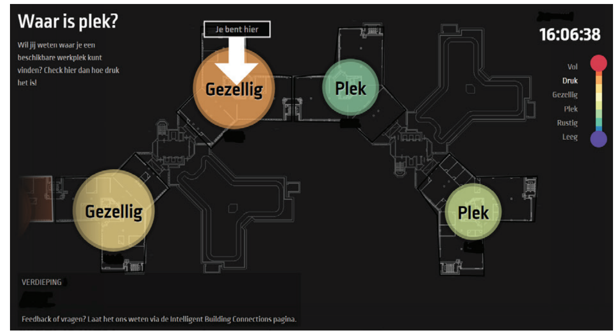
ABN — ABN AMRO — Intelligent Building - Lone Rooftop

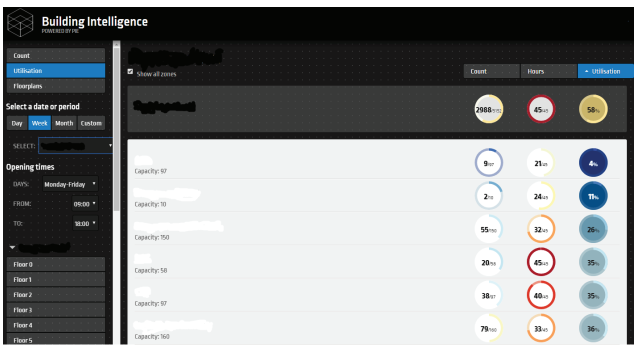
functionalities
Monitoring space use, find a workplace

space types
Offices, (whole building)

User information (employees)

The user - in this case employees - can see the occupancy of different zones in the buildings on TV screens installed on each floor and via the SPOT app. Per floor a number of zones have been defined, consisting of multiple workplaces, of which an indication of the occupancy is given in labels: “full”, “busy”, “calm”, etc.

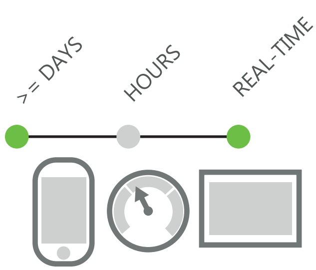




Management information

In the dashboard it is possible to view both real-time and historical data. The user of the dashboard can display the information in diagrams and on blueprints of the building. Recently the dashboard has been updated, which makes it possible to aggregate the data on different levels.

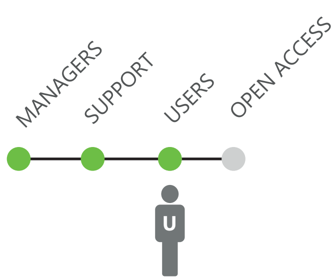
Actuality of the information



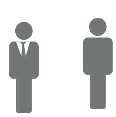
The information displayed in the dashboard for employees, in floorplans and reports is real-time.

The data used in reporting goes from real-time to as far back as possible.

Access levels



The Avex screens display information on real-time availability of workplaces that can be accessed by all employees



The dashboard and reporting functions are available to the BI department and account managers.

Benefits

- determining an accommodation strategy with the collected data
- reducing costs due to less investment in extra accommodation
- advising the building user on the efficient use of space

Side notes

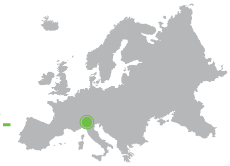
The use of Wi-Fi for this purpose within a bank is a challenge, because the network has a very strong security. In the pilot we tested how to transfer the data from in the organisation to outside (Lone Rooftop, MSE application of Verizon) and then again to inside the organisa-tion.

During the pilot we discovered that this required a lot of effort and we ran into a number of unforeseen complications. Further complicating the matter was the communication of different systems: Lone Rooftop, our network provider Verizon and Avex, the party who provided the TV screens and narrowcasting solution.

AGF

Agnelli Foundation, Carlo Ratti Associati — **Office 3.0**

phase **Implementation** — scale **6.500 m2, 1 building** — duration **June 2017-present**



Project description

There are two problems addressed by Carlo Ratti Associati: the first is energy wasted by heating and cooling empty buildings and the second is how to design a space that maximally enables users. The building enables users to check in, interact with coworkers, book meeting rooms, and regulate environmental settings in order to achieve energy savings and realise the vision for the office of the future.

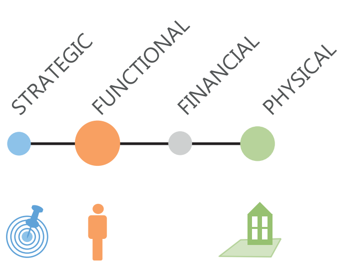
image by Carlo Ratti Associati

Foreseen developments

The building will serve as a testbed for research into the relation between office design and productivity, by analysing building use statistics.

Profile

Why: Objectives

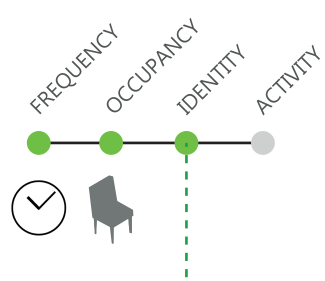


Supporting user activities
Increasing user satisfaction
Reducing CO2 footprint
Stimulating innovation
Stimulating collaboration

Also mentioned: increasing flexibility, supporting image, supporting culture, improving quality of place

Functional goals seem to have priority, by maximally enabling the building's occupants through the use of IoT technology.

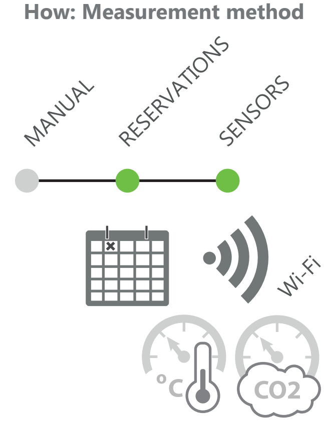
What: Measurement



'The user can interact with the BMS, by downloading an App on his/her smartphone (this enables geolocation). Users have to give their consent to share this data.

The desk or meeting room booked by a building occupant, the occupant's location within the building is determined to adjust the indoor climate to his/her preferences.

How: Measurement method

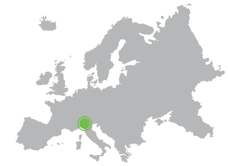


Temperature and CO2 sensors are matched with occupant preferences in order to adjust ventilation and heating settings. Wi-Fi is used for localisation.
Frequency and occupancy data are generated through workplace and meeting room bookings.

AGF **Agnelli Foundation, Carlo Ratti Associati** **Office 3.0**

functionalities
Optimising workplace comfort, room booking, find a workplace

space types
Offices, Meeting rooms



User information (employees)

A building occupant can set his preferred temperature and illumination settings in the app. He/she can also book meeting rooms and co-working spaces and share his/her location within the building.

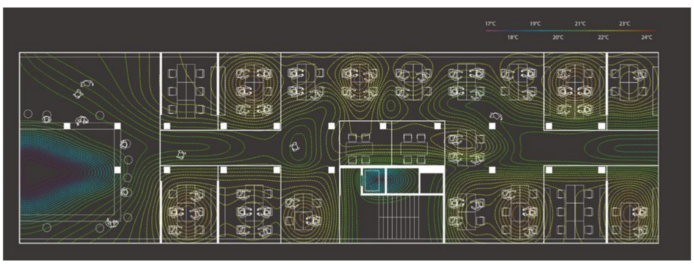
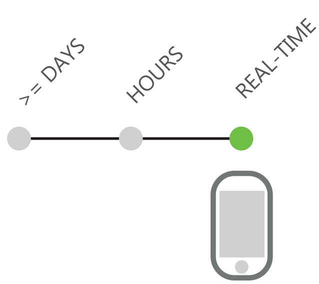


image by Carlo Ratti Associati

Management information

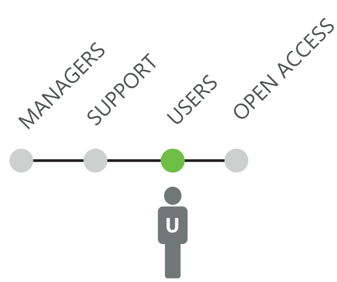
We are not involved on this regard. Siemens and Talent Garden are still discussing on this regard.

Actuality of the information



The information reported in the user app is real-time.

Access levels



Users have access to a smart-phone app.

Benefits

The tool is used for synchronizing energy usage and human occupancy within the building – potentially slashing energy consumption by up to 40%. It is too early to say what the progress is, considering that the building was opened only four months ago.

Side notes

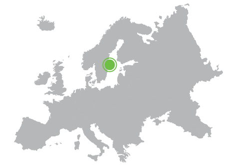
-

ERI **Ericsson** **Flowscape**

phase
Expansion

scale
250.000 m2
5 buildings

duration
?



Project description

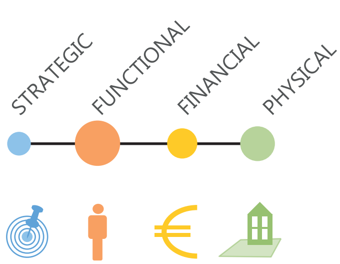
Flowscape started out as an intitiative to provide Ericsson Real Estate more insights on how our premises was used. We later changed the approach to focus on marketing it as a tool to provide the end user a better service to find space when needed. We have looked at different options, both from what sensors to use and also using different system solutions... We finally decided to start with something and as Ericsson is working in the field of IOT we decided to use an application owned and sold by Ericsson as a basis. From sensor perspective we have not limited ourselves to a certain tech.

Foreseen developments

As we get the infrastructure in place our plan is to find more used cases and to improve service delivieries. What to improve specifically has not yet been decided.

Profile

Why: Objectives

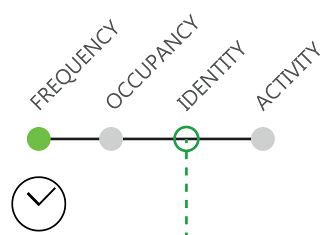


Supporting user activities
Reducing costs
Reducing m2 footprint
Stimulating collaboration

also mentioned: Increasing user satisfaction, increasing flexibility, reducing risks, increasing revenues, reducing CO2 footprint, stimulating innovation, supporting image, supporting culture, improving quality of place

Hopefully all of the mentioned objectives are achieved. Functional objectives have priority.

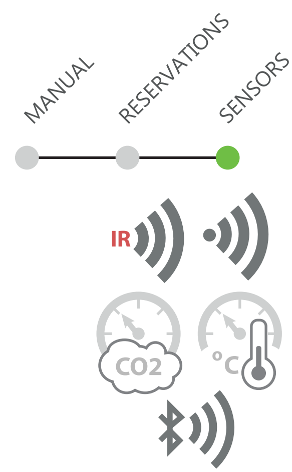
What: Measurement



Indoor positioning is optional. You can choose if you want to use the service or not. If you use it you need to share your info

Currently we know if a room is occupied or not. You are able to use sensors that can detect how many but have not yet used that sensor.

How: Measurement method

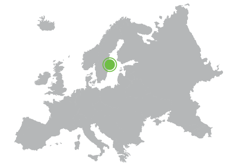


Infrared sensors are used to determine the frequency. Wi-Fi data and beacons are used for indoor positioning.

ERI **Ericsson** **Flowscape**

functionalities
Wayfinding, room booking, find a workplace, monitoring space use

space types
Meeting rooms



User information (employees)

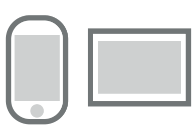
There are different realtime channels, such as an billboard application, a web application and a smartphone application. On these channels the user can view floor plans of the building that display the availability of spaces and book them.

Management information

A lot of realtime data is collected, which can then be transferred for analysis. We are aggregating data into trend analysis. Some reports has been produced but as this is an ongoing work. The development of the analysis will be a continuous work.

Actuality of the information

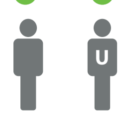
>= DAYS — HOURS — REAL-TIME



The information displayed in the dashboard for employees, in floorplans and reports is (near) real-time.

Access levels

MANAGERS — SUPPORT — USERS — OPEN ACCESS



User have access to user interface. Admin tool can be accessed by operators.

Reporting tool by Real estate and report developer

Benefits

PM

Side notes

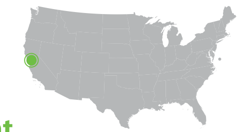
PM

GGL **Google** **'Meeting room Nanny'**

phase **Implementation**

scale **>70 buildings**

duration **2013-present**



Project description

In the 10.000+ meeting rooms in its portfolio Google had a specific problem: that these were being claimed too often for long periods of time. A smart tool was developed to solve this problem. This smart tool is a component of Google's analysis tool, which contains all real estate related data.

Foreseen developments

-

Profile

Why: Objectives

STRATEGIC — FUNCTIONAL — FINANCIAL — PHYSICAL

Supporting user activities

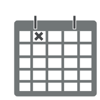
Increasing user satisfaction

What: Measurement

FREQUENCY — OCCUPANCY — IDENTITY — ACTIVITY

How: Measurement method

MANUAL — RESERVATIONS — SENSORS



video conferencing

The objective of the solution is to support user activities – finding out which spaces are needed and making sure that there are meeting spaces available rather than claimed for meetings that will not take place.

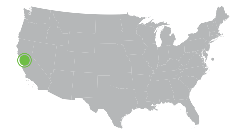
Is a meeting room actually used when it is booked.

The videoconferencing software senses if there are people using the room or not.

GGL   Google   'Meeting room Nanny'

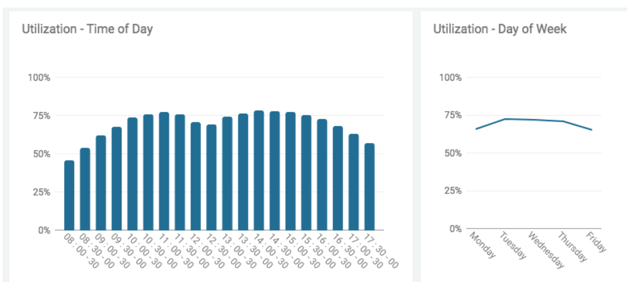
functionalities
Monitoring space use

space types
Meeting rooms



User information (employees)

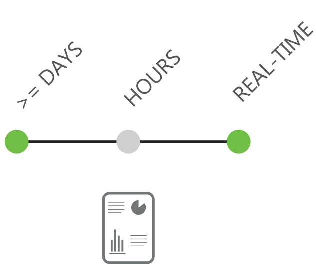
There is no specific user information in the tool - rather the outcomes are periodically shared with employees to show what the impact of claiming space is on the availability of meeting rooms.



Management information

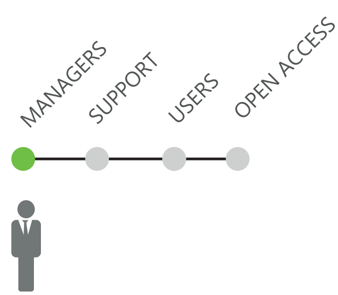
In the tool the campus manager can browse through the portfolio and see which types of meeting rooms are used most frequently (the utilisation rate). Also reports are given on the amount of meetings removed from the calendars of meeting rooms.

Actuality of the information



The data used in reporting goes from real-time to as far back as possible.

Access levels



Reporting tool accessible by real estate management.

Benefits

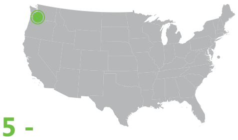
Based on the collected data Google has concluded that it typically builds too many large meeting rooms (8+ people) and that it needs more rooms for 3-8 people.

Also the measurement of actual use is used to remove recurring meetings from calendars: if a recurring meeting has not taken place more than two times it is removed automatically from the calendar.

Side notes

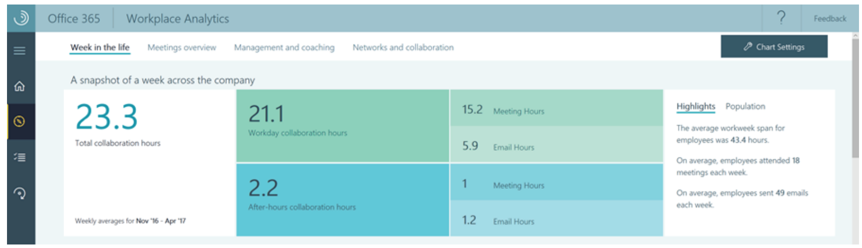
MIC-2 **Microsoft** **Delve / Workplace analytics**

phase **Implementation** — scale **Unknown** — duration **dec. 2015 - present**



Project description

The project was started in order to understand better how networks of people within the organisation work together. Workplace analytics is one of the possible products Microsoft provides in its Office365 suite, which we also apply in our own work environment.



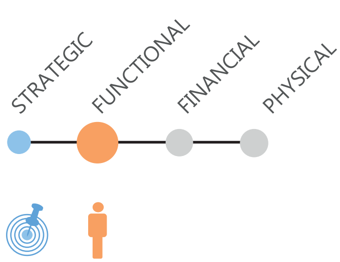
Impression - Workplace analytics dashboard

Foreseen developments

-

Profile

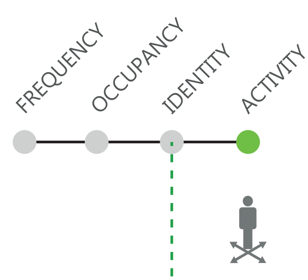
Why: Objectives



Supporting user activities
Increasing user satisfaction
Stimulating innovation
Stimulating collaboration
Supporting culture
Improving quality of place

First priority is supporting our employees.

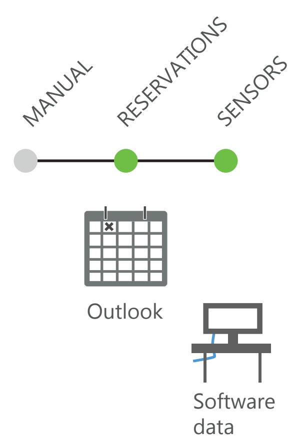
What: Measurement



Customers own their Office 365 data and decide how to apply insights generated by Workplace Analytics to solve tough business challenges. Workplace Analytics only leverages metadata that is aggregated and de-identified.

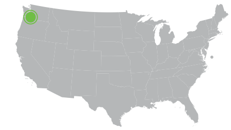
In the tool space use data is not measured, it can be added to the analysis though. What is measured is activity

How: Measurement method



Data from Outlook and Microsoft exchange, showing how people collaborate, how much meetings they schedule, when they are in the office, if they work during their meetings, ...

MIC-2 **Microsoft** **Delve / Workplace Analytics**

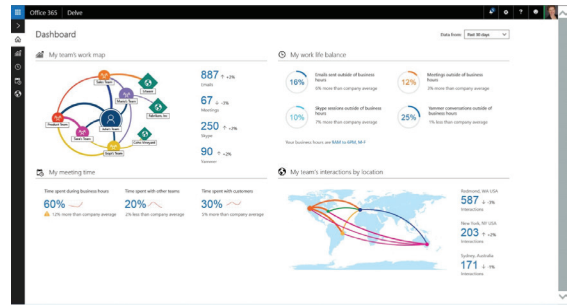


functionalities
Improving employee productivity

space types
Offices, meeting rooms

User information (employees)

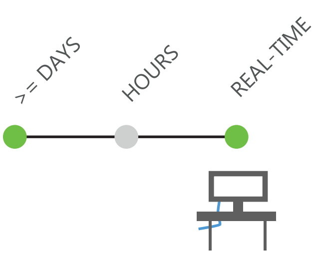
Delve, MyAnalytics / MyAnalytics for teams. Provides insights into data on an individual and team basis in order to maximise productivity
(Mailbox data) Insights into your individual productivity/work habits, in order to help you plan your efficiency.
(Incremental data) Insights into the projects your colleagues are working on, as well as projects that are trending. - anonymous



Management information

Workplace analytics - an organisational view of the aggregated, anonymous data of productivity and how it can be improved. Just like with PowerBI the user has the possibility to generate queries and research relationships between the data.

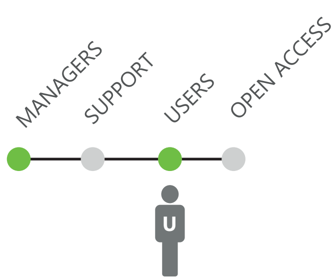
Actuality of the information



The information displayed in the dashboard on the webpage is real-time.

The data used in reporting is on a weekly basis

Access levels



Employees have access to MyAnalytics and MyAnalytics for teams.

Managers have access to Workplace analytics.

Benefits

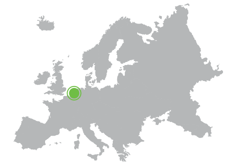
Based on the data we did a rework of our seating arrangement - we put people who work together frequently closer together in the office. Afterwards we found that the amount of collaborations between people increased, but that the amount of time spent per collaboration decreased.

Side notes

The link with the workplace can be made for example by matching the work environment to the amount of hours spent on meetings and e-mail, the meeting spaces can be matched by adjusting the size of the room to the size associated with the highest meeting productivi-ty, etc.

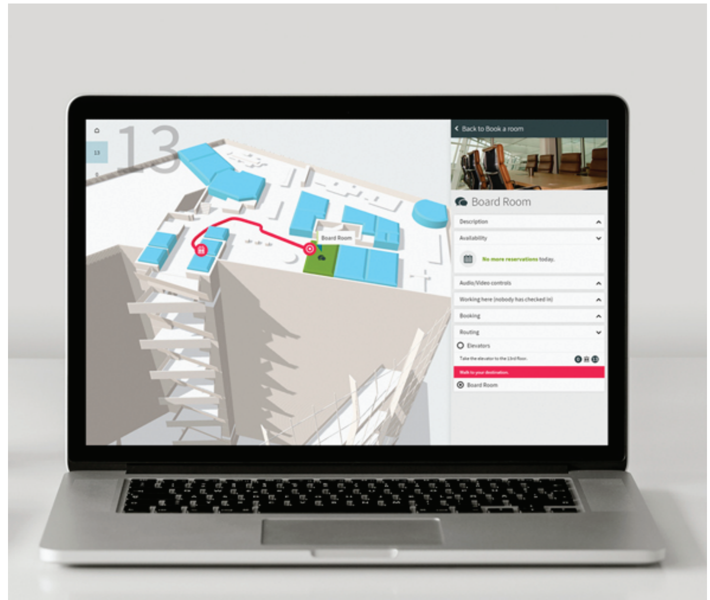
OVG **OVG** **the Edge - Mapiq & Philips**

phase **Implementation** — scale **40.000 m2 1 building** — duration **2014-present**



Project description

The initiative for this development originated from Deloitte's desire to attract talent. The firm saw that it was moving from accountancy into consulting and that in the future it would need to attract highly educated talent. Therefore The Edge was developed as the 'office of the future'. The vision was a building in which everything is connected to the internet (IoT).



Foreseen developments

We continuously look at ways to optimise the building. For instance at the moment we are looking at the operation of our elevators with ThyssenKrupp. Lift movements are very inefficient. It turns out that if you put a sensor in and use it to control the elevator, that it is possible to reduce the energy consumption up to 30 percent and reduce the wear and tear of the elevator.

Another development is the Edge 2.0: we are currently installing iBeacons together with a new, native version of our app to improve localisation in the building.

Profile

Why: Objectives

STRATEGIC FUNCTIONAL FINANCIAL PHYSICAL

Reducing costs

Supporting user activities

Optimising m2 footprint

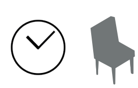
Stimulating innovation

also mentioned: Reducing risks, increasing revenues, increasing user satisfaction, increasing flexibility, reducing CO2 footprint, stimulating collaboration, supporting image, supporting culture, improving quality of place

Reducing costs has priority. The way in which this is realised is via sharing workplaces.

What: Measurement

FREQUENCY OCCUPANCY IDENTITY ACTIVITY



Privacy is addressed by giving everyone a privacy profile page in which they can manage how their data is used for specific functions. For about 90 percent of our systems we do not register information that can be retraced to individuals.

Frequency is measured in the meeting rooms. In the workplaces occupancy per zone is measured via workplace checkin via QR and coded light.

How: Measurement method

MANUAL RESERVATIONS SENSORS

QR-codes

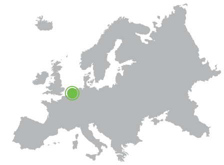
Infrared (passive)

Coded light

RFID (access card)

PIR sensors register activity in a space to determine presence. Coded light works by setting every LED panel to emit light in a slightly different frequency, which enables your smartphone to identify under which LED panel you are located.
The building also has access card data from access gates at the entrance.

OVG **OVG** **the Edge - Mapiq & Philips**

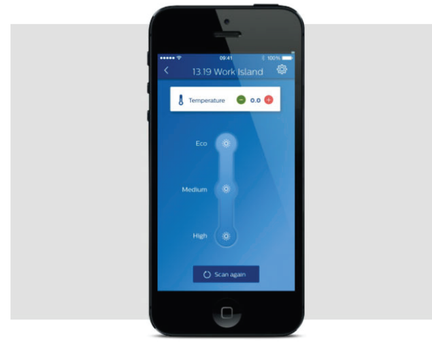


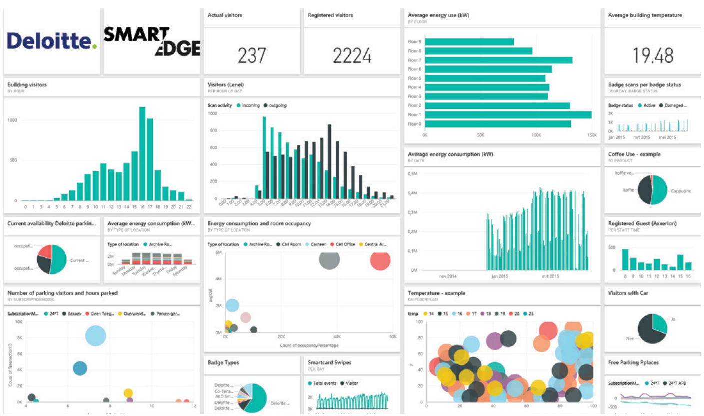
functionalities
Optimising workplace comfort, find a workplace, room booking, wayfinding, monitoring space use

space types
Offices, meeting rooms (whole building)

User information (employees)

The user can use an app to check in at a workplace via QR codes or coded light. The user can use controls for rooms and workplaces to change temperature and light. Also they can see floorplans on which he/she can navigate to a workplace or meeting room.



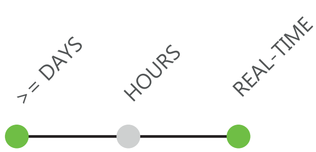


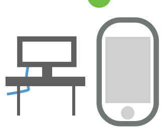
Management information

The manager can access a PowerBI dashboard in which he/she can design elements based on the available data. The dashboard on the left is available to everyone working in the Edge and shows information about the amount of visitors, the use of parking facilities, energy consumption and temperature in the building.

Also there are specific dashboards and reports for building management data and space use of each organisation in the building.

Actuality of the information

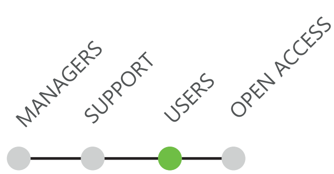




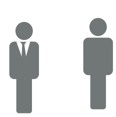
The information in the dashboard (webpage) and user app is displayed real-time

The data used in reporting goes from real-time to as far back as possible.

Access levels



Employees have access to the user app and a dashboard showing building information



Specific individuals (5-6) have access to specific dashboards and reports for building management.

Benefits

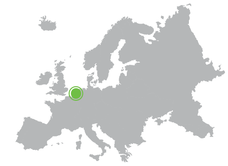
There were no objectives defined prior to the project. We do measure some metrics though. For instance Deloitte knows that since the delivery of the building the amount of job applications has increased significantly. Also, 65% of those applicants state in their applications that they want to work in the Edge! Also, further proof that suggest that smart buildings work is that at the start Deloitte had 1800 employees using 1000 desks, and now they have around 3400 people working in the Edge - and only 100 desks have been added.

Side notes

Localisation for the colleague finder turned out to be very difficult technically. QR codes do not work well enough, because people do not always use them: you can occupy a workplace without scanning the QR code. iBeacons with a user app is the best solution.

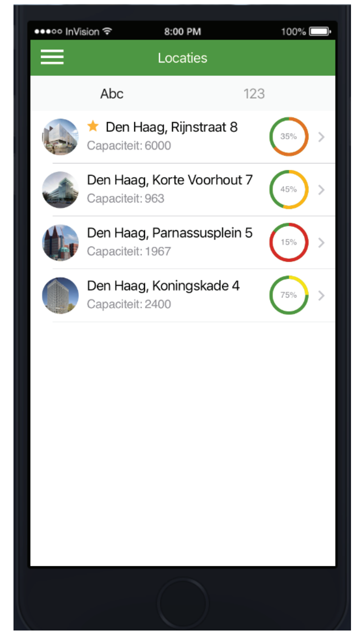
NLG-1 — **Dutch government** — **Plekchecker**

phase **Implementation** — scale **80.000 m2 1 building** — duration **July 2017-present**



Project description

The initiative was started because of the implementation of the I-strategy of the government, the governmental accommodation system and the furbishing of the office at the Rijnstraat. In that building the norm will be 0,7 workplace per 1 employee. The development of the smart tool was started to help users find a workplace. First this was done within the organisation, but later an external party was added. The Plekchecker is foremost developed by the government and partly by an external party.

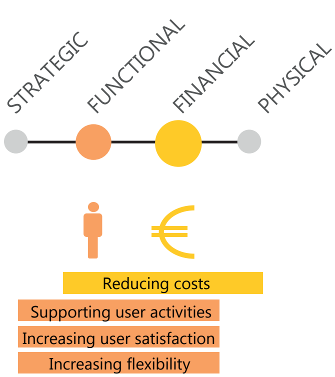


Foreseen developments

The foreseen developments are (1) complying with all our requirements; (2) expanding to more buildings; (3) determining if investment is needed in current and future wishes with regard to the smart tool.

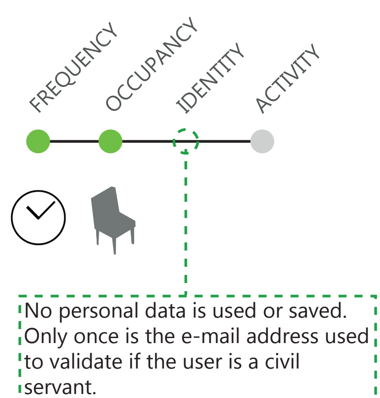
Profile

Why: Objectives



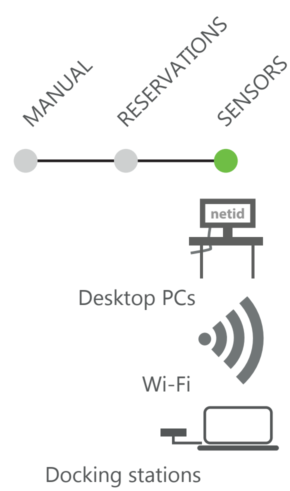
Financial objectives have priority, they are achieved by reducing the amount of offices and using the existing space more effectively.

What: Measurement



Via the Wi-Fi network an indication is given of the occupancy on floor-level. On zone level the data of port replicators and desktop PCs is used.

How: Measurement method

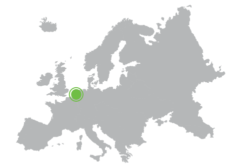


Wi-Fi measures the amount of devices inside a building that tries to connect with the network. Via desktop PCs and port replicators/docking stations the use of these devices can be detected, and thereby the frequency.

NLG-1 — **Dutch government** — **Plekchecker**

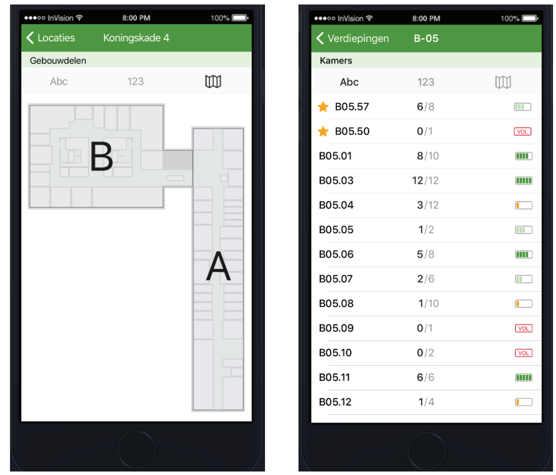
functionalities
Find a workplace, monitoring space use

space types
Whole building



User information (employees)

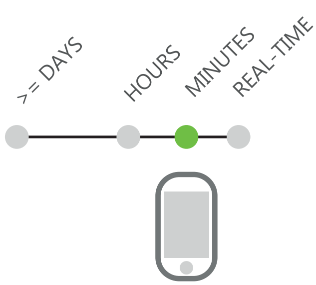
The user sees a list with buildings, in which it it possible to click further to lists of floors and defined zones per floor. Per floor an indication of the occupancy is visible. There are also floor plans available, but they are still separated from the real-time data.



Management information

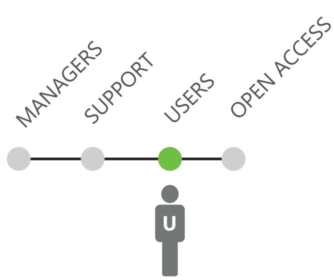
The occupancy reports based on the collected Plekchecker data has not been developed yet. At the moment there are talks with facility services providers about the form of these reports. This functionality will then be developed in a separate development process.

Actuality of the information



The information is updated every few minutes (ca. 3 minutes) in the Plekchecker.

Access levels



Employees that are serviced by the government's ICT shared service centre.

At the moment we are exploring how to shape different roles in the tool.

Benefits

In the business case a calculation has been made of the time that a civil servant spends on finding a workplace to indicate the potential savings. It is not possible to report on that yet - in the future the savings will be in the adjustment of spaces with low utilisation or in adjusting the way we work (e.g. spreading meetings over the week).

Side notes

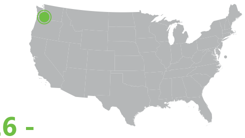
Wi-Fi makes it possible to show the occupancy within 5-10 meters. With algorithms this information is displayed in zones, with a reliability of 90 percent. That determines the size of the zone, which in some cases can become too large to offer the users the level of detail they desire.

MIC-1 Microsoft Smart building app

phase **Pilot**

scale **80.000 m2 4 buildings**

duration **jan. 2016 - present**

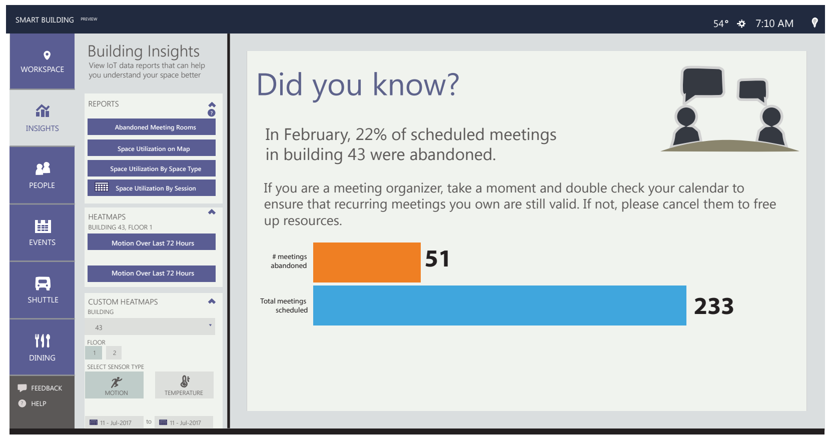


Project description

The initiative was taken more from a hypothesis if it was possible to create an application with the stated functionalities based on our expertise at Microsoft. Initially we looked at more traditional ways of measuring space use, such as PIR sensors underneath desks, but we concluded that the return on investment was not high enough. Therefore we used data from existing infrastructures.

Foreseen developments

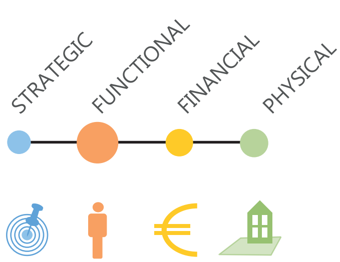
If we can get the right return on investment, we would like to develop an app that displays the data, making the tool more user-friendly



Impression - Smarter buildings dashboard on digital signage at Microsoft

Profile

Why: Objectives



Supporting user activities

Managing costs

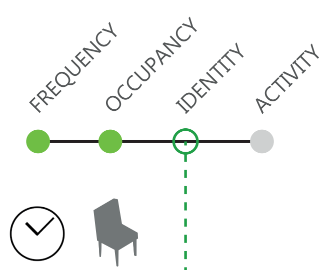
Optimising m2 footprint

Stimulating innovation

also mentioned: increasing user satisfaction, increasing flexibility, supporting culture, improving quality of place

First priority is supporting our employees, then the efficient management of assets. The third priority is to showcase our technology as Microsoft.

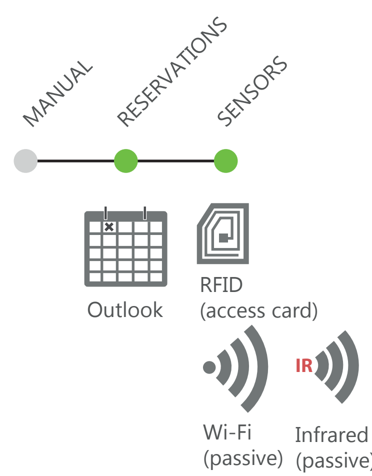
What: Measurement



Microsoft has a very strict privacy policy, so we make sure that anonymisation happens correctly. Anonymisation happens directly after registration of a device.

We measure the peak average utilisation, which is a metric that shows the average utilisation during a predefined peak period of the week (Tuesday- Thursday, 9AM-5PM). For meeting rooms, scheduled use and # of people are compared with actual use.

How: Measurement method

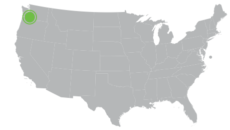


Access card data shows the amount of people in the building; Wi-Fi data shows the location of devices; PIR sensors measure if a meeting room is in use. Outlook data is used for meeting rooms

MIC-1 **Microsoft** **Smart building app**

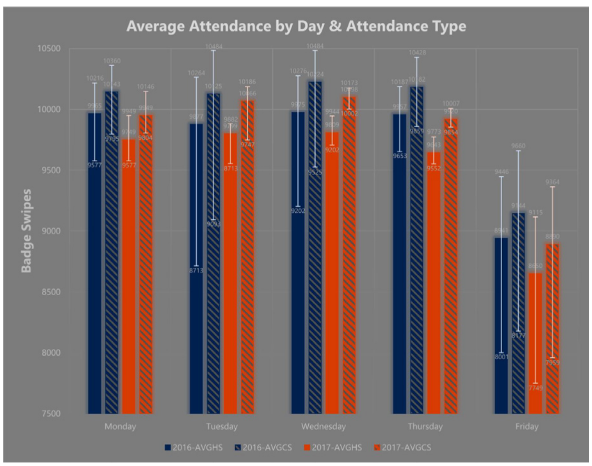
functionalities
Find a workplace, Room booking

space types
Offices, meeting rooms



User information (employees)

The user can see a floor plan in which the availability of desks (in zones) and meeting rooms are indicated in green and red. When zooming in, information about the temperature and noise levels are also given to help the user select a workplace that fits his/her needs



Management information

The dashboard shows numerous forms of data for buildings over a period of time. Per building information is shown of the people assigned to that building over time, which is compared to the use of each building. Microsoft uses its own platform - PowerBI - in which the data from the different sources is collected and where it can be combined and aggregated in any way possible.

The image shows an example of a report of the average attendance based on badge swipes.

Actuality of the information

>= DAYS — HOURS — REAL-TIME

The information displayed in the dashboard on the displays is real-time.

The data used in reporting goes from real-time to as far back as possible.

Access levels

MANAGERS — SUPPORT — USERS — OPEN ACCESS

The employees can access the user dashboard.

The dashboard and reporting functions are available to the RE&FM team.

Benefits

In the offices we measure a peak utilisation rate of 85 percent. Keep in mind that not always this is the best measure of the value of a space. Our games room for instance only has an occupancy rate of 30 percent during the day, but according to employees the effectiveness when it is used is very high.

Side notes

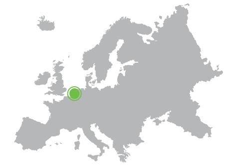
Some experiments have been done with Raspberry Pi computers with occupancy, temperature and noise sensors attached to them.

EMC Erasmus MC programme of requirements

phase
Design brief

scale
13.000 m2
1 building

duration
foreseen
Q1 2018



Project description

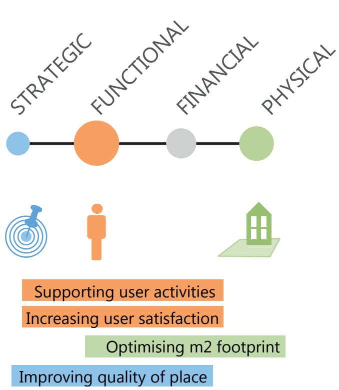
EMC is about to change their office workplace concept to be able to accommodate more employees in the building. About 20% more people will use this building in the future due to the demolition of their current offices. Implementing the new workplace concept is met with resistance of the end users. In order to address this problem EMC is thinking of a solution that gives users insight into the occupancy of workplaces, helping them to find workplaces, as well as to monitor the occupancy of the office in order to determine if extra space is needed or not. Functionalities might be added to further support users.

Foreseen developments

-

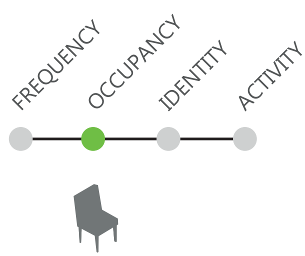
Profile

Why: Objectives



Supporting users has priority.

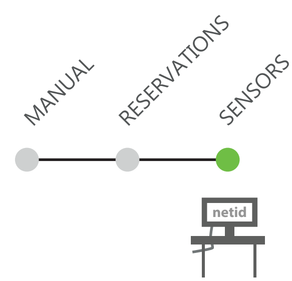
What: Measurement



(intended)

The use of a desktop PC is measured per workplace.

How: Measurement method



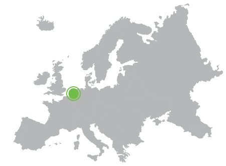
Desktop PCs
(intended)

The ICT department has a system in which all desktop PCs are monitored - this system usually contains a registration of the amount of PCs, their location and their current activity. This activity (login by users) can be monitored to derive the occupancy of offices.

EMC **Erasmus MC** **programme of requirements**

functionalities
Find a workplace, monitoring space use

space types
Offices, Meeting rooms



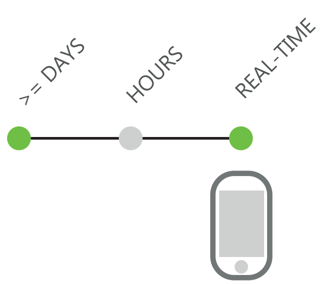
User information (employees)

The user receives access to a dashboard that displays the workplaces in the building and whether the workplaces are available.

Management information

The real estate department needs access to data on the space use of the office environment and meeting rooms during the day for offices, floors and the whole building in order to make appropriate decisions.

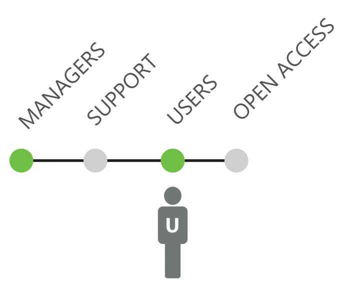
Actuality of the information



The user interface needs to display near real-time data in order to provide actionable information.

The reporting tool must include both real-time and historical data.

Access levels



Users have access to user interface.

Reporting tool accessible by real estate management.

Benefits

EMC has set an occupancy of 60-75 percent of each workplace as objective. If the occupancy is lower, a department can be accommodated more efficiently. If the occupancy is higher, a department needs more workplaces.

Side notes

PM - no experience yet.

4.3. Cross-case analysis

In this chapter a number of insights are drawn up based on the data collected in the cases, which are shown in the previous chapter.

Similar solutions, but different reasons for initiation

At the surveyed organisations the solutions seem relatively similar in the sense that they measure space use to support users and optimise space use (with the exception of Delve at Microsoft), and in some cases also to save energy. However the interviewees have stated different reasons for initiating their smart tools, and solutions differ slightly in if they focus on workplaces, meeting rooms, or both.

ABN AMRO mentions the desire to get insight into hidden vacancy in order to optimise their space use. Ericsson provides a similar explanation, giving the demand for more insight into the use of their premises as reason to initiate the project. Interestingly ABN AMRO started with gaining insight into the use of their office workplaces, whilst Ericsson started with insight into the use of their meeting rooms.

The Dutch government gives a more layered explanation: their project was started for both strategic reasons and practical reasons. On the one hand they were implementing a new strategy and accommodation system, whilst on the other hand one of their office buildings was being refurbished. Their smart tool gives insight into the occupancy of their workplaces (in zones). The Erasmus Medical Centre has a similar problem: they are changing their workplace concept, for which they require a solution that helps users find available workplaces and determine if extra space is needed.

Problems Solutions	Management of scarce resources	How to help employees find available spaces in new office concept	Energy waste in buildings, how to enable users	How to attract future talent to the organisation	Over-claiming of meeting rooms	Is it possible to create an application based on in-house expertise	Understand-ing how networks of people collaborate
Smart tool that shows real time occupancy within office buildings	ABN Amro	Dutch government, Erasmus MC					
Smart tool that allows users to check in and regulate environmental settings			Agnelli Foundation	OVG			
Smart tool that shows availability of meeting rooms	Ericsson						
Smart tool that monitors meeting room use and removes unused reservations					Google		
Smart tool that monitors meeting room use and building use						Microsoft - Smart building app	
Smart tool that monitors software use to understand collaboration patterns							Microsoft - Delve

Table 4.2 – Different problem-solution relationships across cases

At Microsoft the initiative to build the smart building app was taken to find out if such a solution could be developed by the company itself based on their expertise, but also as part of a change from individual workplaces to shared workplace concepts. Microsoft looks at space use in both workplaces and meeting rooms. Google has also developed their own solution to solve a very practical problem: that meeting rooms were being claimed too often. Their tool is thus aimed at improving the space use of meeting rooms. Carlo Ratti Associati name both sustainability and wanting to support users as reasons for initiation of the Office 3.0 project. This has led to a solution that is aimed at optimising workplace comfort, but also enables booking workplaces or meeting rooms. OVG states that the reason for realising the Edge is Deloitte's desire to attract talent, from which a vision developed to realise the office of the future.

The cases reveal that the primary reasons named for initiation of smart tools (or smart buildings) are a demand to gain insight into the space use and a need to inform users in case of a transition to shared workplace concepts. Other reasons that are named are wanting to reduce energy consumption and to attract talent.

Project status shows organisations are further along

When looking at a timeline of the smart tools surveyed at organisations it immediately becomes apparent that organisations are further along than international universities. Four of the nine surveyed tools were already in use before the start of 2017, and a large majority of the applications are in an implementation stage. Another two have been implemented this year. Only one of the nine cases is in a design brief stage. The implementation period of Flowscape at Ericsson and Delve at Microsoft are unknown.

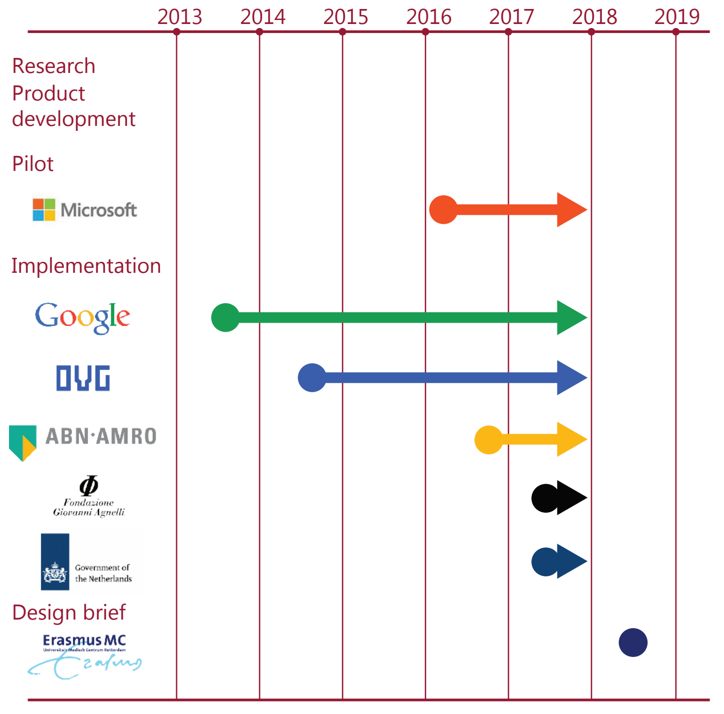


Figure 4.2 – Timeline of smart tools. The implementation period of Flowscape at Ericsson and Delve at Microsoft are unknown.

Foreseen developments – developing user apps

Further reflecting the actuality of the subject matter is that almost all cases mention foreseen developments for their smart tools. Only the cases of the meeting room nanny at Google and Delve at Microsoft do not mention foreseen developments.

An often-mentioned, foreseen development is the development of a user app. At ABN AMRO and Microsoft the information on workplace availability is currently viewable on displays in their office buildings. The Edge offers an app, but it is web-based and is being developed towards a native app.

Another foreseen development is using the data for research or further optimisation. Carlo Ratti Associati mention using the Agnelli Foundation headquarters building as a testbed for research into the relationship between office design and productivity. Similarly, OVG is continuously looking at ways to further optimise the Edge: an example is given of their current work into optimising the use of their elevators.

Similar to the universities, adding additional functionalities is mentioned in some cases. The Dutch government, ABN AMRO and Ericsson all state that additional functionalities might be added. ABN AMRO wants to get insight into the frequency and occupancy rates of meeting rooms. The Dutch government and Ericsson do not specify what functionalities they would like, but that they will determine which additional functionalities are desired and if they will invest in them.

Costs – difficulty to obtain comparative data

With regard to investment and operating costs it was not possible to gain data in all available cases. Because of this and the request of some cases to treat the information anonymously, the information has been omitted from the case data reported in the previous chapter. Instead, an anonymised comparison is given across all cases (chapter 3, 4 and 5) in chapter 6.

Benefits are mostly assessed in terms of increased space use

During the data collection process it was decided to add a question to the templates, being: "What objectives are defined to be achieved with the tool, and what is the progress on these objectives since implementing the tool?" This question was added to gain insight into the key metric(s) which organisations report on in order to assess to what extent their smart tools are successful.

Because the question was added later, data was collected for 7 out of 9 cases.

At ABN AMRO the mentioned benefits relate to the use of the information generated with the smart tool to make smarter decisions. It helps to determine the accommodation strategy, to reduce investment costs for extra accommodation and to advise building users.

The interviewee at Microsoft was not specifically asked this question, but some data was collected. With its smart building app Microsoft measures the peak utilisation rate of its office workplaces, which is defined as the utilisation on Tuesdays, Wednesdays and Thursdays between 9AM and 5PM. This is around 85 percent. However, if the objective with the smart tool was to increase the peak utilisation rate and by how much it has increased is unknown. The data from Delve is collected to gain insight into how networks of people work together. The data has been used to rework an office environment, putting people who collaborated often close to each other. Afterwards it was found that the amount of collaborations between people increased, but that the time spent collaborating decreased. However, if this was the objective prior to the application of

Delve is not known. Similarly it is noted that the data collected on meeting productivity, based on employee activity on their laptops during meetings, can be used to redesign meeting room environments.

At the Agnelli Foundation Headquarters the energy savings potential of synchronising energy usage to human occupancy is estimated to be up to 40 percent, but because the building has only opened a few months ago it is too soon to say what the energy savings will be.

At the Erasmus Medical Centre the use of the smart tool will help to monitor workplace occupancy. The target set is a workplace occupancy of 60-75 percent. If the percentage is lower, the accommodation can be made more efficient. If it is higher, the department needs more space.

At Google the Meeting room nanny was developed to increase the actual frequency and occupancy rates of the meeting rooms. Based on the data Google has concluded that its meeting rooms are too large – it needs more meeting rooms for groups of 3-8 people and less meeting rooms for larger groups. The tool also automatically removes regularly scheduled meetings that do not take place. Thus there is evidence that the tool works, although exact figures are not provided.

At the Edge no specific objectives were defined prior to the implementation of the building. However, Deloitte does know that since the opening of the building the amount of job applications has increased significantly. Of those applicants 65% state that they want to work in the Edge. This data suggests that the building contributes to attracting (and retaining) talent. Furthermore evidence is provided that space use can be optimised: the amount of Deloitte employees working in the Edge has increased from 1800 to 3400, whilst the amount desks has only increased by 100. Of course there are other variables can influence this ratio – for instance the amount of part-time employees or the time employees spend working at their clients' offices.

The Dutch government has calculated the savings in time spent on searching a workplace in their business case. This will be difficult to monitor, though. In the future savings will be on adjusting spaces with low utilisation or adjusting the way we work (spreading activities over the week).

The data that is collected shows a very diverse picture. In almost all cases some form of data is collected to assess the benefits, mostly relating to frequency and occupancy rates of meeting rooms and workplaces. In some cases there is a clear objective stated prior to implementation, in others there is not. In some cases quantitative data is provided as evidence, whilst in others the conclusions that are taken based on the data are shared.

Objectives are primarily functional

The interviewees were asked to state to which objectives their smart tools or intended smart tools contributed. For this question the framework developed by Den Heijer et al. (see chapter 1) was used: this framework states the objectives through which the campus adds value to the university. The results are displayed in figure 4.3.

The documented smart tools are all aimed at functional objectives such as supporting user activities and increasing user satisfaction, and in most of the cases functional objectives have priority. In addition most cases indicate that their smart tool adds value to the organisation through strategic objectives, e.g. stimulating innovation or supporting culture. Financial and physical objectives are mentioned often, but only two out of nine cases indicate that these objectives have priority.

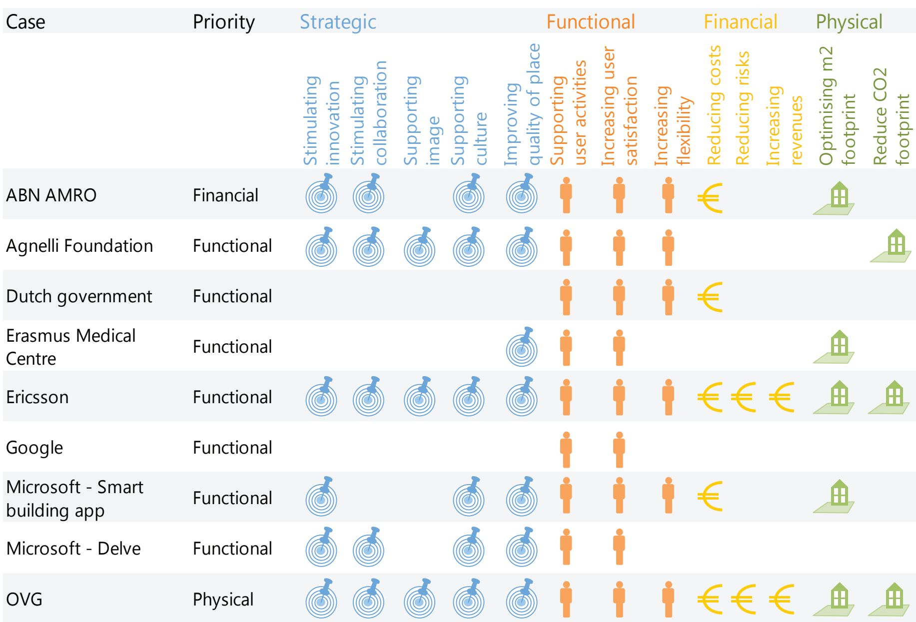


Figure 4.3 – Cases and the amount of objectives they contribute to per category.

Focus on frequency and occupancy levels in measuring space use

Typically space use is measured in terms of frequency in meeting rooms and occupancy in workplaces. Cases in which both frequency and occupancy are measured thus provide real-time data for both offices and meeting rooms. The only case that collects data on activity is Delve, though the data is employee-centred rather than space use-centred. This means that an employee can use the data to determine how much time he/she spent in meetings, but it is not used to determine the use of a certain meeting room in the office.

There are some slight nuances to be made. Most of the frequency and occupancy data is based on sensors. Agnelli Foundation uses reservation data to determine frequency and occupancy: employees check-in to use a workplace or a meeting room. Google measures only frequency via its sensing technology, however it can determine the scheduled frequency and occupancy rates via its room booking system.

Case	Privacy	Frequency	Occupancy	Identity	Activity
ABN AMRO	With Wi-Fi personal data is collected. Lone Rooftop deals with this issue by anonymizing its data differently every day and by anonimizing it directly after data collection		✓		
Agnelli Foundation	The user can interact with the BMS, by downloading an App on his/her smartphone (this enables geolocation). Users have to give their consent to share this data.	✓	✓		
Dutch government	No personal data is used or saved. Only once is the e-mail address used to validate if the user is a civil servant.	✓	✓		
Erasmus Medical Centre	Not applicable		✓		
Ericsson	Indoor positioning (for wayfinding) is optional. Users can select if they want to use the service or not, for which they need to share information.	✓			
Google	Not applicable	✓			
Microsoft - Smart building app	Anonymisation happens directly after registration of a device.	✓	✓		
Microsoft - Delve	Users own their own data and can decide how to apply the insights generated by Workplace analytics. Workplace analytics only leverages metadata that is aggregated and anonymised.				✓
OVG	Users have a privacy profile page in which they can manage how their personal data is used for specific functions.	✓	✓		

Figure 4.4 – Cases and the ways in which they measure space use. If applicable, privacy issues are addressed.

Privacy is dealt with in different ways:

- Personal data ownership, where users decide how to share their data (Microsoft Delve, OVG)
- The opt-in principle, where users agree to share their data in order to make use of the service (see Agnelli Foundation, Ericsson)
- Direct anonymization, where the organisation anonymises the data after collection and prior to analysing the data (see ABN AMRO, Microsoft)

Measurement methods: smart tools with multiple sensors

Many different measurement methods are used in the cases. This is specified in figure 4.5, where the measurement method is specified in terms of what type of sensor is used and what the specific application is. Furthermore sensors that do not measure space use are mentioned such as temperature and CO2 sensors.

The first important finding is that the use of multiple sensing methods is quite popular amongst organisations – 5 out of 9 cases use multiple sensing methods. Usually these cases include not only sensors that measure space use, but also space properties like temperature and CO2 concentration.

Secondly 4 out of 9 cases make use of data from reservation systems to assess their space use. Google and Microsoft use this data to optimise the use of their meeting rooms. In the Agnelli Foundation HQ and the Edge users check-in to workplaces or meeting rooms: data that is used to monitor space use as well.

Thirdly there is a distinction in the way Wi-Fi is used in different cases. ABN AMRO and the Dutch government use Wi-Fi data to determine occupancy in zones of their buildings. In order to do this data on device connections and/or connection attempts can be used. Agnelli Foundation, Ericsson, and Microsoft use Wi-Fi to determine the location of users inside the building for wayfinding purposes. In order to do this data on connection attempts are needed.

Finally, both Agnelli Foundation HQ and The Edge offer its users the ability to personalise the indoor climate, which is why they have integrated CO2 and temperature sensors in their solution.

Figure 4.5 – Cases and the sensors they use to measure space use (or other space properties).
(see next page)

Case	Measurement method	Manual	Reservations	Sensors	Sensor application
ABN AMRO	The amount of people is measured. First, the devices are counted, both actively via connections and passively via connection attempts, on a certain time in a certain place. This measurement is processed by an algorithm that pairs devices that belong to one person			Wi-Fi	Connections, connection attempts
Agnelli Foundation	Temperature and CO2 sensors are matched with occupant preferences in order to adjust ventilation and heating settings. Wi-Fi is used for localisation. Frequency and occupancy data are generated through workplace and meeting room bookings.		Reservations: check-in by employees	Wi-Fi, CO2, temperature	Connection attempts
Dutch government	Wi-Fi measures the amount of devices inside a building that tries to connect with the network. Via desktop PCs and port replicators /docking stations the use of these devices can be detected, and thereby the frequency.			Wi-Fi, PC login	Wi-Fi: connection attempts. PC login: desktop and docking stations
Erasmus Medical Centre	The ICT department has a system in which all desktop PCs are monitored - this system usually contains a registration of the amount of PCs, their location and their current activity. This activity (login by users) can be monitored to derive the occupancy of offices.			PC login	Desktop PCs
Ericsson	Infrared sensors are used to determine the frequency. Wi-Fi data and beacons are used for indoor positioning.			Wi-Fi, Bluetooth, Infrared, CO2, temperature	Bluetooth: iBeacons. Wi-Fi: Connection attempts. IR: meeting room sensors
Google	The videoconferencing software senses if there are people using the room or not.		Calendar data	Cameras	Videoconferencing system
Microsoft - Smart building app	Access card data shows the amount of people in the building; Wi-Fi data shows the location of devices; PIR sensors measure if a meeting room is in use. Outlook data is used for meeting rooms		Outlook data	Wi-Fi, Infrared, RFID	Wi-Fi: connection attempts; IR: meeting room sensors. RFID: access card data
Microsoft - Delve	Data from Outlook and Microsoft exchange, showing how people collaborate, how much meetings they schedule, when they are in the office, if they work during their meetings, ...		Outlook data	Software data	
OVG	PIR sensors register activity in a space to determine presence. Coded light works by setting every LED panel to emit light in a slightly different frequency, which enables your smartphone to identify under which LED panel you are located. The building also has access card data from access gates at the entrance.		Reservations: check-in by employees via QR and coded light	Infrared, RFID, temperature, CO2	IR: meeting room sensors. RFID: access card data

Actuality of information: difference in provision of user information, similar requirements for management information.

With regard to the information generated by the smart tool the actuality of the user information and management information was also one of the properties asked. With regard to the user information all cases deliver or desire real-time data. The Dutch government interviewee has further specified their update frequency, which is 3 minutes. Most user information is provided via apps, but also in some cases displays or webpages are used.

Management information shows a much more unilateral picture, with almost all cases specifying that the data can be aggregated over the desired time period. In some cases no specification is given because this aspect is still in development.

Case	User information	Management information
ABN AMRO	The information displayed on floorplans for employees is near real time.	The information in floorplans and reports is (near) real-time. The data used in reporting goes from real-time to as far back as possible.
Agnelli Foundation	The information reported in the user app is real-time.	in development
Dutch government	The information is updated every few minutes (ca. 3 minutes) in the Plekchecker.	in development
Erasmus Medical Centre	The user interface needs to display near real-time data in order to provide actionable information.	The reporting tool must include both real-time and historical data.
Ericsson	The information displayed in the dashboard for employees, in floorplans and reports is (near) real-time.	in development
Google	-	The data used in reporting goes from real-time to as far back as possible.
Microsoft - Smart building app	The information displayed in the dashboard is real-time.	The data used in reporting goes from real-time to as far back as possible.
Microsoft - Delve	The information displayed in the dashboard is real-time.	The data used in reporting is on a weekly basis
OVG	The information in the dashboard and user app is displayed real-time	The data used in reporting goes from real-time to as far back as possible.

Figure 4.6 – Cases and actuality of the information reported

Access levels

Finally, the access levels within the use of the smart tools have been collected. All tools make a distinction in information available to users and managers. In a few cases supporting staff (e.g. business intelligence, report developers or IT) have access to the reporting tools next to campus managers. No cases are found where user information is accessible to everyone –it is restricted to employees.

Case	Specification	Managers	Support	Users	Open access
ABN AMRO	The Avex screens display information on real-time availability of workplaces that can be accessed by all employees. The dashboard and reporting functions are available to the BI department and account managers.	●	●	●	
Agnelli Foundation	Users have access to a smartphone app.			●	
Dutch government	Employees that are serviced by the government's ICT shared service centre have access to user information; At the moment we are exploring how to shape different roles in the tool.			●	
Erasmus Medical Centre	User have access to user interface; Reporting tool accessible by real estate management.	●		●	
Ericsson	User have access to user interface. Admin tool can be accessed by operators.Reporting tool by Real estate and report developer	●	●	●	
Google	Reporting tool accessible by real estate management.	●			
Microsoft - Smart building app	The employees can access the user dashboard. The dashboard and reporting functions are available to the RE&FM team.	●			
Microsoft - Delve	Employees have access to MyAnalytics and MyAnalytics for teams. Managers have access to Workplace analytics.	●		●	
OVG	Employees have access to the user app and a dashboard showing building information. Specific individuals (5-6) have access to specific dashboards and reports for building management	●	●	●	

Figure 4.7 – Cases and access levels

4.4. Additional: Analysing pedestrian flows

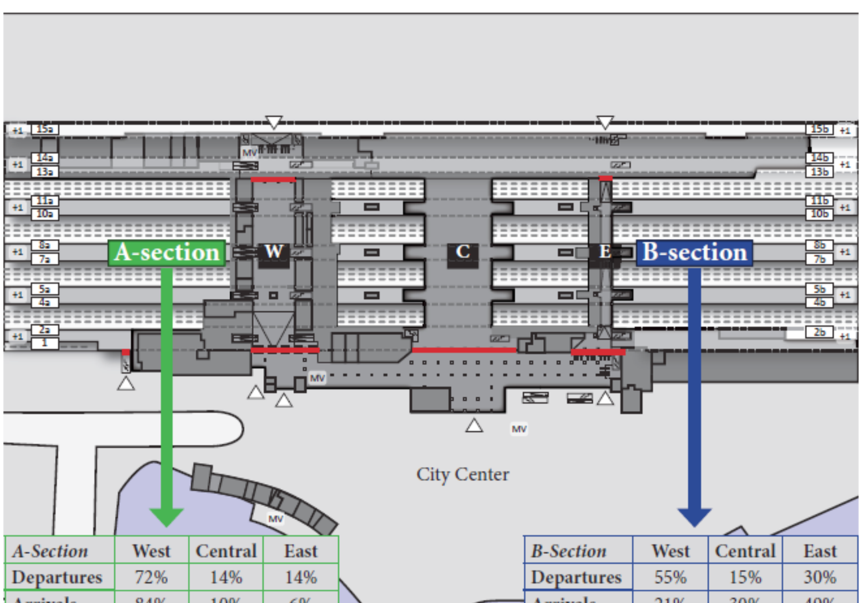
A sub-question within the use of smart tools at other organisations is how organisations use the measurement of user flows to inform their users and management. In the first year of research numerous Dutch universities expressed an interest in monitoring user flows (LEI, EUR, UVT). Erasmus University has indicated that insight into pedestrian flows during the day could help campus management to make informed decisions about the opening hours of buildings. Leiden University has also expressed interest in knowing the flows of people within buildings and in between buildings for emergency response and other safety reasons. Tilburg University mentioned that the data can be used to inform decision making on the access of buildings: how to design routes, where to locate bicycle parking places, etc. but that it does not have to be monitored consistently.

Train stations

At Netherlands Railways (NS) information on pedestrian flows is used to set capacities for escalators and stairs and to position services within the station correctly (van den Heuvel & Hoogenraad, 2014).

Information on pedestrian flows is collected in three different ways:

1. The Station Transfer Model (Van den Heuvel, Dekkers, & De Vos, 2012). The station transfer model estimates pedestrian flows using data from ticket sales, which is refined by doing surveys in trains and counting in- and outgoing passengers on platforms. This data is available for all stations.
2. The SMART Station (Daamen, Van den Heuvel, Ton, & Hoogendoorn, 2015) measures pedestrian flows by using Wi-Fi and Bluetooth data in the station. This is used in a few large, complex stations with continuous operational challenges (Van den Heuvel et al. 2014).
3. The Station Transfer Monitor (van den Heuvel & Hoogenraad, 2014). The Station Transfer Monitor estimates pedestrian flows using data from automatic fare collection (AFC) data enriched with spatial characteristics of train stations, such as the location of smart card validators.



A-Section	West	Central	East
Departures	72%	14%	14%
Arrivals	84%	10%	6%

B-Section	West	Central	East
Departures	55%	15%	30%
Arrivals	21%	30%	49%

Figure 4.8 Route choices for departing and arriving passengers for the A- and B- platform sections at Amsterdam Central Station (van den Heuvel & Hoogenraad, 2014).

The information on pedestrian flows is used to:

- Estimate which platforms within a station are used most frequently (1). Using data from the Station Transfer Model the amount of passengers arriving and departing from each platform in a station can be estimated. This data can be used to determine the profitability of retail locations.
- Estimate which access routes to platforms perform at capacity (1). Using data from the Station Transfer Model the amount of passengers arriving and departing from each platform in a station can be estimated. This data can be used to determine if the amount of stairs, escalators and elevators is sufficient.
- To determine the impact of congestion from platform to station on the route choice of arriving passengers (2). Using Wi-Fi and Bluetooth data at Utrecht Central station a study showed that when a delay is around 45 seconds, around half of the people take the non-congested route. Under normal circumstances this is only ten percent.
- To study what route choice departing passengers make to access platforms (2). Using Wi-Fi and Bluetooth data at Utrecht Central Station a study showed that three factors influence the route choice of passengers: the time a route takes, the orientation of the access route (favouring access routes that require them to take a right turn) and the location of the departing train on the platform.
- Detect which platforms have long check-out times, which indicates congestion (3); The STM yields estimations of the time it takes passengers arriving on a platform to check-out of the station. This can be used to adjust train operations, station operations and even the station layout.
- Assess the impact of schedule changes on the waiting time of passengers (3). The STM yields estimations of the number of passengers affected by a scheduling change, which can be used in planning decisions or in adjustments to make longer waiting times more convenient;
- Assess which routes passengers take to access the platforms (3). The STM can be used to analyse the use of different access routes in a station (if such a situation exists). At Amsterdam Central Station the results impacted the major overhaul planned for the station.

Airports

At various airports information on passenger flows is used. Surprisingly not much scientific literature is found on the use of sensing technology to observe pedestrian flows in airports. Schauer, Werner, and Marcus (2014) mention the potential to use information on current pedestrian flows in airports to reduce travel time and management costs. By knowing where passengers are within the airport or what the expected business will be, additional doors, ticket shops or control gates can be opened or closed. They also mention the use of this information for commercial purposes and to inform people. (Ma, 2012, p. 71) further mentions that simulation of passenger flows can help to analyse existing performance levels, to plan resourcing requirements for a future flight schedule or to assist in planning changes prior to implementation.

Information from four different sources has been collected.

- At Munich Airport Schauer et al. (2014) evaluate the estimations of pedestrian flow of different Wi-Fi and Bluetooth measurement approaches by comparing them to data from the security checking process. Before and after the security checkpoint Wi-Fi and Bluetooth data is collected on the amount of passengers over time and compared with data of the amount of users that have passed through the security checkpoint. They conclude that the information can be used to make a practical estimation, but that the use of external sources is needed to provide a reliable tracking system based on Wi-Fi.

- At Brisbane Airport (Ma, 2012) and Barcelona Airport (Fonseca i Casas et al., 2014) agent-based simulation models are developed to gain insight into how passengers flow through parts of the airport, rather than using measurements to determine what passengers actually do. The models incorporates behavioural aspects that influence the flow of passengers through airports, such as the willingness to shop.

Inner city areas

In inner city areas mobility patterns and user flows are used to observe special events or changes that occur because of events. Yoshimura et al. write that tracking pedestrian activity in shopping areas has been identified as a critical research area for urban researchers a long time ago. Potential value of the research lies in predicting the number of visitors to shops or shopping centres. From a retailer's perspective this is interesting because of the relation to turnover of shops and real estate value; to city authorities the analysis is useful to predict the consequences of urban planning and market shares. (Yoshimura, Amini, Sobolevsky, Blat, & Ratti, 2017, p. 41)

A few examples of research done in inner cities are:

- Yoshimura et al. (2017) use Bluetooth to measure pedestrian's mobility patterns in Barcelona during a special event, examining differences between discount days and normal sale days in the shopping district of the city. Their findings were that people behaved differently on the Saturdays during the discount period then on normal Saturdays and other weekdays: for example, pedestrians were found to more actively explore the district during discount days.

- At Tartu University, Estonia, smartphone GPS data was used to map out the use of urban space, visited locations and the preferred mode of transport of respondents. This was done in a period of 1,5 years observing the relocation of two institutions. The visualisations show the increase of home-work distance after relocation and that relocated workers spent less time in the city centre than before relocation. (Ahas, Poom, Aasa, & Silm, 2017)

- In Ghent, Belgium, Bluetooth data is used to observe the Ghent Festivities event. Data was collected on the amount of users, the share of returning visitors, and flow maps of visitors during the event. The analysis of this data shows for example the use of different public squares over the course of the event and the transport mode that visitors use. The amount of visitors detected with Bluetooth was estimated to be around 11 percent. (Versichele, Neutens, Delafontaine, & Van de Weghe, 2012)

Finally, Prentow, Ruiz-Ruiz, Blunck, Stisen, and Kjærgaard (2015) conduct an experiment at a hospital in order to help inform the planning of hospital activities. They use Wi-Fi to study the user flows in a hospital complex in Aarhus, Denmark. They are able to estimate when people enter and exit the various buildings in the complex.

To summarise

In this chapter the application of user flows in various contexts is observed. The purposes for which user flows are used in different sectors can be globally divided into three categories:

Short term (<1 year): Continuous monitoring of user flows to set and/or adjust capacities where bottlenecks occur to optimise operations. At airports this can refer to opening and closing control gates, baggage drop-off or ticket shops. At stations this can refer to the adjustment of train stopping positions at platforms.
(See: airports and train stations)

Middle term (1-5 years): Continuous or incidental monitoring of user flows for commercial purposes. By observing user flows decisions can be made for the adding and/or positioning of retail locations.
(See: train stations and inner cities)

Long term (>5 years): Incidental monitoring or simulation of user flows for the purpose of (re)designing buildings. By observing user flows decisions can be made on the capacity of routes or the positioning of functions within buildings.
(See: hospitals, train stations, airports)

The examples in this chapter in which user flows are measured for the long term are most applicable to the demands put forward by universities: designing areas between buildings and making decisions about opening hours. Improving emergency response best fits the examples that measure user flows for short-term purposes, although the examples that are observed do not deal with emergency response.

4.5. Conclusion

The question to be answered in this chapter is:
What smart tools are available at other organisations?

To answer this question, nine organisations were interviewed, which resulted in nine cases of smart tools.

Smart tools to find available workplaces and meeting rooms

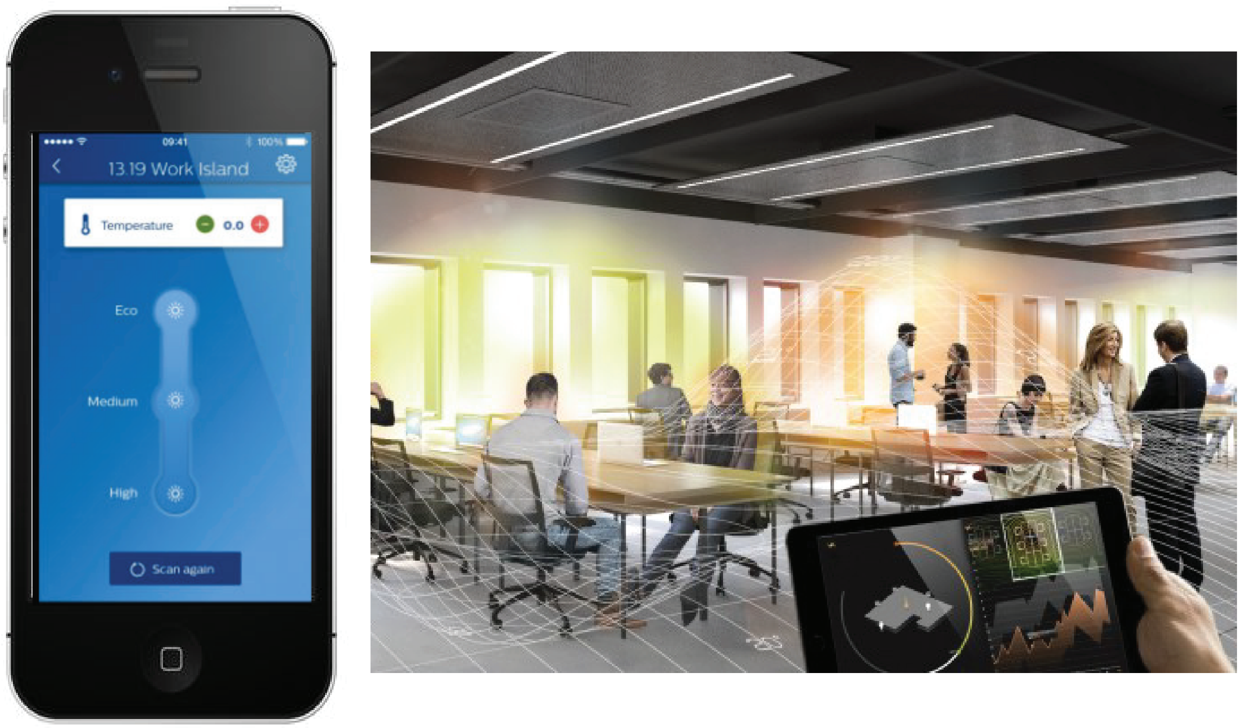
In six of the nine cases real-time information is provided to employees to find available workplaces. Organisations do this by using data from their Wi-Fi network (Dutch government, ABN AMRO), PC or docking station use (Dutch government) or workplace check in by employees (Agnelli Foundation, OVG).

Furthermore three of the nine cases provide real-time information on available meeting rooms. They use passive infrared (PIR) sensors to determine if meeting rooms are in use or not (Microsoft, Ericsson and OVG).

Figure 4.9 – Examples of user apps: to find available office workplaces at the Dutch government, and to find available meeting rooms at Ericsson

Smart tools to optimise user comfort

At OVG and the Agnelli Foundation user apps are also used to allow users to set the lighting and temperature levels for their workplace, in addition to finding available workplaces and meeting rooms. In these cases buildings are extensively sensored in order to be able to determine and adapt indoor climate on a workplace or sub-workplace level.



OVG

Fondazione Giovanni Agnelli

Figure 4.10 – Examples of user apps: to optimise workplace comfort at OVG and Agnelli Foundation

Smart tools to optimise meeting room use

At Microsoft and Google smart tools are used to identify scheduled meetings that are abandoned or that do not take place at all. By removing recurring meetings that repeatedly do not take place and making meeting rooms available once meetings have been abandoned the use of meeting rooms is optimised. This is done by measuring the frequency in meeting rooms, via videoconferencing software (Google) and passive infrared sensors (Microsoft).

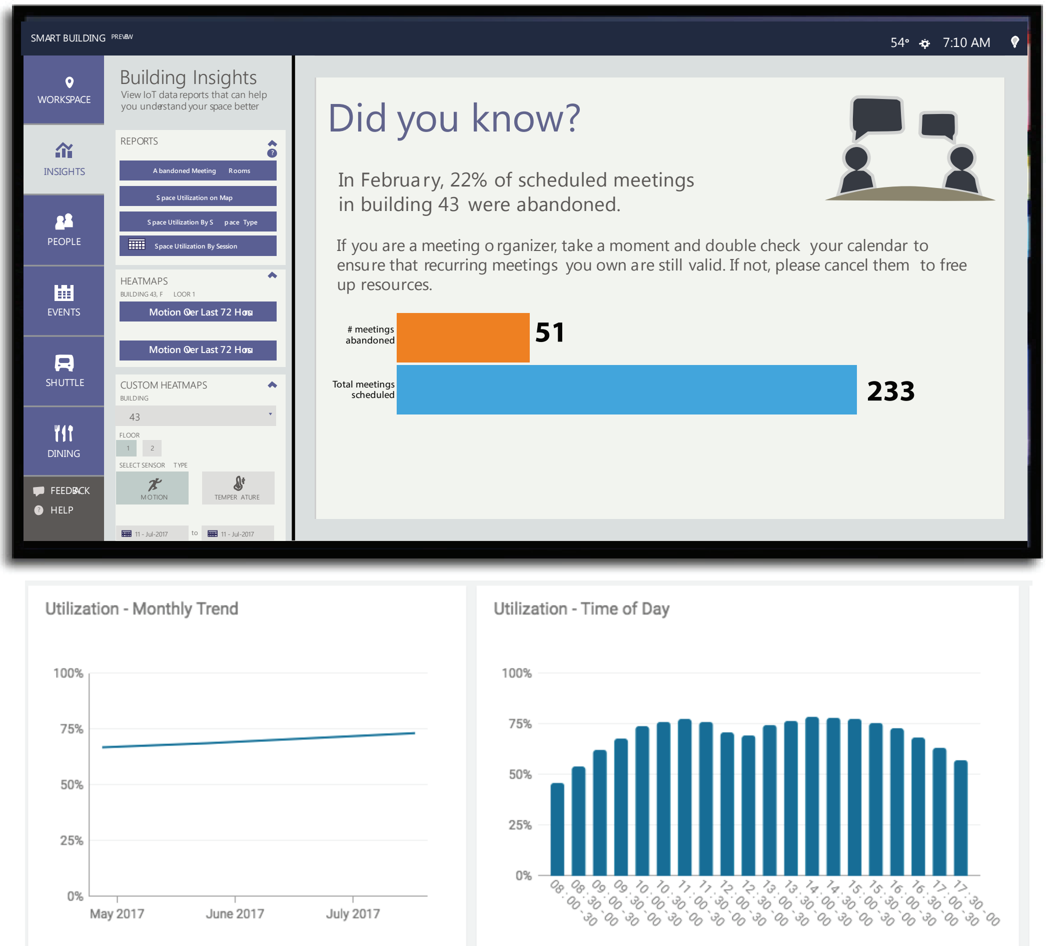


Figure 4.11 – Examples of optimising the use of meeting rooms at Google and Microsoft

Findings from the cross-case analysis

These nine cases reveal that organisations have similar smart tools, but different reasons to initiate their development. Figure 4.12 shows an overview of what they are working on, when positioned in the current state of smart tools and next steps of the previous research – see also figure 2.3 and 2.4 in chapter 2. The organisations are working on smart tools that both monitor their space use and help their employees find available workplaces and/or meeting rooms; and in two cases also to align energy use to building use.

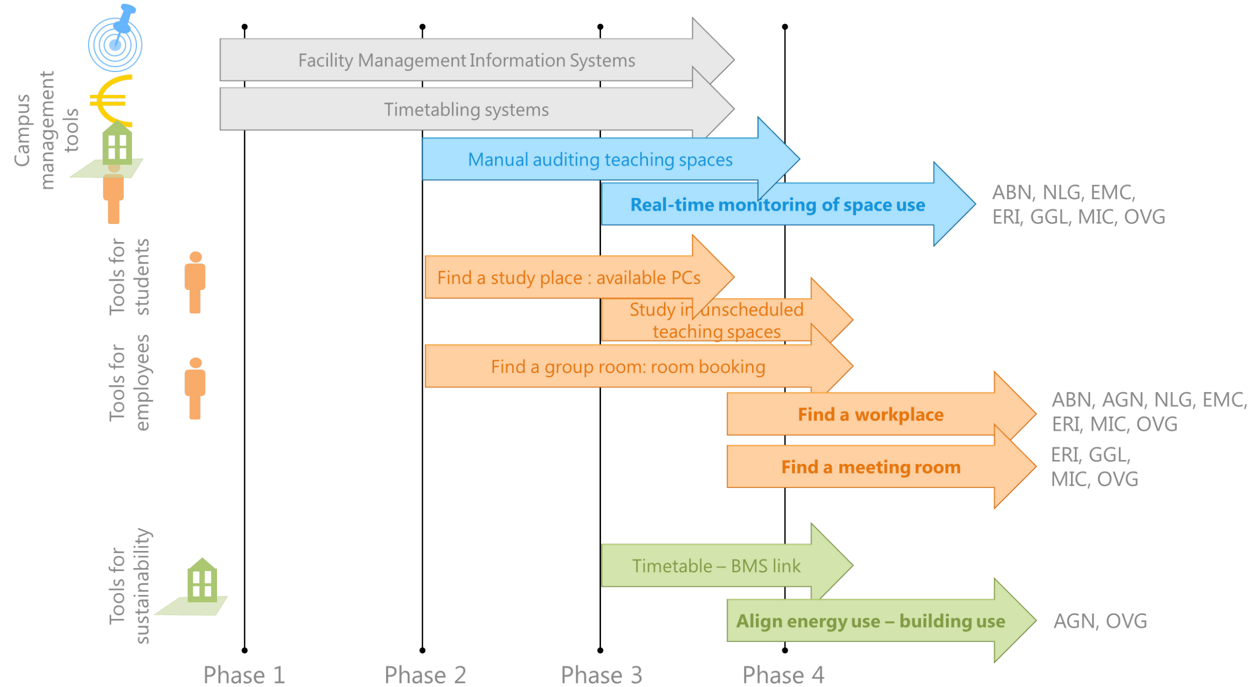


Figure 4.12 – Overview of available smart tools.

Phase 1: no smart tools; phase 2: prevalent smart tools in 2016; phase 3: new smart tools in 2016; phase 4: ongoing smart tools in 2017. Arrows with bold text represent smart tools found in this study.

Furthermore, the following conclusions can be drawn with regard to these nine cases: The cases have similar smart tools, but different reasons to initiate their development

- Four of the nine surveyed tools were already in use before the start of 2017, and a large majority of the applications are in an implementation stage. Only one case was in the design brief stage.
- Foreseen developments focus mostly on the development of user apps.
- The cases are mostly aimed at adding value through functional objectives. Almost all cases also add value through strategic objectives and most cases add value through financial and physical objectives.
- Frequency and occupancy are almost exclusively the levels that space use is measured on.
- Five of the nine cases use multiple sensors in their smart tools. Four out of nine smart tools use reservation systems, of which two examples use workplace check-in to determine workplace occupancy. Furthermore Wi-Fi is used either to measure space use or for indoor positioning (wayfinding).
- Information is provided in near real-time to users, but via different outputs. The requirements for management information are the same across cases, using reports almost exclusively as output.
- User information is in all cases restricted to employees. Management information is usually restricted to management, in some cases to support.

Other insights

An exploration of the application of user flows in various contexts is observed by studying publications of research at stations, airports, inner cities and hospitals. The purposes of these studies can be divided into three categories: short term, middle term and long-term. The long-term applications found at hospitals, train stations and airports fit the demands put forward by the universities best.

Chapter 5
Smart tools at Dutch universities

This chapter is aimed at the third component of the research project, which is to update the information collected on smart tools at Dutch universities. The following research question is answered:

What development have the Dutch universities made in comparison to the previous findings?

First, the chapter discusses the process of selecting cases and provides a short description of each case. Then the collected data in the templates is displayed. Based on these templates the properties of the cases are analysed before concluding the chapter.

Photo: Utrecht University

5. Smart tools at Dutch universities

5.1. Cases

This chapter reports the way in which cases were selected and provides a description of the cases.

Case selection

For the selection of cases all fourteen Dutch universities have been included. The map below gives an overview of the universities that are included as a case in this research.

Figure 5.1 - Map including all the cases of Dutch universities

The difference in the case selection compared to chapters 3 and 4 is that all universities were included. Also, the case material was collected at a joint meeting of all universities on the subject. Each university was asked to fill in same information as the other interviewees.

University	Function of interviewee(s)
Erasmus University Rotterdam	Education services
Leiden University	Facility management,
Maastricht University	Facility management; ICT
Open University	Facility management
Radboud University Nijmegen	Facility management
Tilburg University	Facility management
TU Delft	ICT; Library; Real estate management
TU Eindhoven	Education services
University of Amsterdam	Facility management
University of Groningen	Facility management; ICT; Real estate
University of Twente	Real estate ; academic
University of Utrecht	ICT
VU Amsterdam	Facility management; real estate
Wageningen University	Education services

Table 5.1 – overview of interviewees and the roles of the interviewees

Case description

Similar to the universities, the cases provided thus far display a large variety.

Erasmus University has a very compact campus located in Rotterdam. In the campus development they are currently in the process of renovating their Library. Because the building is temporarily unavailable, the university has developed the EUR group study rooms app to help students find a place to study on campus.

Leiden University wants to increase the frequency and occupancy rates and reduce no-shows in its education spaces, which it has been doing for a couple of years. In addition the university has opened a campus in The Hague. In The Hague the university is doing some pilots to help students find their way. Furthermore they are doing pilots for space monitoring with Lone Rooftop and BeSense.

At Maastricht University the responsibility of efficient space use is mostly with the faculties and departments. On a central level facility services looks at how to best support its users. The university has done a pilot with Web Room Booking to help students to find space for group work.

The Open University is a university that offers predominantly online education, with locations all over the Netherlands that are used for both teaching and examinations. The university is currently not using any smart tools; they are, however, looking for a way in which they can make their scheduling and booking processes more effective and efficient.

EUR Group Study Rooms

Erasmus University Rotterdam has developed an app to help students find a place to study during the renovation of their Library building.

The app Group Study Rooms displays possible locations per building, in which students can see if these rooms are available. This information is based on the timetables of these rooms.

PC Availability tools
(previous research project)

Many Dutch universities have websites, apps or monitors on which they display information on the availability of desktop PCs on campus.

Examples that can be found online are:
- Leiden University
- Utrecht University
- University of Groningen
- Tilburg University
- Radboud University Nijmegen
- Wageningen University

Radboud University is very gradually moving towards a campus model in which more space is shared. It uses tools to help employees book rooms and students find study places in order to support this movement.

Tilburg University is growing in terms of students and employees, which requires a more efficient use of spaces and workplaces. The university is in the process of formulating a design brief for a smart tool that will help students and employees book rooms, find free study places and classrooms to study in and generate management information. It is expected to eventually replace their current tools.

TU Delft has a large campus area, on which a large redevelopment is taking place in the next ten years. The university is looking to accommodate its increasing amount users more efficiently. In education spaces and study places it is expanding an implementation of Mapiq in its Library and doing a pilot to monitor space use of education spaces with Lone Rooftop.

TU Eindhoven needed a solution to help facilitate a growth in students and employees within the existing buildings. Therefore it has implemented a solution called Book my Space, by Planon.

At the University of Amsterdam there was a desire of the student council to gain access to the use of teaching space. The university now uses Mapiq to help students with wayfinding and finding space to study.

At University of Groningen real estate, facilities management and IT are looking at smart buildings from three perspectives: saving energy, analysing real estate data and informing users. The university is looking how to develop one or more tools to meet the needs of these perspectives with in-house expertise.

The University of Twente has a strong focus on sustainability and energy savings, which has led to various implementations and pilots that were previously identified. The university is currently working on a research project on changing the way education is scheduled.

At the University of Utrecht the campus development has focused on realising sustainable buildings in recent years. The university now has a perspective in which well-being of students and employees is central. It has done a pilot with Mapiq in the past and is now doing a pilot with Lone Rooftop.

At VU Amsterdam the efficient use of space is an important aspect in the campus development, next to optimally facilitating the primary processes. In order to meet these needs the facility management department has developed Study Spot as a tool together with its users. Their Library is also doing a pilot with Lone Rooftop.

At Wageningen University a number of education buildings were built in the past few years, and they could not expand any further. The university therefore wanted to know how well the recently realised buildings were actually used, which led to the implementation of Lone Rooftop.

5.2. Templates

For most of the cases the smart tool templates were filled in prior to the meeting. For some cases the data from previous research was filled in by the researcher and checked or updated by practitioners. In other cases, the practitioners filled in a new template entirely. A few examples were collected after the meeting.

The templates are provided in order of their phase. First, the implementations are displayed, following by pilots, design briefs and finally research projects.

University	Previously surveyed tools (2016)	Included as case	Other known cases of smart tools
Erasmus University Rotterdam	-		EUR Study rooms
Leiden University	Cube, Free PCs		Mapiq, Lone Rooftop, BeSense
Maastricht University	Web Room Booking		
Open University	-		
Radboud University Nijmegen	Web Room Booking, Availability for students, Planon		
Tilburg University	PC Availability, Web Room Booking, Planon	Design brief	
TU Delft	Mapiq, Workplace Availability Service	Mapiq, Lone Rooftop	
TU Eindhoven	Book my space, Manual occupancy measurement with cameras, Evoko	Book my space	
University of Amsterdam	Mapiq	Mapiq	
University of Groningen	Syllabus-Traka, Available PC in UB	-	
University of Twente	Indoor maps, Facility Scheduler, Nedap, Smart Signs	Research on adaptive scheduling	
University of Utrecht	Study Spot	Design brief	
VU Amsterdam	Studyspot	Studyspot	Lone Rooftop
Wageningen University	Lone Rooftop, Available PC app, Available PCs in PC halls, Web Room Booking	Lone Rooftop	

Table 5.2 – Previously surveyed tools (2016) and smart tools included as case in this research.

TUD-1 **TU Delft** **Mapiq - Blinq Systems**

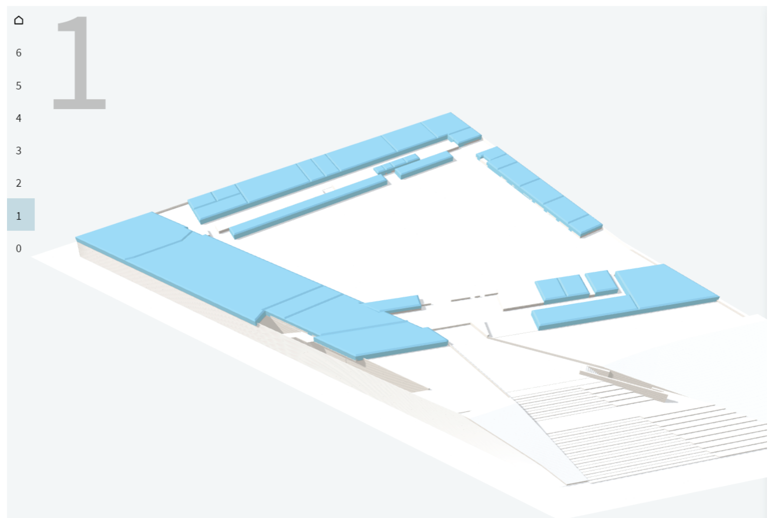
phase **Implementation**

scale **26.000 m2**
2 buildings

duration **2014-present**

Project description

Mapiq is a product that has been developed by two TU Delft alumni. The Library has decided to implement it because of their service concept and the services they want to offer to students. In the development of Mapiq the faculty of Industrial Engineering was done as a pilot, after which Mapiq has been kept running. Recently a number of sensors have been added in the Library to indicate actual use.

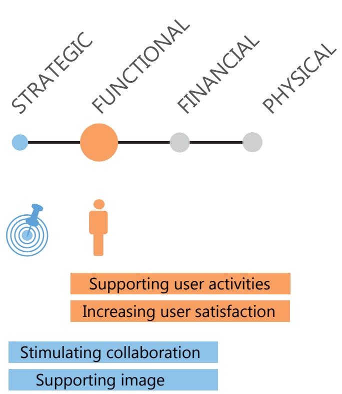


Foreseen developments

The future developments depend on how the users experience the partial availability of information from sensors in the building. We are looking at options to increase the amount of information offered to students based on already available sensors.

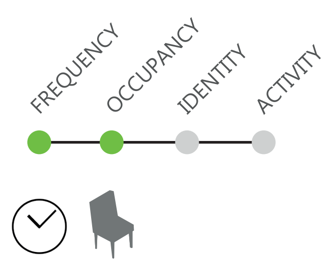
Profile

Why: Objective



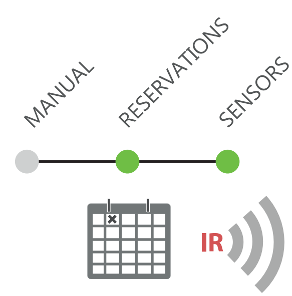
Mapiq supports user activities by offering information with regard to the amenities in the Library and by enabling reservation of project rooms. That indirectly stimulates collaboration.

What: Measurement



The frequency of meeting rooms is determined: both via reserva-tions (booked) and via sensors (in use). The occupancy of 100 workplaces is shown real-time.

How: Measurement method



The data source used is reserva-tions, from the reservation system of Mapiq.
Infrared sensors have been added on 100 workplaces; they measure activity on that workplace. 10 infrared sensors have been added to meeting rooms; they measure activity in the room.

TUD-1 **TU Delft** **Mapiq - Blinq Systems**

functionalities
Wayfinding, find a study place, book a project room

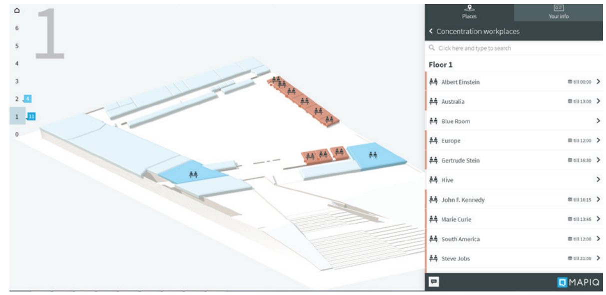
space types
study places, project rooms

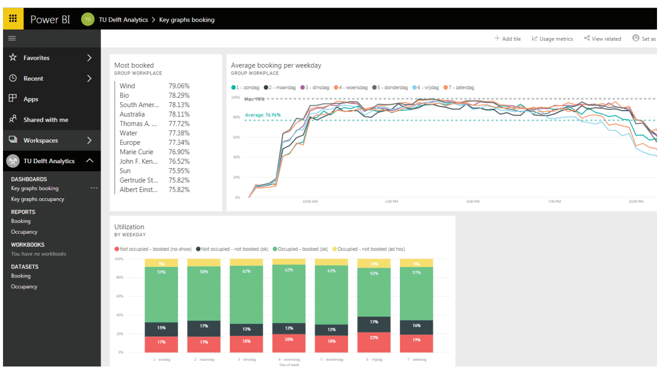
User information

The user can search for a space by space type in the interface, e.g. workplace with a computer or workplace for group. Then the user can see the availabilityof these spaces.

For project rooms the user can make a reservation via a reservation system. The availability of the room is displayed, based on already made reservations.

For each space a route from the entrance to the space can be given.

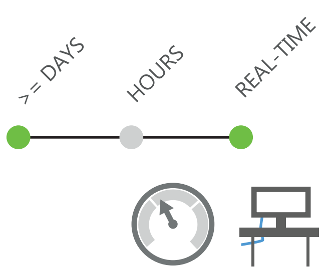




Management information

The campus manager can design reports and dashboards in PowerBI. Dashboards show real-time information; Reports show information over the whole measurement period.

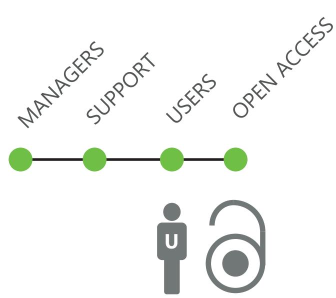
Actuality of the information



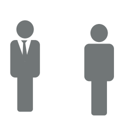
De displayed information on the webpage and in the PowerBI dashboard is (near) real-time.

The reporting function in PowerBI shows real-time data until as far back as possible.

Access levels



De blueprints, location of each space and availability is visible for everybody; reservations can only be made by students and employees.



Support staff can access a backend to the booking tool. PowerBI functions can be accessed by specific individuals.

Benefits

The objective was to improve the service towards students; students are satisfied with the service and the Library has a reduced workload because of the self-reservation system.

Side notes

The implementation of Mapiq has been received very positively by students. The Student Council regularly has meetings with the Library, which are also about Mapiq. They would like to see more information on the availability of study places given the business in the Library during exam weeks. Information on where study places are and which amenities they have, is seen by them as an important first step.

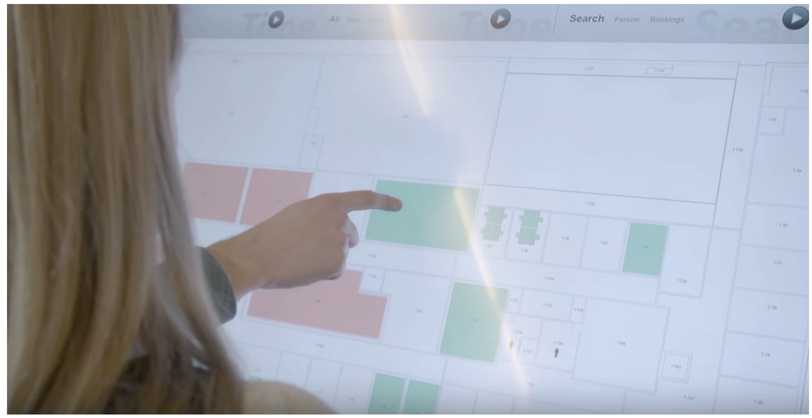
TUE **TU Eindhoven** **Book my space - Planon**

phase **Implementation** — scale **213.000 m2** — duration **Q1 2016 - present**

Project description

The project was initiated because of the strong increase in students studying at TU Eindhoven. The university could not invest in buildings, so the amount of users per m2 needed to increase. A functional programme of requirements was written to six parties. Planon was chosen because they best met the requirements and because it was already used at TU Eindhoven.

The basis is in an implementation phase; the sensoring and linking Syllabus to Planon is in the development phase.



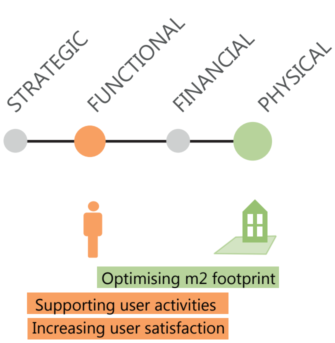
Foreseen developments

Linking Syllabus to Planon, upgrading the release of 2017 (Planon webclient), workplace sensoring, Lora network.

Another objective is to bring the data from Planon and the data from the manual occupancy measurements together in one report.

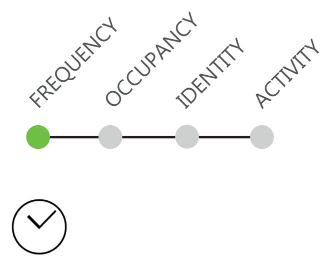
Profile

Why: Objectives



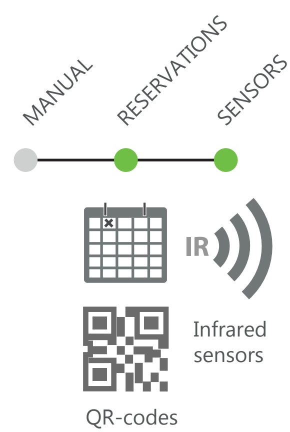
A higher amount of users per m2 has priority, and is achieved by a uniform way of making reservations and findability of available spaces.

What: Measurement



The duration of the reservation is compared to the maximum amount of available hours in order to determine frequency. There is a pilot in one building with sensors, which register the actual frequency and can thus determine no-show and early leave.

How: Measurement method



Reservations are made via Planon. Infrared sensors that are connected to the lighting, detect presence in meeting rooms which indicates if a reservation is used.
In addition manual counts are done (separately) in the education spaces.

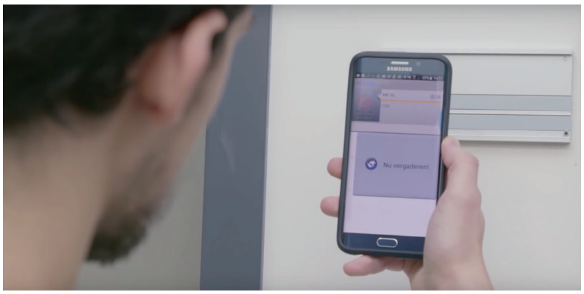
TUE **TU Eindhoven** **Book my space - Planon**

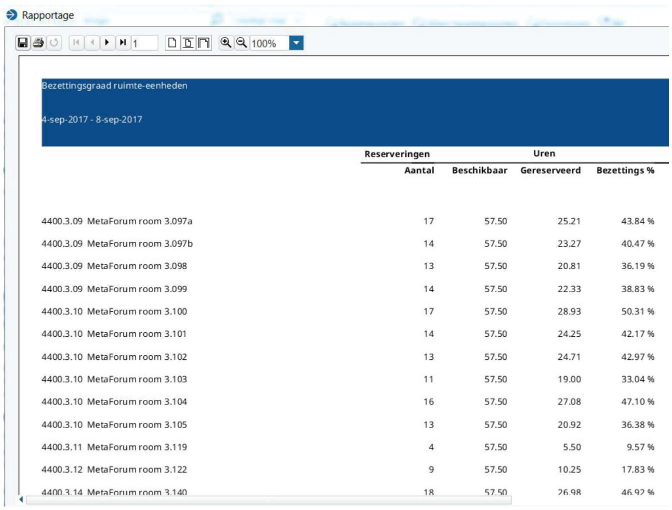
functionalities
Find a workplace, room booking, monitoring space use

space types
Education space, flexible workplaces, meeting rooms

User information

Users can see where the study places, meeting rooms or work places are on campus and if they are available with their smartphones, a website or one of the kiosks. Then they can reserve a workplace or a group room.




Rapportage

Bezettingsgraad ruimte-eenheden

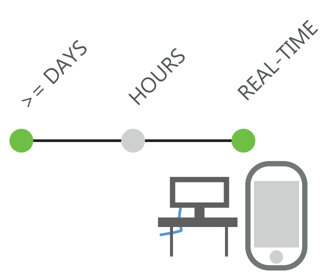
4-sep-2017 - 8-sep-2017

	Reserveringen	Uren		
	Aantal	Beschikbaar	Gereserveerd	Bezettings %
4400.3.09 MetaForum room 3.097a	17	57.50	25.21	43.84 %
4400.3.09 MetaForum room 3.097b	14	57.50	23.27	40.47 %
4400.3.09 MetaForum room 3.098	13	57.50	20.81	36.19 %
4400.3.09 MetaForum room 3.099	14	57.50	22.33	38.83 %
4400.3.10 MetaForum room 3.100	17	57.50	28.93	50.31 %
4400.3.10 MetaForum room 3.101	14	57.50	24.25	42.17 %
4400.3.10 MetaForum room 3.102	13	57.50	24.71	42.97 %
4400.3.10 MetaForum room 3.103	11	57.50	19.00	33.04 %
4400.3.10 MetaForum room 3.104	16	57.50	27.08	47.10 %
4400.3.10 MetaForum room 3.105	13	57.50	20.92	36.38 %
4400.3.11 MetaForum room 3.119	4	57.50	5.50	9.57 %
4400.3.12 MetaForum room 3.122	9	57.50	10.25	17.83 %
4400.3.14 MetaForum room 3.140	18	57.50	26.98	46.92 %

Management information

Occupancy percentages of all reservable spaces: education spaces, study places and flexible workplaces.

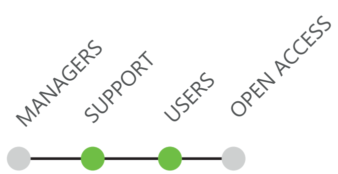
Actuality of the information



Information on the selfservice, app, and the kiosks is real-time.

Reports are available on demand. Dashboards need to be used more in the future.

Access levels



Students and employees have access via Selfservice, an App, Outlook and the Kiosks in the buildings

Secretaries have access to reservations via Planon Procenter.

Benefits

The objective was to increase the frequency rate of meeting rooms and the occupancy rate of workplaces by 10% within four years. After one year the increase is already 13%.

Side notes

Managers get more insight into space use and can make decisions more conciously. Students have a tool to reserve space and have access to more spaces (also in other buildings) than previously.

UvA

Universiteit van Amsterdam - Mapiq

phase
Expansion

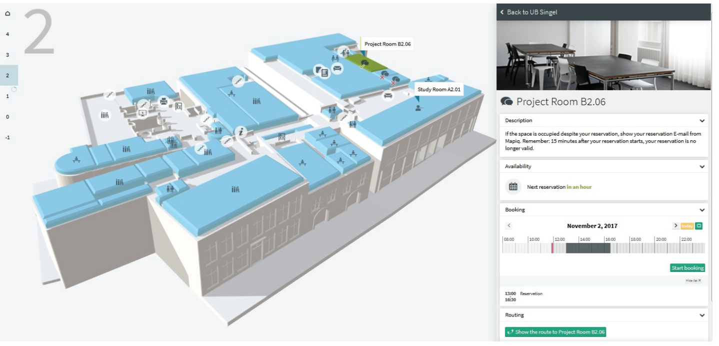
scale
6 buildings
105.184 m2

duration
2015-present

Project description

From the student council of the university and faculties there was a desire to get more access to the classrooms, which used to be restricted for students. Furthermore their demand was to make study places visible. Therefore we started with the implementation of Mapiq: to give students access to classrooms and display study places and project rooms.

Other demands:
Offices: a demand to reserve meeting rooms, find empty flex spaces and increase the findability of colleagues (opt-in).
Offices: frequency and occupancy information, wayfinding and security/emergence response applications.
Accessibility information for students and employees with a handicap.

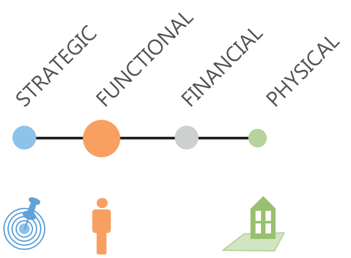


Foreseen developments

Part of the implementation project is realising a link to the scheduling system, in order to use available space in the schedule for self study by students. Also a link to the Wi-Fi network is made in order to display business in the building and in spaces.
Aside from the functionalities for students we are working towards the application on the office spaces for employees.

Profile

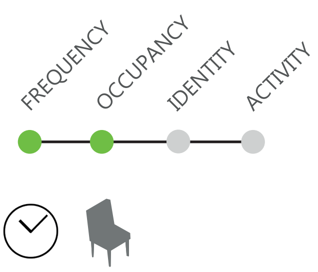
Why: Objectives



Supporting user activities
Increasing user satisfaction
Increasing flexibility
Stimulate collaboration
Improve information services

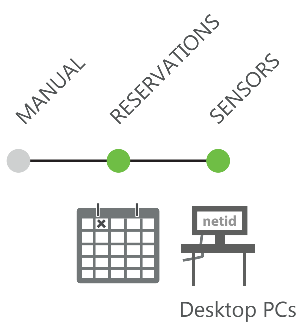
Our objective with Mapiq is to enable users to use the available space better. The next step is to use the information for improved decision-making.

What: Measurement



Different per space: frequency is measured for education spaces and project rooms. Occupancy is measured for PC spaces.

How: Measurement method



Booking data is used from Mapiq and from Syllabus to show availability. Desktop PC usage is logged in order to show occupancy per workplace.

UvA

Universiteit van Amsterdam - Mapiq

functionalities

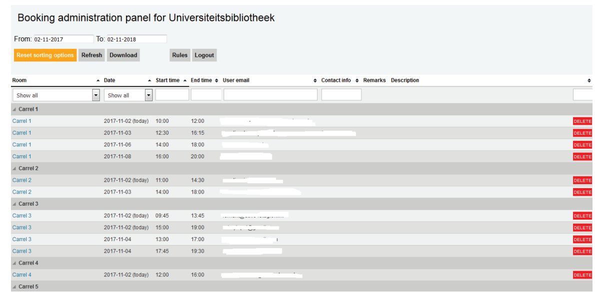
Wayfinding, room booking monitoring space use

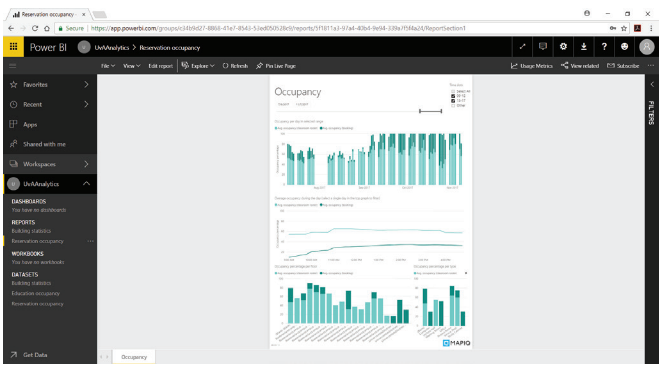
space types

Whole building

User information

The user can search for a space in the interface per type (e.g. PC workplace or group workplace) and see if these spaces are available. Project rooms can be booked via a booking system. For education spaces it is indicated if it is available for self study. For PC places the availability is displayed. The actual availability based on reservations is displayed. For each space a route to the space can be displayed.

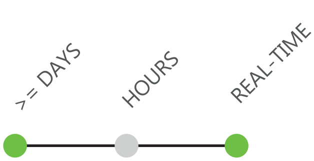


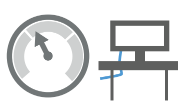


Management information

Via Power BI reports are realised. PowerBI can be used to make dashboards, which is also able to add other information from other sources. This part is still in development.

Actuality of the information

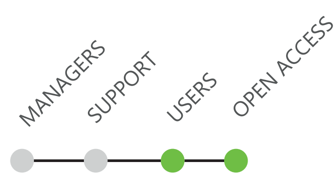




The displayed information on the webpage and in the PowerBI dashboard is real-time.

The reporting function shows real-time data until as far back as possible.

Access levels



The floor plan and location of spaces is visible to everyone.

Room bookings can only be made by students and employees (via UvA netID).

Benefits

Enabling users to use the existing space better is not monitored per se. However, the amount of reservations in Mapiq has increased from 1.600 in 2 buildings to 3.400 in 4 buildings, and is still increasing.
Also, implementing Mapiq will help the university to substantiate their policy and real estate decisions with data.

Side notes

Based on the results of the pilot in two buildings in which students could reserve project rooms and student PCs it was decided to move forward with further implementation. In 2016-17 four buildings were added and in 2017-18 a minimum of three buildings will be added. At the end of 2017 we will do two pilots: one with visualising business with Wi-Fi data and one with linking the scheduling system for flexible use of education spaces.

VU **Vrije Universiteit** **Study Spot**

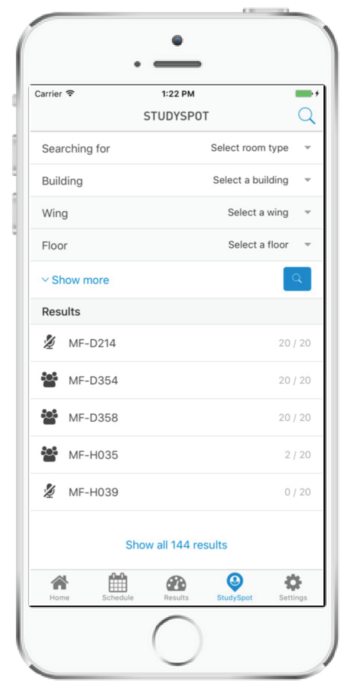
phase **Implementation** — scale **7 buildings 276.484 m2** — duration **2016-present**

Project description

In the campus renewal of the VU optimisation of the space use is an important motive next to facilitating the primary process of the university. Study Spot is a service that has been initiated by FCO, but in a work group with students, employees, researchers and IT. We facilitated the work group in order to achieve a solution that has everyone's support. A PID (project plan) has been made that states what kind of application it is, what the system must be able to do and how the system has been chosen.

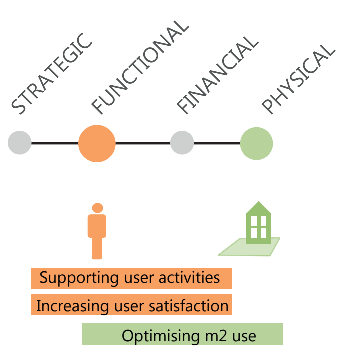
Foreseen developments

In the ideal situation real-time information available to everyone is desired. Maybe a student can receive a push-message at the start of the day in which it says when his/her first lecture is and at what location (LBS). There are different ways to reach that point. If everything is possible, then it is easier to set restrictions from there and only offer parts of the service to different user groups, or to make information unavailable.

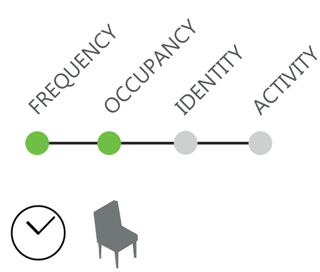


Profile

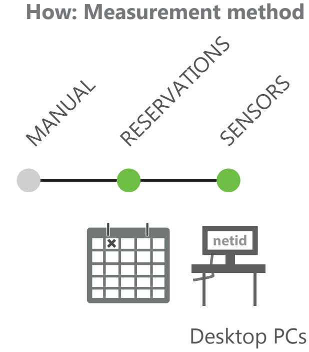
Why: Objectives



What: Measurement



How: Measurement method



Supporting the user has the first priority.

For education spaces and project rooms frequency is shown. For PC halls occupancy.

The booking data from Study Spot and Syllabus are used to show if education spaces and project rooms are in use. PC login data is used to show occupancy data of PC halls.

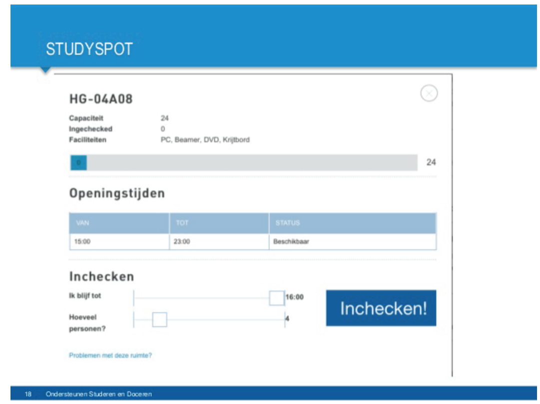
VU   Vrije Universiteit   Study Spot

functionalities
Wayfinding, room booking find a study place

space types
Education spaces, study places, project rooms

User information

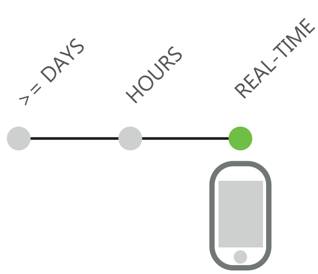
Study Spot displays the availability of education spaces to students based on information of room bookings from Syllabus. Also it displays the occupancy of PC halls. The student is not able to reserve classrooms.



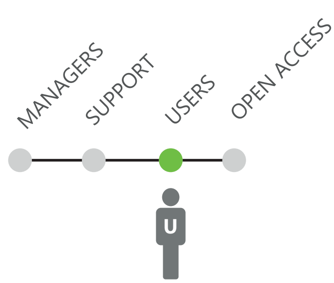
Management information

PM

Actuality of the information



Access levels



Benefits

In order to evaluate Study Spot the data on amount of users is monitored to see how often it is used; also short surveys are done to determine the satisfaction of students.

Side notes

Because of Study Spot the space is used more frequently, which indeed means that the services must be aligned to the increased frequency. The tasks of the wardens has been expanded. for example. When a space is used often by students, it is important that the space is left behind properly for the next lecture.

The information displayed in the app is real-time.

Access to StudySpot is restricted via VUlogin.

WU — **Wageningen University** — **PIE, Clocks (Lone Rooftop)**

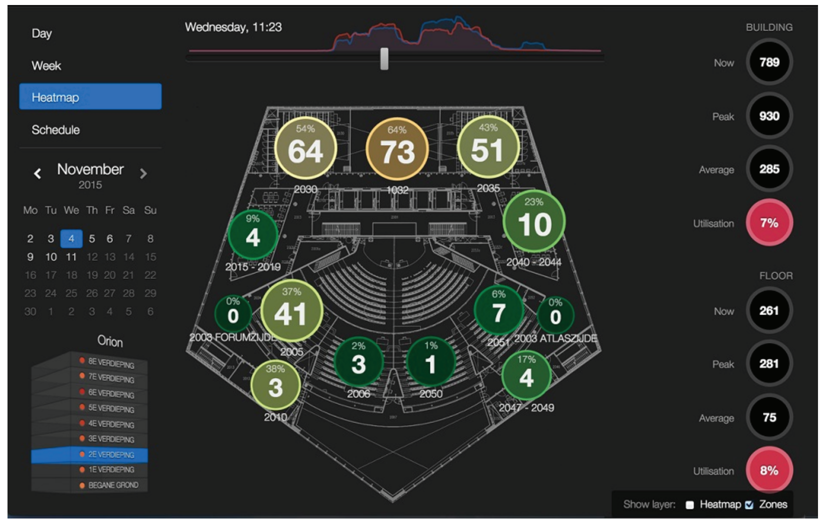
phase
implementation

scale
21.000 m2 NFA
6 buildings

duration
2015 - present

Project description

At the WUR we had a demand for the use of big data and sensors relating to our operations, but it was difficult to formulate a specific application. We didn't know exactly what we wanted to know. In this project we could make it very specific: we measure in specific buildings, we measure students, with a specific method to understand the use of education spaces in relation to the schedule. That makes it easy to steer on the project. At the time the WUR had just built a number of new education buildings, and building more was not an option. Therefore the question was: how well are these buildings actually used? Lone Rooftop came at the right moment, after which we started in 2015.



Foreseen developments

A pilot is being initiated to use the data of building occupancy in building management systems. More accurate measurements on building level and in small spaces will take place in the next few months

Profile

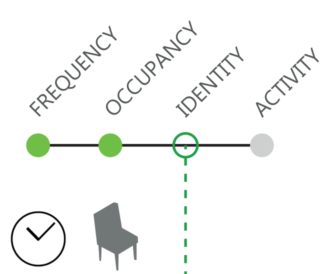
Why: Objectives

STRATEGIC
FUNCTIONAL
FINANCIAL
PHYSICAL

Optimising m2 footprint
Reducing costs

Optimising m2 is done by gaining insight into no-show behaviour. From the facility management perspective the delivery of this information was one of the measures taken to use the existing space more efficiently.

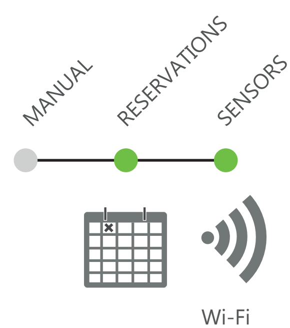
What: Measurement



The IP addresses are anonymised differently each day. Also, this is done before the data leaves the university's network.

An indication of the occupancy is given for a predetermined zone. The size of this zone is aligned to the accuracy of the measurement.

How: Measurement method



Wi-Fi determines where devices are within the building (active and passive). Via an algorithm devices are paired if the algorithm determines they belong to one user. That is how the amount of users in a zone is determined.

WU

Wageningen University

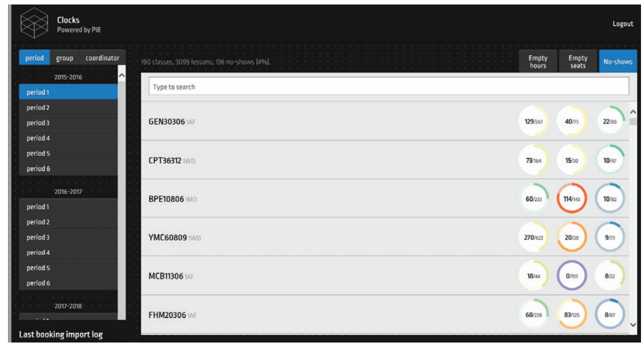
PIE, Clocks (Lone Rooftop)

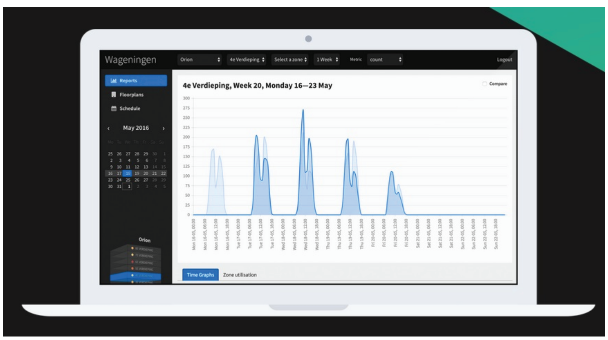
functionalities
Monitoring space use

space types
Education spaces, whole building

User information (scheduler)

The user (scheduler) receives a report in which the occupancy data for lecture halls is linked to scheduling data. The amount of no-shows and occupancy per activity is displayed. The system is also used by location management to get insight into where people are in the building and how many people there are during the day, and during the evening hours.

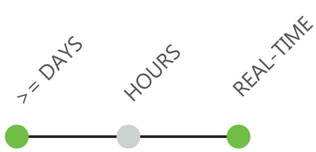




Management information

The manager can see how many devices there are in different zones of the building, although the system is working less with devices and more with users. For the education spaces the data can be linked to the schedule. We are looking specifically at no-shows. The focus is on the use of education spaces and scheduling.

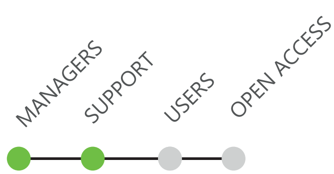
Actuality of the information



The information displayed in PIE is near-real time.

The data used in reporting goes from real-time to as far back as possible.

Access levels



PIE is available to location managers; Clocks is available to schedulers.

PIE and Clocks are available to specific people from Facility Services.

Benefits

The first experiences with the system are that it leads to an improvement of 5-10 procent in space efficiency. In 2018 a new schedule will be implemented that includes more hours per day and shorter hours, which enables us to accommodate growth in the near future.

Side notes

TUD-2 **TU Delft** **Pilot education spaces**

phase **Pilot**

scale **1 building 2.500 m2**

duration **Q3 2016 - present**

Project description

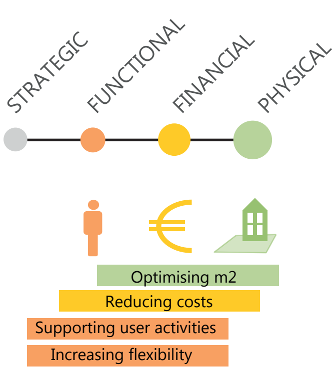
The initiative has been taken because TU Delft wants to get better insight into the use of facilities on campus. The university has been growing in terms of student population for years and that results in pressure on the education spaces. Four years ago we had 1 seat in an education space per student; now we have about 0,85 seat per student. In order to monitor what the effect of this change is on the use of space and to be able to schedule more efficiently in the future, the university decided to start measuring the frequency and occupancy rates real-time for education spaces. Wi-Fi has been selected as preferred method.

Foreseen developments

The next step in this project is to measure frequency and occupancy in education spaces on a campus level.

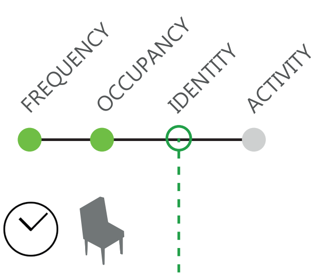
Profile

Why: Objectives



Optimising m2 has priority. On the long term this is achieved because schedulers receive information about the actual use of spaces by users. With that information it is possible to evaluate the space use and search for better solutions together with teachers.

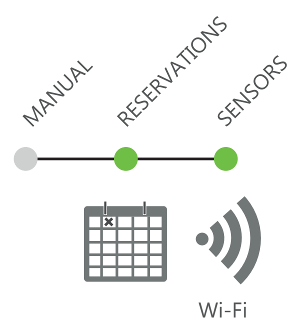
What: Measurement



Wi-Fi data is anonymised on-site before it goes to the cloud. In addition a different encryption is used so users can never be tracked for longer than one day if anyone is able to deanonymise the data.

The amount of devices in the building at a certain moment. That is converted via algorithms to an amount of people.

How: Measurement method



Wi-Fi registers both the amount of connected devices and connection attempts. Based on the signal strength between device and access point the location of a device in the building can be pinpointed.

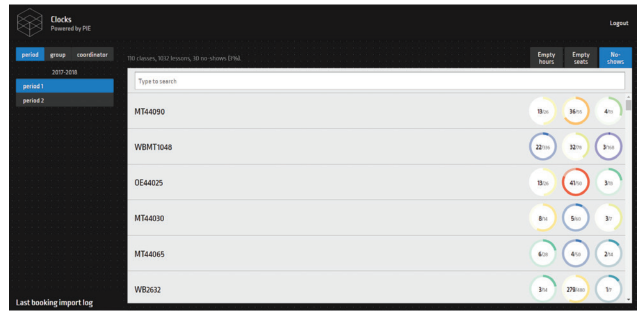
TUD-2 — TU Delft — Pilot education spaces

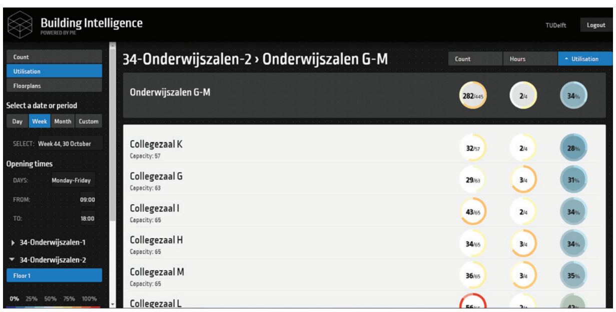
functionalities
Monitoring space use

space types
Education spaces

User information

The user (scheduler) receives a report with in it per course the amount of bookings, the amount of no-shows, empty hours (partly used bookings) and the average occupancy. This makes the performance in relation to the schedule visible.

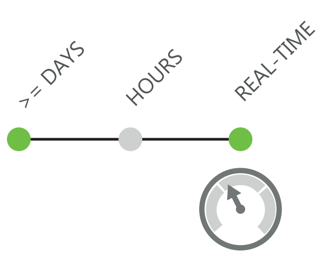




Management information

The manager can see the same reports as the scheduler and also the PIE dashboard in which the whole building is visible. PIE is not linked to the scheduling data, but shows real-time what the use of spaces in the building is in relation to their capacity.

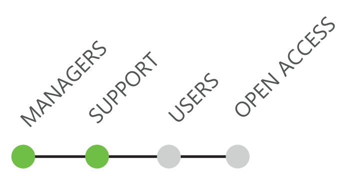
Actuality of the information



PIE displays real-time data.

The information in Clocks is visible real-time; for lectures currently underway a tentative frequency and occupancy is shown. The report shows data per period.

Access levels



The scheduling team has access to Clocks.

A few project team members and two people from the management of a faculty have access to Clocks and PIE.

Benefits

Implementing a system with which the schedulers can evaluate the space use of lecture halls has been identified as one of the measures that enable the university to move to a more efficient space use. The university intends to move from a policy of 0,9 education spaces/student to 0,81 education spaces/student. The pilot is not aimed at assessing what efficiency can be achieved, rather to get experience with the method and testing the results with Wi-Fi in a second building.

Side notes

The reason that this pilot is undertaken is because of the results in the proof of concept in the faculty of Industrial Design Engineering were not as positive as expected. The lecture halls showed promising results, but the other spaces in the building did not. Multiple causes were identified: an open central hall with multiple floors adjacent to it, the pedestrian flows in the hall and around the building, the layout of access points and the way in which the network allocates users to access points. The pilot in 3mE is a test to see if the results in another building are comparable.

UU **Universiteit Utrecht - Proof of concept Lone Rooftop**

phase **Pilot** — scale **2 buildings** — duration **start Q4 2017**

Project description

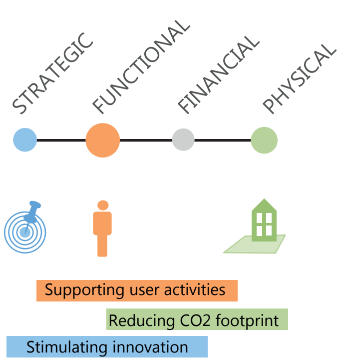
There is insufficient insight into the actual frequency and occupancy rates of the education spaces. Improvement in the education process requires actual insight into the space use of education spaces.

Foreseen developments

Using this kind of technology on a large scale at UU. Selecting a product, based on the experiences of this proof of concept.

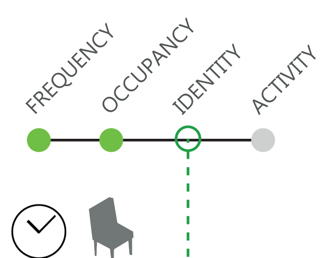
Profile

Why: Objectives



First the objective is to give insight into space use to improve the scheduling process. Then the idea is to apply this technology to improve the comfort of our users, save energy and strengthen the innovative character of UU.

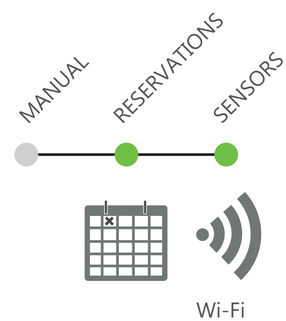
What: Measurement



A PIA has been made by an external bureau. Measures have been identified. A modification agreement has been made with the supplier. Communication with users.

The amount of devices on a certain location in the building. That is converted into an amount of people by an algorithm.

How: Measurement method



Wi-Fi registers both the amount of connected devices and attempts to connect to the network. Based on the signal strength between the device and the access points the location of a device can be pinpointed.

UU

Universiteit Utrecht - Proof of concept Lone Rooftop

functionalities
Monitoring space use

space types
Education spaces

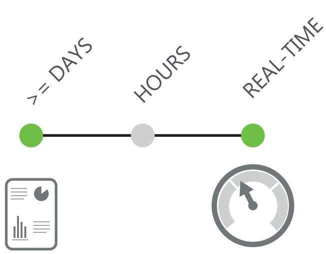
User information

Collecting frequency and occupancy data based on Wi-Fi signals and translating that to overviews displaying the amount of people per education space.

Management information

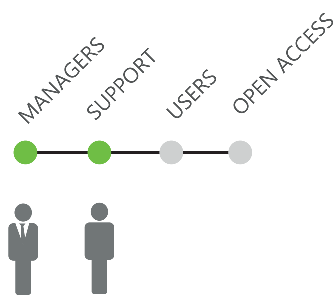
The report gives insight into no-shows, in frequency and occupancy of individual spaces. Information about space use through the day, percentage booked vs. in use, insight into the occupancy (efficient scheduling), information during a whole education period.

Actuality of the information



Dashboards displaying the current situation and reports showing the use over a period are required.

Access levels



Project team members

Benefits

-

Side notes

UvT **Tilburg University** **design brief**

phase
Design brief

scale
2 buildings
5.000 m2 (fase 1)

duration
expected

Project description

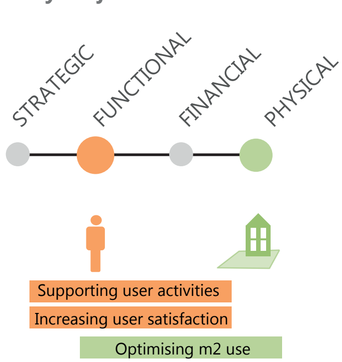
Students have no user-friendly tool to book meeting rooms. We want to increase the frequency rate in meeting rooms and increase the findability of free self-study places.

Foreseen developments

The proposition is to replace Web Room Booking and PC availability with this tool in time. The phasing proposal is to implement 5.000 m2 GFA in 2 buildings first, then to add +13.000 m2 GFA in a new building and finally to add +10.000 m2 GFA with the Library. That is four buildings with possibility for further expansion.

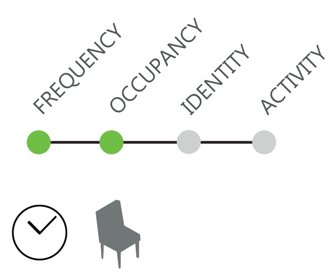
Profile

Why: Objectives



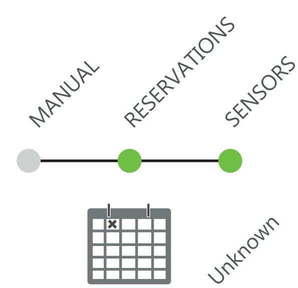
The priority per divisional unit of the university is different. A project initiation document is being drafted at the moment.

What: Measurement



Unknown, but frequency and occupancy are expected.

How: Measurement method



The design brief will state real-time measurement of space use, but it is unknown what sensor it will be.

UvT   Tilburg University   design brief

functionalities
Find a study place, room booking, monitoring space use

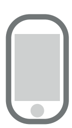
space types
Study places, meeting rooms, project rooms

User information
(unknown)

Management information
(unknown)

Actuality of the information

>= DAYS — HOURS — REAL-TIME



Access levels

MANAGERS — SUPPORT — USERS — OPEN ACCESS

Benefits
(unknown)

Side notes
(unknown)

De design brief will state real-time.

Unknown.

UT — Twente University — Research on adaptive scheduling

phase
Research

scale
5.360 m2 NFA
5 buildings

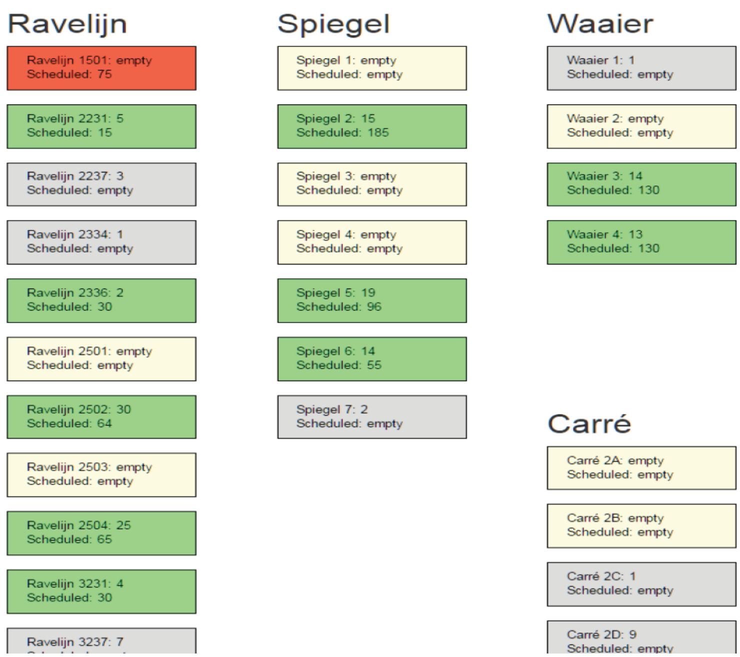
duration
Jan. 2017 - present

Project description

The research on adaptive scheduling is aimed at a concept of education logistics that supports interactive, project-driven learning. Based on the demand of students, a lecturer can choose an available appropriate space when needed - rather than planning a set of lectures in advance. In order to facilitate this, real-time insight into space use is needed.

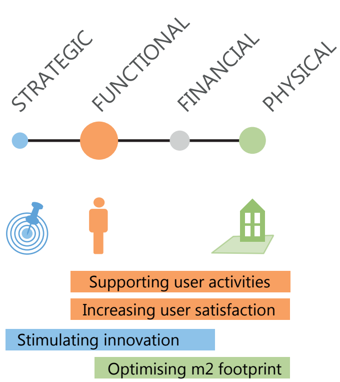
Foreseen developments

The researchers are also working on a method to assess a university timetable (or set of bookings) on suitability for the primary process to balance the current assessment method on efficiency.



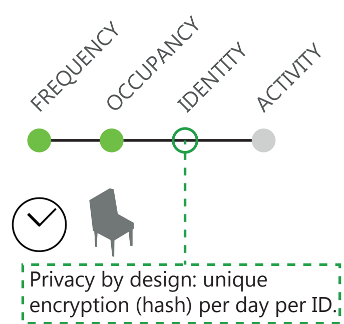
Profile

Why: Objective



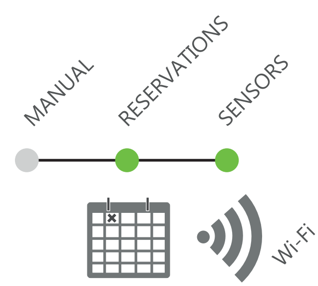
The objectives are achieved by changing the way in which scheduling takes place

What: Measurement



Wi-Fi measures the amount of connected devices located in various parts of the building. This is converted to a number of users by using the data from Eduroam. This number is used to capture frequency and occupancy.

How: Measurement method



Wi-Fi registers the number of registered and unregistered MAC addresses. Question to be answered is what method to use; access points or passive Wi-Fi sniffers.

UT | **Twente University** | **Research on adaptive scheduling**

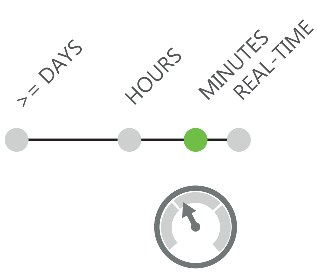
functionalities
Monitoring space use

space types
Education spaces

User information
The users (researchers and technicians) see a dashboard with an overview of the occupancy per space and information on if the space is scheduled or not.

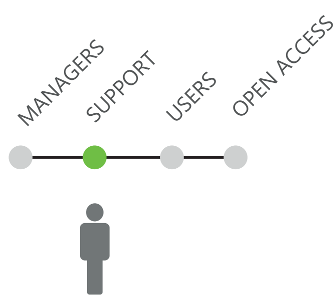
Management information
Same as above.

Actuality of the information



The displayed information updates every six minutes

Access levels



Researchers and technicians have access to the data.

Benefits
The benefit of the project is an solution to the problem of underutilised space and a way to facilitate the foreseen shift of education towards a more demand-based (learner demand) education programme.

Side notes
Different measurement methods are being piloted. At the moment ground-truth measurements are being conducted. We are getting an average of 80-97% accuracy, depending on the measurement method and the algorithm to interpret the data.

https://www.surf.nl/kennisbank/2017/optimaal-roosteren-op-basis-van-realtime-data.html

5.3. Cross-case analysis

In this chapter a number of insights are drawn up based on the data collected in the cases, which are shown in the previous chapter.

Cases focus on supporting students or improving space use; same solutions

The cases displayed reveal that the Dutch universities are focusing on two main problems in their portfolios. The majority of universities have chosen the same suppliers to tackle those problems, in contrast to the cases at international universities where this is more variable.

At TU Delft, University of Amsterdam and University of Tilburg they needed a solution to help students book rooms or classrooms on campus and/or find study spaces. At TU Delft and the University of Amsterdam this had led to an implementation of Mapiq as a solution; University of Tilburg is still in a design brief stage.

At TU Eindhoven, Wageningen University, TU Delft, and University of Utrecht a need is stated to optimise the use of spaces on campus, or at least to gain insight into the use of space. Wageningen University, TU Delft and University of Utrecht are in different stages of their projects with Lone Rooftop to address this problem, focusing on education spaces. TU Eindhoven has focused on study places, project rooms and meeting rooms and has selected Planon as solution.

The problem at VU Amsterdam is somewhere in between these two problems: it mentions both wanting to use the space on campus more efficiently whilst supporting its users. This has resulted in the development of StudySpot.

Finally, at Twente University a research project is done on a new way of scheduling at universities. The concept is to move towards a more demand-based curriculum where classes are held when demanded by project groups. This requires real-time knowledge of classroom availability, which is being developed and tested on campus by researchers.

Problems Solutions	Strong increase in amount of students; need to use space more efficiently; insufficient insight in space use	Optimising the use of existing space and facilitate primary processes	Desire from students to make (the location of) study places on campus visible	Lack of a user-friendly tool to book meeting rooms, find study places	Desire to improve Library services	Need to support a transition to interactive, project-driven learning
Smart tool that shows real time occupancy of education spaces	TU Delft (2), Utrecht University, Wageningen University					University of Twente
Smart tool that allows users to reserve rooms and workplaces	TU Eindhoven					
Smart tool that shows spaces in building and book project rooms					TU Delft (1)	
Smart tool that shows study spaces in building, available classrooms to study in and book project rooms			University of Amsterdam	Tilburg University		
Smart tool that shows available classrooms to study in and book project rooms		VU Amsterdam				

Table 5.3 – Different problem-solution relationships across cases

Timeline shows large number of implementations in 2015-16

When looking at the timeline of the nine cases collected at Dutch universities, it reveals that the majority of the cases (5 out of 9) are in the implementation phase and that these cases have all been implemented in the past three years. When these smart tools were first surveyed, in March 2016, a lot of them had just been implemented.

Because the timeline only displays the cases that are shown in chapter 5.2, there is only one design brief, one research project and two pilots in the timeline. However, the output of the meeting of Dutch universities (see chapter 5.4) reveals that there is much more activity in terms of pilots projects and design briefs.

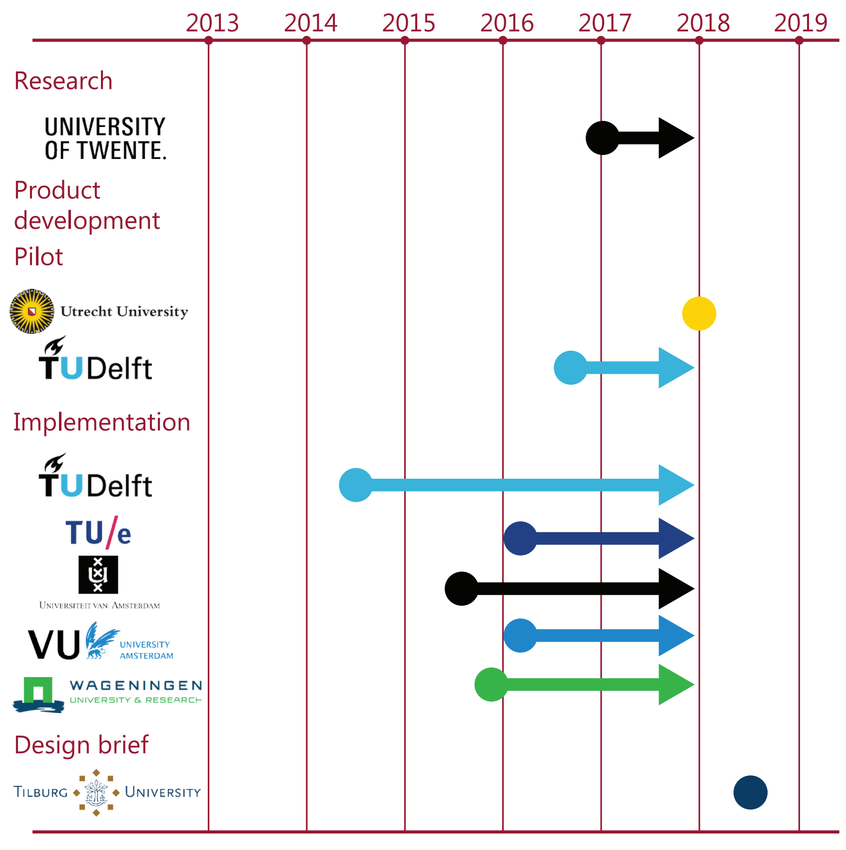


Figure 5.2 – Timeline of smart tools

Foreseen developments: further expansion, more sensors and linking systems

The foreseen developments in the nine cases can be divided into three groups. Firstly a number of universities wants to further expand their (intended) solution over the campus: Utrecht University, TU Delft and Tilburg University mention this.

Secondly, some universities mention adding more sensors to their existing smart tools. TU Delft mentions the possibility of adding more sensors to their application of Mapiq in the Library; VU Amsterdam also mentions adding sensors as a possibility. TU Eindhoven is doing a pilot with sensors on workplaces in one building. The University of Amsterdam will start experimenting with the use of Wi-Fi to give insight into space use with Mapiq. Wageningen University wants to improve the accuracy of their occupancy measurement in small areas in buildings, perhaps by using other sensors.

Finally, a number of universities mention the creation of a link between systems. The University of Amsterdam and TU Eindhoven both want to link their application to their scheduling system (Syllabus, of Scientia). WUR is looking if the Wi-Fi data can be used as input for the building management systems on campus.

Costs – difficulty to obtain comparative data

With regard to investment and operating costs it was not possible to gain data in all available cases. Because of this and the request of some cases to treat the information anonymously, the information has been omitted from the case data reported in the chapter 5.2. Instead, an anonymised comparison is given across all cases (chapter 3, 4 and 5) in chapter 6.

Benefits: different ways to measure how users activities are supported

During the data collection process it was decided to add a question to the templates, being: "What objectives are defined to be achieved with the tool, and what is the progress on these objectives since implementing the tool?" This question was added to gain insight into the key metric(s) which organisations report on in order to assess to what extent their smart tools are successful.

For seven out of nine cases data was collected with regard to the way in which universities report on the benefits of their smart tools. Utrecht University and Tilburg University have not yet formulated objectives.

What stands out when looking at the benefits is the difference in how use of the smart tools that support students are monitored. The University of Amsterdam looks at the amount of reservations made per month as an indicator, which after expanding the solution to 4 building has increased from 1600 reservations per month in 2 buildings to 3400 per month in 4 buildings and is still rising. VU looks at the amount of visitors on Studyspot per month, and also uses short surveys to determine the user satisfaction. TU Delft specifies that students are satisfied with the solution, but not how this is determined.

With regard to optimising space use Wageningen University indicates that their first experiences are a 5-10 percent improvement in space efficiency, and they expect this to increase after implementation of a new schedule. TU Eindhoven set an objective to increase the frequency rate of meeting rooms and the occupancy rate of workplaces by 10% within four years. After one year the increase is already 13%. TU Delft mentions that the smart tool must help in a space use of 0,9 seat per student to 0,81 seat per student, which is a 10 percent improvement in space efficiency – however it has not been implemented yet. Here more quantitative objectives are formulated and evidence is available to monitor the objectives set prior to implementation of the smart tools.
Finally, Twente University's research project will have the benefit of enabling a transition towards a different way of planning and providing teaching space.

Objectives

The interviewees were asked to state to which objectives their smart tools or intended smart tools contributed. For this question the framework developed by Den Heijer et al. (see chapter 1) was used: this framework states the objectives through which the campus adds value to the university. The results are displayed in figure 5.3. For some smart tools the stated objectives can be different than in the previous research because the question was answered by other respondents or because of new insights.

Functional objectives are mentioned most, after which physical objectives are mentioned most: the former in 5 out of 9 cases, the latter in 4 out of 9 cases. The universities are also split in which objectives they prioritise – in three cases they prioritise functional objectives and in four cases physical objectives are prioritised. Financial and strategic objectives are only mentioned scarcely.

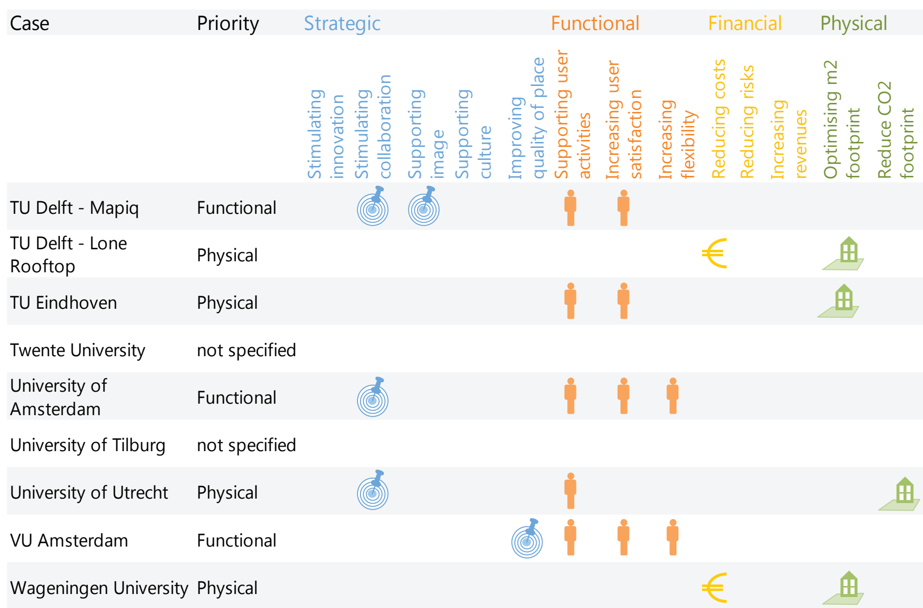


Figure 5.3 - Cases and the amount of objectives they contribute to per category

Measuring space use: almost all cases measure both frequency and occupancy data

The measurement of space use is in almost all cases done both on the level of frequency and occupancy. In the applications which monitor the use of education space – TU Delft, Twente University, University of Utrecht and Wageningen University, frequency and occupancy are both measured via Wi-Fi.

Case	Privacy	Frequency	Occupancy	Identity	Activity
TU Delft - Mapiq	Not applicable	✓	✓		
TU Delft - Lone Rooftop	IP addresses are anonymised differently each day. Also anonymisation is done before the data leaves the university network.	✓	✓		
TU Eindhoven	Not applicable	✓			
Twente University	Privacy by design: unique encryption per day per ID.	✓	✓		
University of Amsterdam	Not applicable	✓	✓		
University of Tilburg	Unknown	✓	✓		
University of Utrecht	A PIA has been made by an external bureau. Measures have been identified. A modification agreement has been made with the supplier. Communication with users.	✓	✓		
VU Amsterdam	Not applicable	✓	✓		
Wageningen University	IP addresses are anonymised differently each day. Also anonymisation is done before the data leaves the university network.	✓	✓		

Figure 5.4 - Cases and the ways in which they measure space use. If applicable, privacy issues are addressed.

In the cases where other space types are monitored – TU Eindhoven, TU Delft (Library), University of Amsterdam, and VU Amsterdam, both frequency and occupancy are measured but depending on the space type. Frequency is measured for meeting rooms and project rooms whilst occupancy is measured for study places.

Only in the cases where Wi-Fi is used privacy is an issue. The way in which the Dutch universities deal with this issue is the same: via on-site anonymization and designing the way data is anonymised.

Measurement methods

Many different measurement methods are used in the cases. This is specified in figure 5.5, where the measurement method is specified in terms of what type of sensor is used and what the specific application is.

Case	Measurement method	Manual	Reservations	Sensors
TU Delft - Mapiq	The data source used is reservations, from the reservation system of Mapiq. Infrared sensors have been added on 100 workplaces; they measure activity on that workplace. 10 infrared sensors have been added to meeting rooms; they measure activity in the room		Self-booking tool	Infrared
TU Delft - Lone Rooftop	Wi-Fi registers both the amount of connected devices and connection attempts. Based on the signal strength between device and access point the location of a device in the building can be pinpointed.		Schedule data	Wi-Fi
TU Eindhoven	Reservations are made via Planon. Infrared sensors that are connected to the lighting, detect presence in meeting rooms which indicates if a reservation is used. In addition manual counts are done (separately) in the education spaces.		Self-booking tool; checkin via QR codes	Infrared
Twente University	Wi-Fi registers the number of registered and unregistered MAC addresses. Question to be answered is what method to use; access points or passive Wi-Fi sniffers.		Schedule data	Wi-Fi
University of Amsterdam	Booking data is used from Mapiq and from Syllabus to show availability. Desktop PC usage is logged in order to show occupancy per workplace.		Self-booking tool; schedule data	PC login
University of Tilburg	The design brief will state real-time measurement of space use, but it is unknown what sensor it will be.		Schedule data	Unknown
University of Utrecht	Wi-Fi registers both the amount of connected devices and attempts to connect to the network. Based on the signal strength between the device and the access points the location of a device can be pinpointed.		Schedule data	Wi-Fi
VU Amsterdam	The booking data from Study Spot and Syllabus are used to show if education spaces and project rooms are in use. PC login data is used to show occupancy data of PC halls.		Self-booking tool, Schedule data	PC login
Wageningen University	Wi-Fi determines where devices are within the building (active and passive). Via an algorithm devices are paired if the algorithm determines they belong to one user. That is how the amount of users in a zone is determined.		Schedule data	Wi-Fi

Figure 5.5 – Cases and the sensors they use to measure space use (or other space properties).

From the figure it becomes clear that all cases rely on data from reservation systems: schedule data, self-booking systems or both. Furthermore all systems use one type of sensor. Infrared sensors, Wi-Fi and PC login data are used to measure space use.
Again a separation is visible between the cases that are aimed at monitoring space use of teaching space and the cases that are focused on study space: the former uses Wi-Fi as sensor whilst the latter uses PC login or infrared data.

Actuality of information

The information reported in figure 5.6 again reveals that the properties of the user information and management information across cases are similar. Most cases (5 out of 9) report management information in both a dashboard and report functionality. The dashboard focuses on the current data whilst the reports function focuses on a longer time period. The way users can access information is different – some cases use user apps, others use webpages, and at TU Eindhoven also kiosks in buildings are mentioned.

Case	User information	Management information
TU Delft - Mapiq	De displayed information on the webpage is near real-time.	The PowerBI dashboard displays real-time information; The reporting function shows real-time data until as far back as possible.
TU Delft - Lone Rooftop		PIE displays real-time data. The information in Clocks is visible real-time; for lectures currently underway a tentative frequency and occupancy is shown. The report shows data per period.
TU Eindhoven	Information on the selfservice, app, and the kiosks is real-time.	Reports are available on demand. Dashboards need to be used more in the future.
Twente University		The displayed information updates every six minutes
University of Amsterdam	The displayed information in the webpage is real-time.	The PowerBI dashboard displays real-time information; The reporting function shows real-time data until as far back as possible.
University of Tilburg	The design brief will state real-time.	
University of Utrecht		Dashboards displaying the current situation and reports showing the use over a period are required.
VU Amsterdam	The information displayed in the app is real-time.	
Wageningen University		The information displayed in PIE is near-real time. The data used in reporting goes from real-time to as far back as possible.

Figure 5.6 – Cases and actuality of the information reported

Access levels

The way in which access levels are specified per case are quite different, in contrast to findings on other aspects of the smart tools.

With regard to the accessibility of smart tools that help students find available space, the information is either open access or restricted to students and employees of the university. In some of these cases it is also specified how the access of management information is organised, whilst in others it is not. At TU Eindhoven and University of Amsterdam this is because this component is still being developed or needs to be used more.

Case	Specification	Managers	Support	Users	Open access
TU Delft - Mapiq	De blueprints, location of each space and availability is visible for everybody. Reservations can only be made by students and employees (via NetID). Support staff can access a backend to the booking tool. PowerBI functions can be accessed by specific individuals.	✓	✓	✓	✓
TU Delft - Lone Rooftop	The scheduling team has access to Clocks. A few project team members and two people from the management of a faculty have access to Clocks and PIE.	✓	✓		
TU Eindhoven	Students and employees have access via Selfservice, an App, Outlook and the Kiosks in the buildings. Secretaries have access to reservations via Planon Procenter.		✓	✓	
Twente University	Researchers and technicians have access to the data.		✓		
University of Amsterdam	The floor plan and location of spaces is visible to everyone. Room bookings can only be made by students and employees (via UvA netID).			✓	✓
University of Tilburg	Unknown				
University of Utrecht	Project team members	✓	✓		
VU Amsterdam	Access to StudySpot is restricted via VUlogin.			✓	
Wageningen University	PIE is available to location managers; Clocks is available to schedulers. PIE and Clocks are available to specific people from Facility Services.	✓	✓		

Figure 5.7 – Cases and access levels

In the cases where education spaces are monitored usually both support staff and campus management have access to the reporting functions. This is organised differently per case, depending on the implementation phase. At Wageningen University location managers and schedulers have access to different parts of their smart tool. At TU Delft this is restricted to a few people of the scheduling department and a few faculty members. At University of Utrecht it is only available to project team members.

5.4. Updating our research via the Smart campus tools meetup

On November 15th 2017 we organised a joint meeting for all Dutch universities on the subject matter together with colleagues from TU Delft's real estate department, to share knowledge and experience gained in practice and insights from our research up to that point. The meeting was attended by over thirty people from nine different universities, including practitioners from IT, education services, policy makers, facilities management and real estate management. The meeting was hosted in the Teaching Lab at TU Delft.

Aside from the presentations given per university, of which the results have been discussed in the previous chapters, a number of topics were discussed.

Figure 5.8 – Presenting the preliminary research results

Joint procurement

In a recently published report by Dutch research networking organisation SURF on location-based services one of the recommendations was to procure these services jointly. The positive aspect of joint procurement is that it would allow the universities to apply more pressure on suppliers to meet their requirements. A possible drawback is that the organisational structures of universities are quite different, which would result in a procured solution that does not fit any of the parties perfectly. The option of procuring in a small group of a few universities could be a feasible solution.

Benefits

Another topic that was discussed at length is what the objective of the smart tool is and why some universities are not yet monitoring if that objective is achieved. Especially when it comes to user satisfaction universities struggle with collecting evidence to monitor the implementation of their smart tools: evidence that is necessary to find a balance between the occupancy of buildings and satisfaction of users.

Implementing smart tools within the organisation

An important aspect that needs to be taken into consideration when defining the benefits is how to implement smart tools in the organisation. One of the practitioners put this as follows: there is an measurement problem (how accurate are the measurements), a tooling problem (what should the interface look like) and an implementation problem (what is the objective and how is it achieved). In a smart tool that monitors the space use of teaching space it is essential to identify what needs to be changed in the organisation and its work processes in order to make a better schedule next year. In a smart tool that helps students find available space it is essential to identify how to maximise the use of these tools by students and what the rules are: e.g. what are the rules for making reservations or occupying study places.

5.5. Conclusion

The question to be answered in this chapter is: What development have the Dutch universities made in comparison to the previous findings?

To answer this question, the Dutch universities were asked to update the data collected in the previous research to fit the data collection format and to include the development of the past 1,5 years. This has resulted in nine cases to be compared. In addition a meeting was held on November 15th 2017, in which the universities presented and discussed their progress on the topic.

Smart tools to find available study places – and teaching space to study in

At three Dutch universities (VU Amsterdam, University of Amsterdam, TU Eindhoven and TU Delft) smart tools are being used to help students find a place to study on campus. These smart tools offer either the possibility to book rooms or information on the availability of study places with desktop PCs. What makes the smart tools at VU Amsterdam and the University of Amsterdam particularly interesting is that they offer students to study in teaching space by showing if rooms are available. This information is based on the timetables of the university. The findings in other cases reveal that other universities in the Netherlands are considering similar applications.

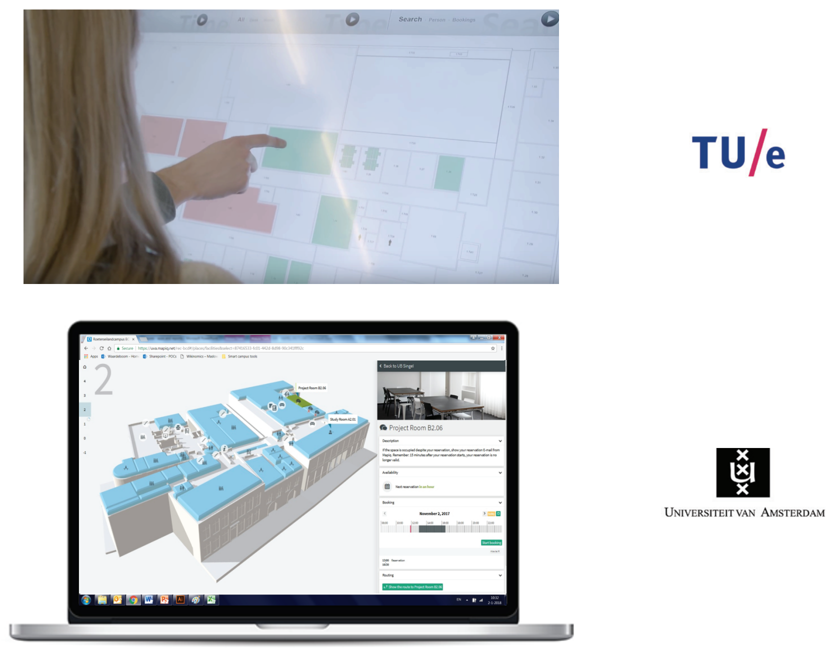


Figure 5.9 – Smart tools to find available study places at TU Eindhoven and the University of Amsterdam

Smart tools to optimise the use of teaching space

Wageningen University monitors and improves the use of teaching space across campus. Using Wi-Fi data from the university's campus network the frequency and occupancy rates are determined per activity in the university's schedule. Again, the findings in other cases reveal that other universities in the Netherlands have started to do this as well or are considering a similar application.

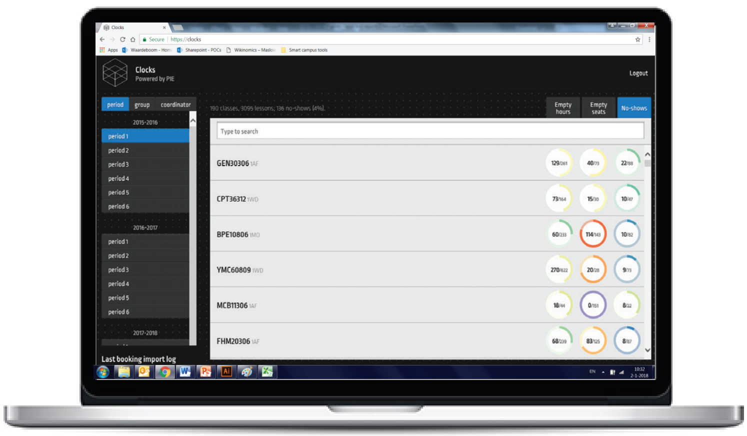


Figure 5.10 – Using a smart tool to optimise teaching space at Wageningen University

Findings from the cross-case analysis

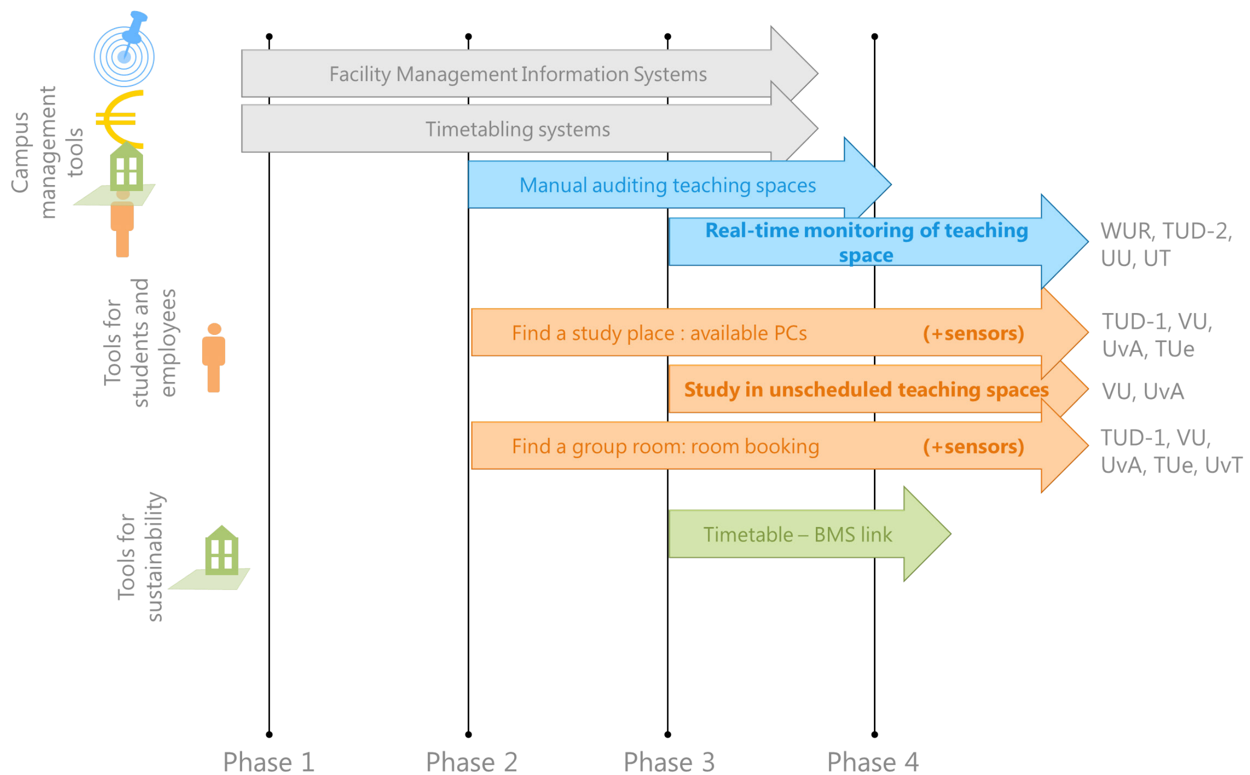
These nine cases reveal that the Dutch universities have quite similar problems and similar solutions. Figure 5.11 shows an overview of what they are working on, when positioned in the current state of smart tools and next steps of the previous research – see also figure 2.3 and 2.4 in chapter 2. The smart tools that Dutch universities are currently working on, and are included as cases in this chapter, focus either on real-time monitoring of teaching space or on smart tools supporting students, in which multiple functions are brought together. Previous research concluded that by looking at all available smart tools –which includes more room booking apps and available PC apps- the focus of smart tools was for the largest part to add value by supporting students.

Furthermore, the following conclusions can be drawn with regard to these nine cases:
The cases focus on improving space use or supporting students, developing or implementing the same solutions.

- Six of the nine surveyed tools were already in use before the start of 2017, and a majority of the applications are in an implementation stage. One case is in the design brief stage, two cases in the pilot stage and one in a research stage.
- Foreseen developments focus on further expanding the solution across the real estate portfolio, adding sensors to existing solutions and linking the smart tool to scheduling systems or building management systems.

- The benefits for smart tools that monitor the space use of teaching space are set prior to implementation and can be reported on. For tools that support students these objectives are harder to define prior to the implementation and monitor during the implementation; this is also confirmed at the joint meeting (see ch. 5.4)
- The cases are mostly aimed at adding value through functional objectives, but physical objectives (optimising m2) are also mentioned often.
- In each case space use is measured in frequency and occupancy.
- All cases use scheduling data in their smart tools and one type of sensor. Wi-Fi, infrared sensors and PC login data are used to measure space use.
- Information is provided in near real-time to users, via websites or user apps. The requirements for management information vary in the sense that both dashboards and reports are used as output.
- User information is either open access or restricted to university users. Access to management information varies across cases.

Figure 5.11 – Overview of available smart tools. Phase 1: no smart tools; phase 2: prevalent smart tools in 2016; phase 3: new smart tools in 2016; phase 4: ongoing smart tools in 2017.



Additional findings

The joint meeting of the Dutch universities resulted in the following findings and recommendations:

- Further attention needs to be paid to a method to monitor user satisfaction of smart tool implementations.
- The relation between the organisation and the smart tool that is implemented is very important when defining the benefits to be achieved with the smart tools.
- Joint procurement with a few universities that have a similar demand could be an option that might be worthwhile to explore further.

Chapter 6
Synthesis

In chapter 6 all the findings of the research are brought together in a synthesis with the objective of providing a practical guide to the topic of smart campus tools. This is done by using a combination of the output from interviews, reading literature and experience from practice.
The chapter includes the following components:

Generic information applicable to smart campus tools (6.1-6.2)
- Aspects relevant to implementing smart campus tools
- Comparison of costs and m2

Specific information per case type (6.3-6.8)
- Smart tools to find available study places
- Smart tools to optimise teaching space use
- Smart tools to share teaching space for studying
- Smart tools to find shared workplaces
- Smart tools to align building use and energy use
- Smart tools to improve meeting room use

Chapter 6.3 to Chapter 6.8 are structured by using the process framework for campus management (see chapter 1.2). For each case type the following aspects are described using the information collected in chapters 3-5:
- Current mismatch. A description is given on the developments that have led to the implementation of the smart tool
- Future mismatch. Information on future developments that might impact the need for the smart tool are identified.
- Selecting alternatives. Information is given to support decisions on selecting smart tools, primarily with regard to the types of sensors used in relation to the specific function(s). This complements the content of chapter 6.1, which is not dependent on the intended function(s) of the smart tool.
- Planning the transformation. In this step recommendations are given related to the implementation of the smart tool: which parties to include, what steps need to be taken to achieve the expected benefits of the smart tool, what side effects of the implementation could be and how the data could additionally be used.

6. Synthesis – practical guidelines to smart campus tools

6.1. Aspects relevant to implementing smart tools

Before describing the different types of cases found in this research and their specifics, this chapter describes information relevant to the implementation of all smart tools. In the cases you will find that the available information focuses largely on characteristics of smart tools: what are their objectives, how do they measure space use, what information is provided to the user etc. These (functional) characteristics help to select smart tools based on what functions they provide. This is already a difficult task: information on cost-benefit relationships of smart tools is limited and due to the fast-developing market also very uncertain, which makes it difficult to construct good business cases.

However, practitioners have also indicated that attention to other aspects is needed, i.e. what efforts need to be taken to implement a solution. We assess sensor types by three interrelated efforts: legal, organisational and technical efforts.

- Legal efforts concern the activities that need to be undertaken to comply with privacy law – or the amount of effort required to comply with privacy law;
- Organisational efforts concern the need to inform stakeholders in the organisation and the amount of effort required from the organisation to implement a solution;
- Technical efforts concern the efforts required from the organisation to install and maintain the infrastructure.
- Each of these efforts is described in more detail below.

Technical effort

In order to assess the technical effort required to implement a smart tool, a categorisation of implicit and explicit measurement by Christensen (2014) is used. With implicit measurement it is meant that a sensor is used to measure something for which it is not designed – e.g. a CO2 sensor is also used to infer frequency. These ranks show a varying degree of implementing additional infrastructure, which is associated with a higher technical effort.

Categories	Examples of Activities
0 – No amendment to existing systems, except in the collection and processing of data. (e.g. using access gates)	• Unlocking/linking the data to other systems
1 – Adding software to existing systems to generate data (e.g. using Wi-Fi to estimate occupancy)	• Acquiring additional software or licenses • Calibration of the software
2 – Adding hardware and software to existing systems to add new sources of data	• Installing the sensors; e.g. need for power outlets, ethernet connection • Maintaining the sensor infrastructure • Recording infrastructure in information systems and building schematics

Table 6.1 – Assessment matrix of technical effort

Legal effort

In order to assess what legal conditions need to be satisfied with smart campus tools, the EU's General Data Protection Regulation (GDPR) has been used. A brief summary of the GDPR can be found in the appendices. The table below states four different categories of data collection in smart tools and what efforts might be needed to satisfy the GDPR conditions.

Categories	Activities
0 – GDPR requirements that in any case need to be fulfilled	• Hire a data protection official (2a) • Compose a registry with all processing of personal data (3a) • Write an organisational privacy policy (3b) • Secure personal data (3c, in relation to 3a) • Enable users to easily enforce their rights stated in (4a-e)
1 - Minor. Personal data is used, e.g. login data to gain access to smart tool	(In addition to 0) • Argue the need to collect this data based on an agreement (1d) – in order to restrict access to the application for users, a login portal is needed • Even in minor cases of personal data use by third parties (i.e. login data), a data processing agreement with the supplier of the smart tool is necessary. (3c, 4a-e) • Add case to existing documents (3a, 3b)
2 – Uncertain. Personal data is collected, but anonymised.	(In addition to 0) • Justify if the need to collect the data applies via user permission or legitimate interest (1a or 1f); In case of user permission, ensure that the conditions are met • Assess whether privacy by design (2b) is met • (Optional) Conduct a DPIA (2c) • Sign a data processing agreement with the supplier of the smart tool (3c) • Add case to existing documents (3a, 3b)
3 – Extensive. Personal data is collected and used.	(In addition to 0) • Justify if the need to collect the data applies via user permission or legitimate interest (1a or 1f); In case of user permission, ensure that the conditions are met • Assess whether privacy by design (2b) is met • Conduct a DPIA (2c) • Sign a data processing agreement with the supplier of the smart tool (3c) • Add case to existing documents (3a, 3b)

Table 6.2 – Assessment matrix of legal effort. The numbers refer to content that can be found in the appendix (N.B. this matrix is drafted to give an indication of the workload associated with the implementation of certain smart tools. For exact instructions consult a legal expert)

Organisational effort

In order to assess what the organisational effort would be to implement a solution, the level of (perceived) intrusiveness is assumed to be the primary yardstick. Intrusiveness is linked to privacy, but not exactly the same – a person can experience a sensor as being intrusive. An example is the use of cameras that process imagery directly and send anonymous output (i.e. user count) and do not store images. It is important to avoid misconceptions of what sensors register. For example, practitioners even mention examples of students asking questions of what a PIR sensor under a desk can see. Furthermore, the level of intrusiveness of sensors can influence the implementation process in other ways, e.g. more stakeholders that want to be informed and consulted in the process

The activities described in the table are in addition to any measures that should be taken in order to satisfy legal requirements.

Categories	Examples of Activities
0 – Sensor not regarded as intrusive, no personal data collected	• Notify representative student and employee bodies
1 – Sensor not regarded as intrusive (or not recognised as sensor), but data collection regarded as intrusive	• Involve representative student and employee bodies in design and decision-making process • Provide information to students and employees prior to implementation
2 – Sensor regarded as intrusive	• Involve representative student and employee bodies in design and decision-making process • Provide information to students and employees prior to implementation • Provide access on-site at sensors to additional information, e.g. via QR codes

Table 6.3 – Assessment matrix of organisational effort

Assessing the effort required to implement smart campus tools

The tables from this chapter can be combined to make an assessment of available alternative smart tools that the organisation is considering. See for example table 6.4. The higher the total sum of efforts in the table is, the more time it will take to implement a solution and the more workload it will require from the organisation. It is important to be aware of these efforts prior to implementation.

Required solution	Real-time occupancy of study places located in large rooms	
	Smart campus tool 1	**Smart campus tool 2**
Sensor used	Wi-Fi	PIR workplace sensors
Legal effort	2	0
Organisational effort	1	1
Technical effort	1	2
Total costs	x	y

Table 6.4 – Example of a comparison between two alternatives

6.2. Comparison of costs and m2

In the for all the cases collected the amount of investment costs and operating costs per m^2 GFA were asked. In the format the costs associated with investment and operating costs were specified. At the outset of the research the idea was to use this data to see if there were any relations visible between the amount of m^2 covered by a smart tool implementation, the costs and perhaps the type of application. However, for various reasons it was not possible in all cases to retrieve this data.

Smart tools are a relatively small part of total RE costs

Based on the data that was collected, an attempt has been made to create benchmarks in which practitioners can position their implementations. Figure 6.1 shows the collected data on investment costs per square meter GFA. The data points show quite a large variance –from €0,7 per m^2 to €18 per m^2. Obviously the solutions that include investment in sensor infrastructure are those which have a higher investment cost.

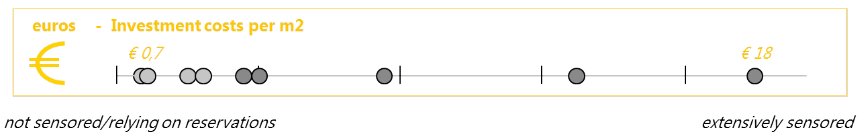


Figure 6.1 – Overview of data on investment costs/m^2 – dark coloured data points include real-time data.

The data on operating costs per m^2 is displayed in figure 6.2. Unfortunately very little data was collected on this variable. A lot of the projects that were not in the implementation phase were not able to report on the operating costs yet, whilst others chose not to disclose this data. The collected operating costs vary between close to € 0 to € 1,9 per m^2. Different reasons can be found to explain high or low operating costs. Self-developed software is typically found to have very low operating costs, whilst third-party solutions usually have high operating costs. The data point on the far right is a pilot project in a part of a building, which means that in the implementation stages the operating costs per m^2 might be much lower.

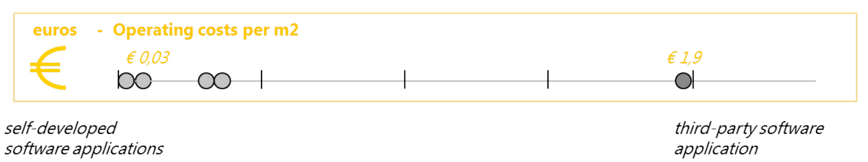


Figure 6.2– Overview of data on operating costs / m^2 on which the smart tool is implemented – dark coloured data points include real-time data.

When comparing these numbers with benchmarks on workplaces costs - for example the Netherlands Facility Costs (NFC) Index, which lists the annual costs for a m^2 education space at € 189 per m^2 GFA per year in 2015 – the costs associated with smart tools are (by estimation) a factor 10 smaller.

The annual costs can also be used to estimate what the benefits might be. The tangible benefits mentioned in the various cases in chapter 3, 4 and 5 include energy savings and opportunity costs due to increased frequency and occupancy rates. If the costs of smart tools are a tenth of the total costs of a workplace, then a 10 percent more efficient use of space would be enough to offset the costs.

Of course, intangible benefits such as user satisfaction and student or employee productivity further influence the balance of costs and benefits. The emphasis of many cases on these benefits suggests that the added value of effectively supporting users on campus might even be greater than that of using space more efficiently.

Smart tools implemented on small part of RE portfolio

In addition to the data collected on costs, for some of the cases also data was available on the % of the real estate portfolio that the smart tool was implemented on. The data of the amount of m^2 that the smart tool covered, was asked for each case. The data of the total portfolio size was in some cases delivered by the interviewee, in other cases data was used from the research group's European Campus and Campus NL projects.

Figure 6.3 shows the % of the portfolio covered with smart tools. The vast majority of the cases for which the data is available have implemented smart tools in one building or a few buildings, covering between 1 and 10 percent of their total portfolios. This includes most of the cases in pilot, research and living lab stages. In addition, of the smart tools including sensor data are found to be in this range. One of the cases has implemented a sensored solution across 15 percent of their portfolio. Then, a number of cases are found of smart tools relying on reservation data that are implemented across much larger ranges of the real estate portfolio – 34, 58 and 71 percent respectively.

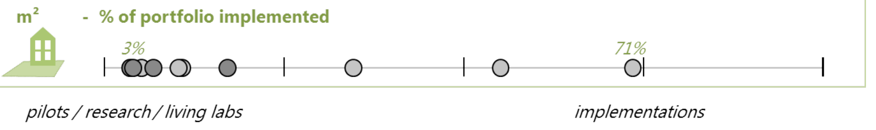


Figure 6.3 – Overview of data on % of RE portfolio on which the smart tool is implemented – dark coloured data points include real-time data.

6.3. Smart tools to find available study places

This first subchapter describes a smart tool that offers information on the real-time availability of study places for students. Table 6.5 lists the properties of these cases. In this research the cases of University of Leuven and TU Eindhoven are the main references.

Availability of study places	
Implementations	KU Louvain, TU Eindhoven, TU Delft
Future cases	Aarhus University, DTU, Tilburg University
Additional references	Cambridge University
Components of problem statement	There are not enough study places in the main library; Students have difficulty finding their way on campus; The service delivery of library needs to be improved; Strong increase of students and a need to increase the amount of students per m2;
Components of the solution	In addition to providing real-time information on the availability of study places on campus, the smart tool can provide: - Location of study places on campus - Availability of small group study rooms
Benefits	Better spread of occupancy rates across campus locations; Increased user satisfaction; Increase in amount of bookings per month; 13 percent increase in occupancy rates of workplaces and frequency rates of small group study rooms;
Objectives	Primarily supporting user activities, increasing user satisfaction, increasing flexibility.
Space use measurement	Occupancy of study places; frequency of group study rooms.
Measurement method	Access gates, infrared sensors, iBeacons for study places, workplace reservations Reservation systems for group study rooms
Actuality of information	Real-time information for users. Reports are from real time to as far back as possible, but are not available in all cases.
Accessibility of information	Either open access or restricted to university users.

Table 6.5 – Properties of cases of smart tools that show availability of study places.

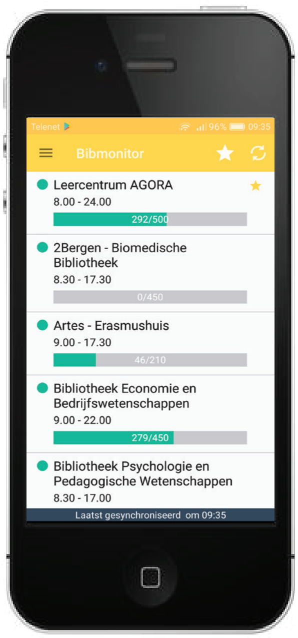
Current mismatch

Due to the increasing demand of students to study on campus there is increasing pressure on the existing study places offered by universities. Students perceive a shortage of study spaces when they are unable to find an available place. Universities provide study places according to norms. Especially at Libraries a shortage of study places is felt, a place which students most commonly go to either because they expect there to be study places or because they want to study quietly.

For universities making decisions on study places is hard, because there is little to no evidence to support these decisions. How well are study places used? What study places do students prefer? For students finding a study place is hard, because information on the location of study places is not always available, leaving them to depend on their knowledge of where study places are. Offering students information on the availability of study places not only shows them where study places can be found, but also helps to collect evidence on the use of these study places.

Future mismatch

The demand for study places could increase further if the university decides to move to project-based learning models. Furthermore, if the amount of students studying on campus increases and studying on campus leads to better study results, then the amount of study places required per student will increase. An average student in the total student population will study for a shorter duration, but be present on campus to study much more often than at present. A decrease in the demand for study places could be caused by the increasing use of spaces not provided by universities, such as the spaces mentioned in chapter 3.4.



KU LEUVEN

Figure 6.4 – Using a smart tool to show study place availability at University of Leuven

Selecting alternatives

A smart tool that helps students to find available study places can lead to both an increased user satisfaction and an increase in the occupancy rates.
When considering this type of smart tool the most important aspect to decide on is what sensor to use. This will depend on the situation of study places on campus. If all or a large majority of study places are clustered in separate buildings then the use of access gates is an interesting option. The total amount of people present in the building is then compared to the total capacity of the building. However, this does mean that access to public buildings is restricted.

If these buildings are entirely in use by students Wi-Fi could also be used to get this number, or if study places are located in large rooms (>50 study places) across campus. There are no cases in which this has been applied though. If the study places are scattered across campus in small amounts than iBeacons are probably the preferred sensors. In the case of Aarhus University might provide experience of such an application. An alternative is the use of workplace check-in, which is used at TU Eindhoven to reserve study places.

This information might also be used to inform the design of buildings: what is the preferred way to locate study places if we want to use a certain technology?

Planning the transformation

In order to implement the solution within the organisation a number of recommendations are made.

In the preparatory stages...

- It is wise to include student bodies in formulating demands. The increasing amount of smart tool references will help to reduce the amount of time needed to do this.
- The implementation of these type of smart tools will be supported by student bodies, although too much focus on improving the efficiency of space use will raise concerns. However, the implementation can help to generate evidence to discuss these issues, as can benchmarking with other universities.

In order to achieve an increased user satisfaction and (if desired) an increased occupancy of study places...

- The results from chapter 3 and 5 show that with regard to user satisfaction there is not really a common method to set objectives for user satisfaction and evaluate those objectives. Having such a method and collecting the information will help universities make decisions on smart tools as well as learning more from other cases how they can most effectively support their students.
- Student bodies can help to increase the use of the smart tool by students, which will increase the overall user satisfaction and frequency and occupancy rates
- After implementation a place is needed where students can give feedback; either third party or by the university
- Information on the availability of study places can lead to issues relating to behaviour: e.g. students who occupy a spot with their laptop or books but are out for lunch will not be counted by the smart tool, although the place will seem occupied. Establishing rules for the fair use of study places is important to avoid frustrations and to make sure that everyone follows those rules
- Campus management will have to analyse the space use data resulting from the

smart tool and translate it to actionable information. This data analysis requires specific skills. A common practice in defining and setting a desired values for study place occupancy and sharing what decisions are made based on this data could be very valuable.

Side effects of the implementation can be...

- Information on the availability of study places can lead to a further increase of students studying on campus: students who would fail to find a study place and go home can now find a study place on campus.Increased use of study places might lead to higher operational costs: e.g. costs to extend opening hours or increase the frequency that study spaces are cleaned.

Additional use of data...

- Using occupancy rates (per zone or per building) to research what types of study places are used best and which places can be improved.
- When using access gate data it is possible to conduct a study of the relation between studying on campus and study results.

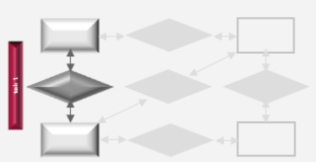
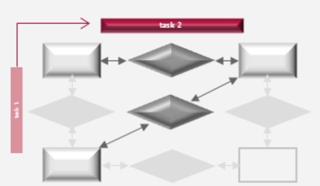
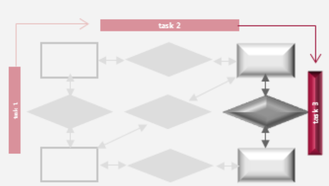
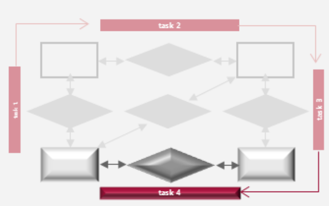
Smart tools to find available study places	
	1. Determining the current match: “what we need” versus “what we have” Demand: a large need for study places, as perceived by users Supply: study places on campus, provided according to norms Mismatch: Absence of real-time data to help students find available study places; absence of reporting on space use to help decision makers evaluate norms.
	2. Determining the future match: “what we (might) need in the future” versus “what we have now” A possible further increase of the demand, due to a change in learning models and/or increase of student performance.
	3. Weigh and select alternatives for “what we should or could have” Selecting the type of sensor depends on the situation of study places on campus. Clustered study places can be measured via access gates or maybe via Wi-Fi. Scattered study places can be measured via iBeacons or workplace check-in.
	4. Plan the transformation: from “what we have” to “what we selected in step 3” Recommendations are given on how to implement the solution.

Table 6.6 – Summarising the contents of chapter 6.3.

6.4. Smart tools to optimise teaching space use

This subchapter describes a smart tool that helps universities to optimise the use of their teaching space. Table 6.7 lists the properties of these cases. For teaching space the main reference is Wageningen University.

Optimising teaching space use	
Implementations	Wageningen University
Pilots	Sheffield Hallam University, TU Delft
Future cases	Twente University, Utrecht University, (Oxford University)
Components of problem statement	Teaching space at university tends to be overbooked; The university could not building more teaching space; To accommodate an increase in the student population; Insufficient insight into the frequency and occupancy rates of teaching space; To facilitate an on-demand education programme.
Components of the solution	Real-time information on the frequency and occupancy of lecture halls, linked to the timetable
Benefits	5 to 10 percent improvement in space efficiency Intent to support a 10 percent decrease in education spaces per student A solution to the problem of underutilised space and to facilitate a shift towards demand-based education programmes.
Objectives	Primarily optimising m2
Space use measurement	Frequency and occupancy of teaching spaces
Measurement method	Wi-Fi , (infrared) , Scheduling data
Actuality of information	No user information; Both dashboards and reports to optimise space use; Only dashboard in order to facilitate on-demand education
Accessibility of information	Restricted to campus managers, scheduling team members or a project team.

Table 6.7 – Properties of cases of smart tools that optimise teaching space.

Current mismatch

This type of smart tool can be seen as an improved version of the manual teaching space audits that are common at universities. These audits are used to report on the efficiency of the space use on campus and to make decisions on investment in education spaces. Over the past few years universities have started sharing their education spaces between departments, leading to higher frequency and occupancy rates as universities have continued to grow.

Due to the pressure on resources at universities there is a demand to further increase the use of space. This would be possible by minimising the amount of no-shows that take place during the year and/or by determining the match between the capacity of teaching space and the expected amount of students. In order to do this the space use audits do not suffice, as they are usually not linked to the data of activities in the timetable.

Future mismatch

With regard to the future mismatch the research done at Twente University is interesting. They foresee a change in the educational practice at universities, moving from the current model towards a demand-based model where students themselves determine when they require teaching or supervision. This type of change increases the demand to link the measurement of space use to the scheduling process.

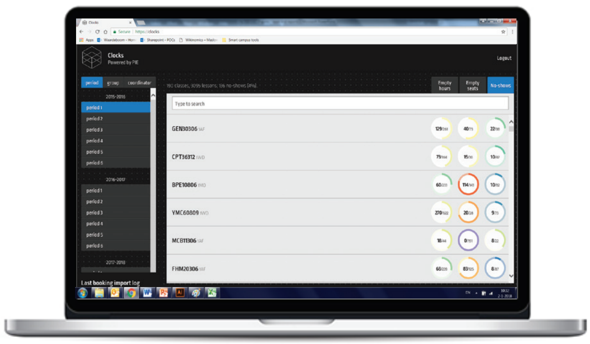


Figure 6.5 – Using a smart tool to optimise teaching space at Wageningen University

Selecting alternatives

The smart tool described in this chapter collects data on the frequency and occupancy rates of each activity during a period. This not only makes it possible to report on space use; it can also be used to evaluate the schedule itself and make improvements to that schedule for the next academic year.

In contrast to the smart tools for study places there is much less variability in the smart tools that optimise teaching space use. This can be caused because the measurement of space use in education spaces is a much more common practice than for study places and because the focus on efficiency makes it easier to set objectives.

In the cases that optimise teaching space Wi-Fi is used as measurement method. The most important question with regard to sensing technology is what sensor to use for smaller spaces (<40 seats). Both Wageningen University and Sheffield Hallam University are looking into this matter. Oxford University is considering a moveable set of sensors to periodically monitor and evaluate multiple space types, amongst which teaching space.

Planning the transformation

In order to implement the solution within the organisation a number of recommendations are made.

In the preparatory stages...

- Students and employees need to be informed prior to implementation, especially with regard to the compliance with privacy regulations
- Support from the university's IT department is needed to deliver floor plans with access point locations, properly configure the university's wireless network and make sure that data is stored and transferred properly.
- It is important to realise that the performance of Wi-Fi as a measurement method depends on the characteristics of the wireless network and the building – therefore doing a pilot and step-by-step implementation is recommended.

In order to achieve an increase in frequency and occupancy rates of teaching space...

- The department responsible for scheduling needs to be able to translate the reports to conclusions that help improve the schedule in the next academic year.
- Data on the planned and/or expected amount of students is needed in order to determine how well the teaching space capacity matches with the demand in group sizes on campus.
- Schedulers need to discuss no-shows with the academic staff in order to improve the schedule the next year.

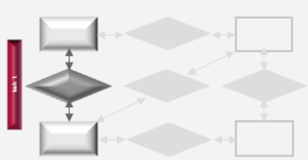
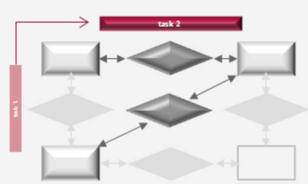
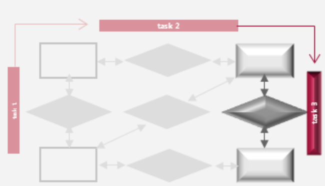
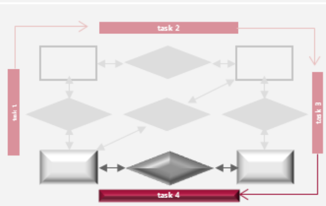
Side effects of the implementation can be...

- Higher frequency and occupancy rates of teaching space can lead to more time required in the scheduling process: if the amount of constraints is the same but there is less time or space to schedule the same amount of activities in, then there are fewer feasible and desirable options for the schedule.
- Better information upfront on the amount of activities that need to be planned and the expected group sizes will reduce the amount of time required to create the schedule.

Additional use of data...

- No-show behaviour can be linked to properties of scheduled activities that are thought to cause this behaviour, e.g. if an activity is scheduled outside of the own faculty or outside of peak hours. This analysis can help inform how desirable these options are.
- Data on the reducing amount of students attending lectures over the course of a period can help to inform decisions about the space that needs to be reserved during the semester.
- See research of Twente University: Rather than evaluating a schedule and its outcome based on efficiency metrics (frequency and occupancy) they are developing a method to evaluate the schedule based on effectiveness metrics: suitability as determined by the teaching staff.

Table 6.8 – Summarising the contents of chapter 6.4.

Smart tools to optimize teaching space use	
	1. Determining the current match: "what we need" versus "what we have" Demand: growth of education programmes and therefore demand of teaching space Supply: same amount of teaching space due to pressure on resources Mismatch: Absence of real-time data to further increase the frequency and occupancy rates of the teaching space on campus
	2. Determining the future match: "what we (might) need in the future" versus "what we have now" A possible further increase of the demand for real-time data due to a change in educational practice.
	3. Weigh and select alternatives for "what we should or could have" A smart tool in which for each activity in the timetable the frequency and occupancy are determined. Wi-Fi is commonly used as measurement method.
	4. Plan the transformation: from "what we have" to "what we selected in step 3" Recommendations are given on how to implement the solution.

6.5. Smart tools to share teaching space for studying

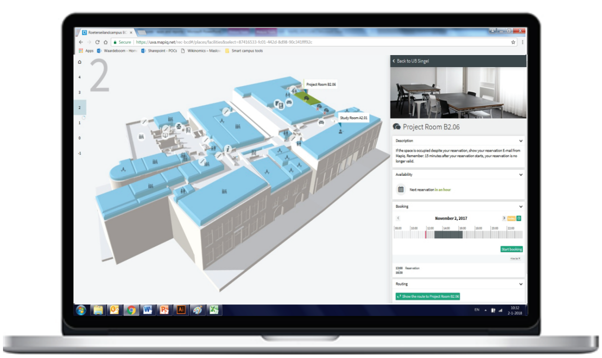
This subchapter describes a smart tool that helps universities to share the use of their teaching space for studying. In chapter 5 cases have been described of smart tools for teaching space. Table 6.9 lists the properties of these cases. For teaching space the main reference is the University of Amsterdam.

Sharing teaching space for studying	
Implementations	University of Amsterdam, VU Amsterdam
Components of problem statement	Study places on campus are not visible, access to teaching space is restricted for students A demand to both facilitating studying on campus and optimise space use
Components of the solution	Real-time information on the availability of teaching space based on the timetable Additional components are: - Availability of study places with PCs - Room booking for small group study spaces
Benefits	Use of the smart tool by students is observed through the amount of reservations made or the amount of users using the webpage.
Objectives	Functional: supporting user activities, increasing user satisfaction, increasing flexibility
Space use measurement	Frequency of teaching spaces
Measurement method	Scheduling data
Actuality of information	User information is real-time; reporting goes back to as far as possible.
Accessibility of information	User information is open access or restricted to university users. Reporting functions unknown or are in development.

Table 6.9 – Properties of cases of smart tools that share teaching space for studying.

Current and future mismatch

The current and future mismatch are the same as described in chapter 6.2.



UNIVERSITEIT VAN AMSTERDAM

Figure 6.6 – Smart tools to find available study places at the University of Amsterdam

Selecting alternatives

The smart tools described in this chapter share teaching space for studying based on availability in the timetable. The main idea behind this type of smart tools is that in the optimisation of teaching space it is nearly impossible to reach scheduled frequency and occupancy rates of more than 75 percent. This is caused by the high amount of constraints involved in planning education at universities. This means that regardless of the effort the vacancy of teaching space will be 25 percent or higher. Especially for classrooms this makes it is interesting to use this space for other purposes, such as studying.

A challenge for these smart tools when compared to the mismatch is that it does not provide real-time data on the availability. This makes it hard to measure the benefits of implementing such a smart tool in terms of the improvement in space use. In the cases it is visible that indicators are used as evidence, such as the amount of reservations made or the amount of users that use the webpage. Furthermore it gives students an indication of availability: students know that they can study at that location, but not if the space is already filled with other students or not.

Planning the transformation

In order to implement the solution within the organisation a number of recommendations are made.

In the preparatory stages...

- It is wise to include student bodies in formulating demands. The increasing amount of smart tool references will help to reduce the amount of time needed to do this.
- Clear rules need to be set on the use of teaching space for studying prior to implementation with a representative student body to avoid problems

In order to achieve an increased use of teaching space for studying...

- Student bodies can help to increase the use of the smart tool by students, which will increase the overall user satisfaction and frequency and occupancy rates
- After implementation a place is needed where students can give feedback; either third party or by the university

Side effects of the implementation can be...

- Increased operating costs to make sure the space is suitable for teaching after being used for studying
- Increasing use of teaching space by students can lead to new demands for the facilities in teaching spaces, e.g. presence of power sockets.
- If the application is successful, eventually classrooms will become filled with students, which will lead to complaints because the smart tool shows the space as available. Occupancy sensors will then be needed.

Additional use of data...

The solution described only shows availability based on the timetable of teaching space and is not able to record the occupancy when the space is used by students.

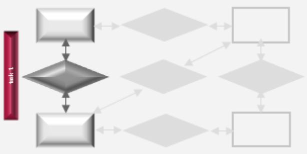
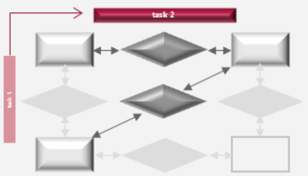
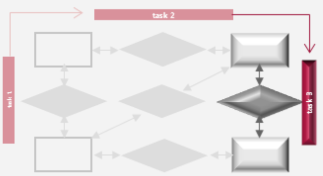
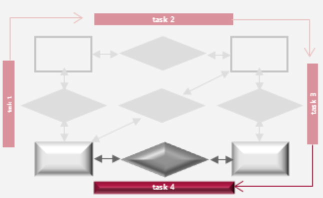
Smart tools to share teaching space for studying	
	1. Determining the current match: “what we need” versus “what we have” (See chapter 6.3) Demand: a large need for study places, as perceived by users Supply: study places on campus, provided according to norms Mismatch: Absence of real-time data to help students find available study places; absence of reporting on space use to help decision makers evaluate norms.
	2. Determining the future match: “what we (might) need in the future” versus “what we have now” (See chapter 6.3) A possible further increase of the demand, due to a change in learning models and/or increase of student performance.
	3. Weigh and select alternatives for “what we should or could have” A smart tool to share teaching space for studying, as in any case teaching spaces have a 25-30 percent vacancy rate. Schedule data is used as measurement method. The solution mainly helps students to find study places, but does not completely address the mismatch due to absence of real-time data.
	4. Plan the transformation: from “what we have” to “what we selected in step 3” Recommendations are given for different stages of the implementation. In this solution the recommendations focus on how to make sure that the teaching activities are not impacted by the use of the space by students.

Table 6.10 – Summarising the contents of chapter 6.5

6.6. Smart tools to find shared office workplaces

This subchapter describes a smart tool that helps to find available workplaces in offices with shared workplace concepts. Table 6.11 lists the properties of these cases. The main reference for this type of smart tool is ABN AMRO.

Finding available workplaces	
Cases	ABN AMRO, Dutch government
Future cases	Erasmus MC
Components of problem statement	Need to manage scarce resources better; To support a norm of 0,7 workplace per 1 employee
Components of the solution	Real-time information on the availability of office workplaces.
Benefits	Reduction on the time spent to find a workplace; Adjusting spaces with low utilisation rates
Objectives	A combination of functional and financial/physical.
Space use measurement	Occupancy of individual workplaces or zones of workplaces
Measurement method	Wi-Fi, PC login data
Actuality of information	User information is real-time; reporting goes back to as far as possible.
Accessibility of information	User information is restricted to employees. Reporting functions are restricted to campus management

Table 6.11 – Properties of cases of smart tools that help to find shared office workspaces.

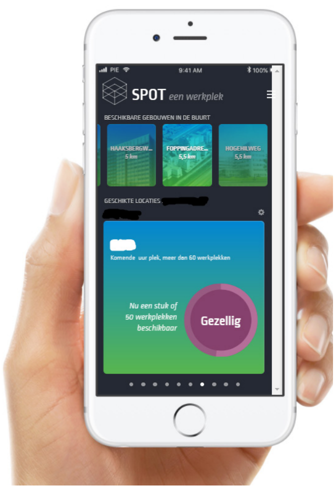


Figure 6.7 Beta version of the SPOT app at ABN AMRO

Current mismatch

The current mismatch is caused because of a transition to shared workplace concepts. Shared workplace concepts are usually designed to support different types of activities at the workplace. However, compared to individual workplace concepts there is a reduced amount of workplaces, which is why people cannot always find a workplace that suits their needs. Furthermore, in shared workplace concepts the workplaces available to the employee can be located on multiple floors or in multiple buildings.

Future mismatch

In academic settings shared workplace concepts are not common. A large increase is not expected due to the doubts raised on the effectiveness of shared workplace concepts by the academic community.

Selecting alternatives

The smart tool provided in these cases is an app to help users find available workplaces in the different locations. This is done via already existing infrastructure such as Wi-Fi or docking stations for laptops. These references can be used by universities in cases where shared workplace concepts exist or are considered.

The main issue in selecting Wi-Fi or docking stations is how accurate the information available to the employee must be. If an estimation on a floor or sub-floor is sufficient, Wi-Fi can be used as a method. If an estimation per workplace is desired, then the use of docking stations is the preferred method. The suitability of using docking stations as method also depends on the users of the workplace. If everybody has the same types of laptops and uses the docking stations the method is very suitable; if the organisation has a large number of contractors using their offices who make use of different laptops and do not use the docking stations, the method is unsuitable.

Planning the transformation

In order to implement the solution within the organisation a number of recommendations are made.

In the preparatory stages…

- Implementing this type of smart tool often comes with a transition to shared workplace concepts. Shared workplace concepts in academic environments are contested
- It is necessary to involve the employee council and agree with them on the type of sensor used and what the purpose of the system is in order to address privacy concerns.

In order to achieve a shared workplace concept…

- Implementation of an app in which to find available workplaces is necessary.

Side effects of the implementation can be…

- An increased amount of employees on the same number of m2 office space can lead to other 'bottlenecks' e.g. elevator capacity, size of restrooms, amount of coffee machines.

Additional use of data…

- None; the data should only be used for the purpose agreed on prior to implementation.

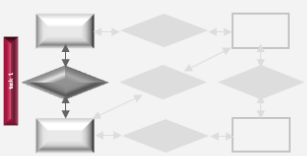
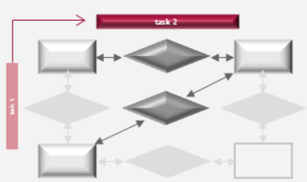
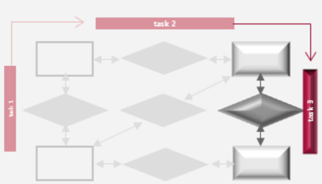
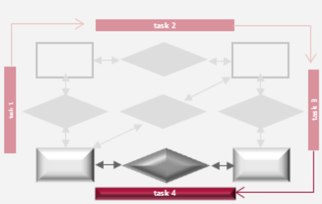
Smart tools to find shared office spaces	
	1. Determining the current match: "what we need" versus "what we have" Demand: Need to find a workplace relating to the activity to be done Supply: Reduced amount of workplaces due to transition to shared workplace concept; workplaces across multiple floors or buildings available to all employees. Mismatch: Necessity to help employees find an available workplace that suits their needs.
	2. Determining the future match: "what we (might) need in the future" versus "what we have now" An increase in the demand for this type of smart tools at universities is not foreseen.
	3. Weigh and select alternatives for "what we should or could have" A smart tool to find available workplaces in different locations. The use of Wi-Fi or docking stations as measurement method depends on the required accuracy. For floor or sub-floor level Wi-Fi can be used; for workplace level docking stations can be used.
	4. Plan the transformation: from "what we have" to "what we selected in step 3" Recommendations are given on how to implement the solution.

Table 6.12 – Summarising the contents of chapter 6.6

6.7. Smart tools to align building use and energy use

This subchapter describes a use case for a smart tool that helps align building use and energy use. Table 6.13 lists the properties of these cases. OVG is the main reference for this type of smart tool.

Focus here is on implementation of a solution that optimises comfort, not the aspects of finding a workplace which are also present in these cases, but have been discussed in the previous chapter. In individual workplaces a workplace finder is unnecessary; aligning building use and energy use can be beneficial in all types of offices.

Align building use and energy use	
Cases	OVG, Agnelli Foundation
Research	Carnegie Mellon University
Components of problem statement	An organisational need to attract talent, building the office of the future; Energy wasted by heating and cooling empty buildings; Designing space that maximally enables users.
Components of the solution	Enabling users to check in to their workplace; Regulate temperature and lighting settings for their environment; Book meeting rooms Find colleagues
Benefits	Increased amount of job applications; Accommodating more employees in the same space (from 1.800 employees and 1.000 desks to 3.400 employees and 1.100 desks); (Expected) energy savings up to 40 percent;
Objectives	A combination of functional and financial/physical.
Space use measurement	Occupancy of workplaces; frequency of meeting rooms.
Measurement method	Workplace check-in, infrared sensors for meeting rooms.
Actuality of information	User information is real-time; reporting goes back to as far as possible.
Accessibility of information	User information is restricted to employees. Reporting functions are restricted to campus management

Table 6.13 – Properties of cases of smart tools that help to improve user comfort

Current mismatch

Two mismatches are identified between current demand and current supply. Firstly, in many buildings the installations providing heating, ventilation and lighting are not connected to the demand, leading to an excess of energy consumption. Secondly, employees are found to have different preferences with regard to indoor climate settings. Being able to influence these settings and making them in alignment with their preferences is believed to increase productivity.

Future mismatch

The mismatch between building use and energy use can change due to changes in both aspects:

- Building use can change because of an increase or decrease in the amount of employees working for an organisation or department, or because of an increase or decrease in the amount of hours that they work in the office.
- Energy use can change because of changes in the building installations and their settings, or changes in the climate (for example in case of relocations), increasing the demand for adjustment of indoor climate by employees.

OVG

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Figure 6.8 – Examples of user apps: to optimise workplace comfort at OVG and Agnelli Foundation

Selecting alternatives

At OVG and the Agnelli Foundation user apps are used to allow users to set the lighting and temperature levels for their workplace, in addition to finding available workplaces and meeting rooms. In these cases buildings are extensively sensored in order to be able to determine and adapt indoor climate on a workplace or sub-room level. This is not only done to save energy, but also to improve the comfort levels of users in the building. If universities decided to make a transition to smart buildings these cases can provide helpful as references of what is (maximally) possible in this area – both for offices with individual and shared offices.

Additional evidence is provided by the research projects done by Carnegie Mellon University: in the GENIE project the availability of software thermostats resulted in improved user satisfaction and in the Sentinel project 17,8 percent energy savings were achieved by controlling HVAC systems based on occupancy data.

Planning the transformation

In order to implement the solution within the organisation a number of recommendations are made.

In the preparatory stages...

- It is necessary to inform the employee council on the purpose of the app and how the data of the workplace check-in is used.
- The building should be fitted with temperature and lighting sensors and controls to adapt them;
- In the app it should be determined to what extent users have control over temperature and lighting: how high and low can they set it.

In order to achieve an increase in user satisfaction and energy savings...

- The user app needs to be used by as many employees as possible

Side effects of the implementation can be...

- That the energy consumption for heating increases due to a preference for a warmer environment.

Additional use of data...

- Can be used to inform employees of the workplaces in the building that by default match better with their temperature and lighting preferences. This could increase the willingness to share workplaces.

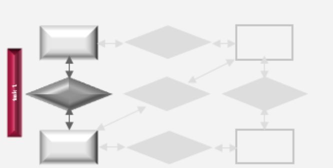
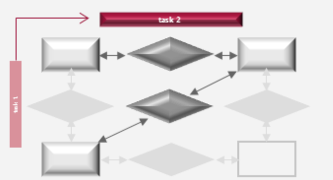
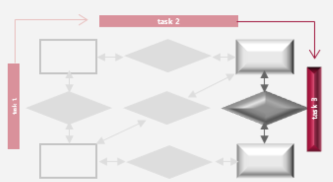
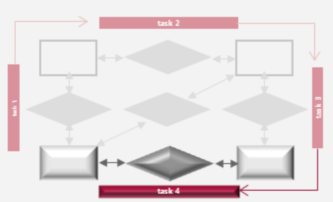
Smart tools to align building use and energy use	
	1. Determining the current match: “what we need” versus “what we have” Demand: Need to provide heating, ventilation, lighting during occupation of offices and meeting rooms when occupied. Preferences vary per employee Supply: Provision of heating, ventilation and lighting during opening hours at standardised settings. Mismatch: Overconsumption of energy, inability to personalise environment.
	2. Determining the future match: “what we (might) need in the future” versus “what we have now” The future mismatch can change both because of changes in the use of the building by the organisation and because of changes in the way energy is provided and used.
	3. Weigh and select alternatives for “what we should or could have” A smart tool to set lighting and temperature settings. Buildings in which this is done are extensively sensored in order to determine and adapt indoor climate on a workplace or sub-room level.
	4. Plan the transformation: from “what we have” to “what we selected in step 3” Recommendations are given on how to implement the solution.

Table 6.14 – Summarising the contents of chapter 6.7

6.8. Smart tools to improve meeting room use

This subchapter describes a use case for a smart tool that helps to improve meeting room use. Table 6.15 lists the properties of these cases. Google and Microsoft are the main cases in this chapter.

Improving meeting room use	
Cases	Google, Microsoft, Ericsson
Components of problem statement	Need for more insight into use of premises; Providing the end user with better service; Meeting rooms are claimed too often for long periods of time;
Components of the solution	Finding available meeting rooms or automatic removal of recurring meetings that are not used
Benefits	Adaption of design briefs for offices to include more offices for 3-8 people Unknown amount of removed meetings
Objectives	Primarily supporting user activities
Space use measurement	Frequency of meeting rooms
Measurement method	Infrared, videoconferencing system
Actuality of information	User information is real-time if available; reporting goes back to as far as possible.
Accessibility of information	User information is restricted to employees. Reporting functions are restricted to campus management

Table 6.15 – Properties of cases of smart tools that help to improve user comfort

Current mismatch

The need for this type of smart tools is caused by a shortage of meeting rooms because of overbooking. In organisations that have a high employee turnover rate overbooking can be a problem because meeting rooms still include reservations made by people who do not work there anymore. A growing amount of employees can also result in a shortage of meeting room space. Organisations have only a finite amount of meeting rooms, therefore it is important that reservations are always used and/or that when a meeting ends early the room can be made available. Without real-time information on the space use it is not possible to determine this.

Future mismatch

The future mismatch depends on variables such as the amount of employees working for the organisation, the amount of meetings they schedule per week, and the amount of people attending those meetings.

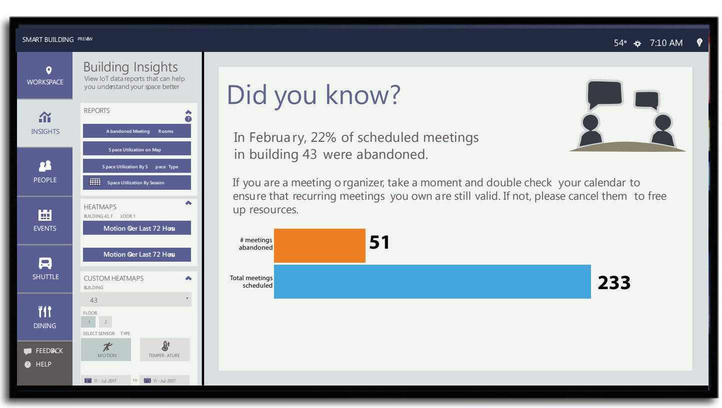


Figure 6.9 – Optimising the use of meeting rooms at Microsoft

Selecting alternatives

For meeting rooms similar smart tools can be used for two different purposes. By using passive infrared (PIR) sensors (Ericsson, Microsoft, OVG) or videoconferencing software (Google) can be used to show employees which meeting rooms are available and can be booked. At Google and Microsoft the use of space is also measured to determine if meetings are abandoned early or even to remove recurring meetings that do not make use of the space from the calendar.

At Google the amount of meetings removed from the calendar can be reported on, indicating the extent to which the meeting rooms are optimised. Unfortunately the increase that is achievable in frequency rates is unknown.

The extent to which the problem of non-existing recurring meetings exists, depends on the organisation. Registering when meetings are abandoned early is expected to benefit universities more than the removal of recurring meetings that do not take place, considering the large demand for ad hoc meetings.

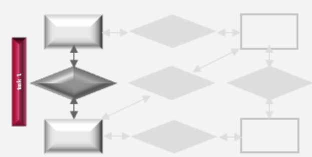
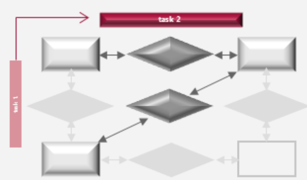
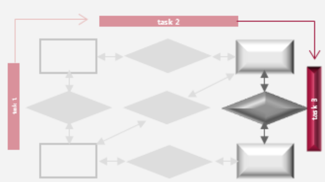
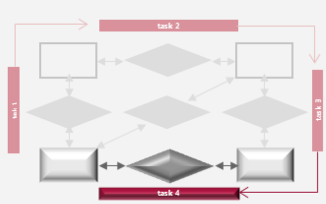
Improve meeting room use	
	1. Determining the current match: "what we need" versus "what we have" Demand: High demand for meeting rooms due to growth in employees; 'Fictive' demand due to reservations for meeting that do not exist anymore. Supply: Finite amount of meeting rooms Mismatch: Inability to determine if meeting rooms are left unused.
	2. Determining the future match: "what we (might) need in the future" versus "what we have now" The future mismatch depends on variables such as the amount of employees working for the organisation, the amount of meetings they schedule per week, and the amount of people attending those meetings.
	3. Weigh and select alternatives for "what we should or could have" A smart tool to help employees book available meeting rooms and/or to determine if meetings are abandoned early and can be removed from the schedule.
	4. Plan the transformation: from "what we have" to "what we selected in step 3" Recommendations are given on how to implement the solution.

Table 6.16 – Summarising the contents of chapter 6.8

Planning the transformation

In order to implement the solution within the organisation a number of recommendations are made.

In the preparatory stages...

- It is necessary to inform the employee council on the purpose of the app and how the data is used.

In order to achieve an increase in frequency and occupancy rates of meeting rooms...

- Allowing employees to reserve meeting rooms will increase the frequency rate of meeting rooms, as well as the amount of no-shows.
- Removing recurring meetings will increase

Side effects of the implementation can be...

- Observing an increase in the expected frequency of meeting rooms because ad-hoc meetings are registered in the booking system

Additional use of data...

- Comparing meeting room capacity to required group sizes to inform decisions on (future) space requirements

6.9. To summarise

In chapter 6.1 a framework for the assessment of legal, technical and organisational efforts is given. The framework can be used to assess how much effort it will take from the organisation to implement a solution.

In chapter 6.2 an overview is given on the data collected on the costs of smart campus tools and the amount of the real estate portfolio on which they are implemented. Evidence on costs suggests that the costs for smart campus tools are a small part of the total workplace costs, and that these can be offset by the potential benefits. Data on the amount of m2 on which smart campus tools are implemented shows that many implementations are on a relatively small percentage of the portfolio.

Chapter 6.3 to 6.8 provide generalised descriptions of types of cases. Input is given on the current mismatch, future mismatch, selecting alternatives and planning the transformation.

In each chapter primary references are suggested based on how long the solution is implemented and how much m2 is covered with the solution.

- Smart tools to find available study places – KU Louvain
- Smart tools to optimise teaching space use – Wageningen University
- Smart tools to share teaching space for studying – University of Amsterdam
- Smart tools to find shared workplaces – ABN AMRO
- Smart tools to align building use and energy use - OVG
- Smart tools to improve meeting room use – Google and Microsoft

Chapter 7
Conclusion

In this chapter the research question is answered based on the data collected in chapters 3, 4 and 5, and the synthesis of these chapters in chapter 6.

The main research question is:
What smart campus tools are available at universities and other organisations and how do they compare to the use of smart tools at universities in the Netherlands?

Chapter 7.1 provides the conclusion, after which chapter 7.2 provides recommendations.

Photo: Interior of the Agnelli Foundation Headquarters. Photo by Beppe Giardino

7. Conclusion

7.1. Answering the main research question

This chapter provides an answer to the research question of this research:

What smart campus tools are available at universities and other organisations and how do they compare to the use of smart tools at universities in the Netherlands?

In order to answer this question data was collected for a total of 27 cases of smart tools, expanding and complimenting the findings from previous research done in 2016. The research includes nine cases for international universities, nine cases for other organisations and nine updated cases for Dutch universities.

At **international universities** two implemented user apps are found and one pilot project to optimise teaching space. The other six cases are in a pilot stage or design brief, revealing that many universities are busy with the subject. New smart tools are being considered, researched, developed and tested to support students and employees, optimise space use and save energy.

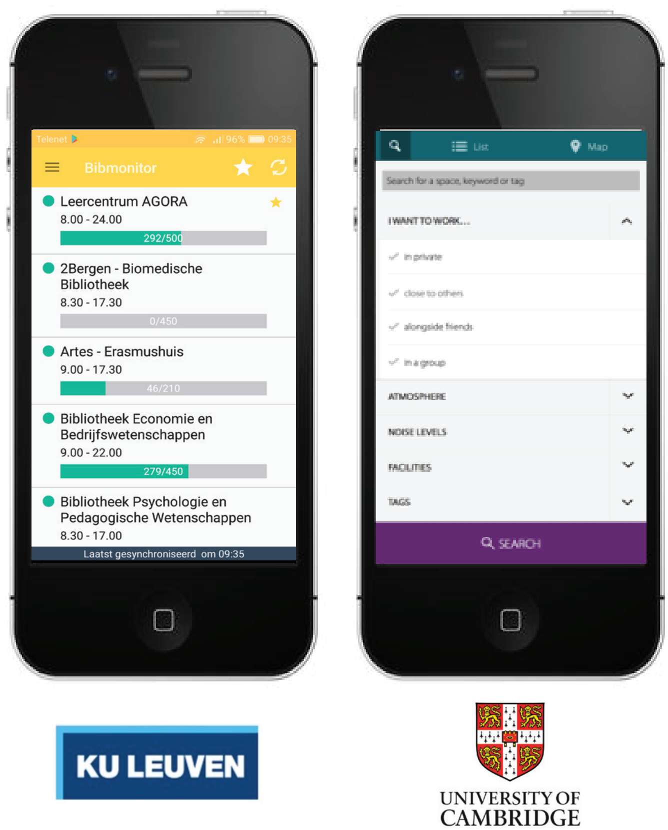


Figure 7.1 – Implemented smart tools at international universities

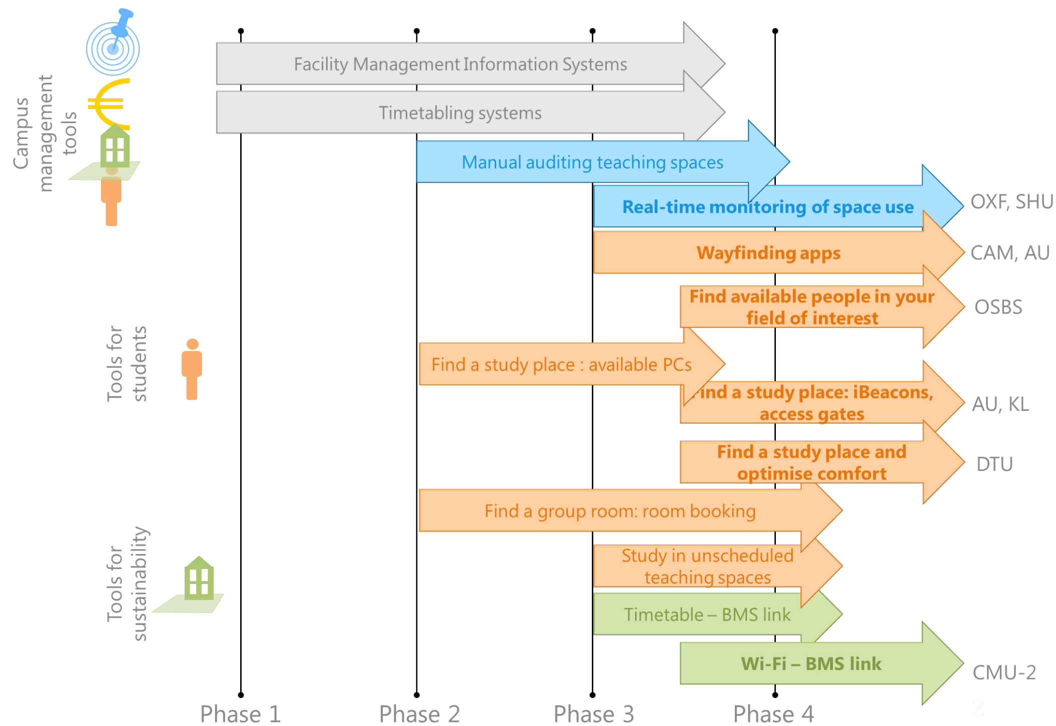


Figure 7.2 - Overview of available smart tools at international universities. Phase 1: no smart tools; phase 2: prevalent smart tools in 2016; phase 3: new smart tools in 2016; phase 4: ongoing smart tools in 2017. Arrows with bold text represent smart tools found in this study.

At **other organisations** most cases reveal that organisations are working on smart tools that both monitor their space use and help their employees find available workplaces and/or meeting rooms; and in two cases also to align energy use to building use. Most smart tools are in the implementation phase and have been implemented since a few years. Organisations are generally further along than universities with their implementations. Multiple cases are found that use multiple types of sensors in their smart tools.

OVG

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Figure 7.3 – Aligning building use and energy use, at organisations

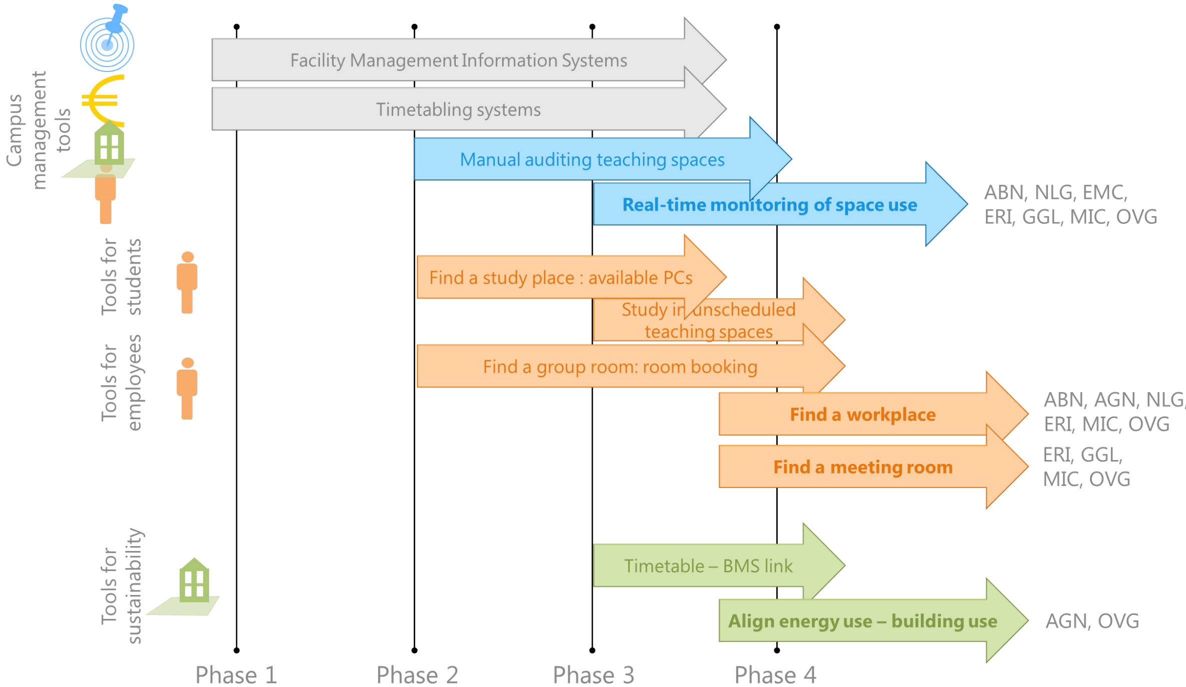
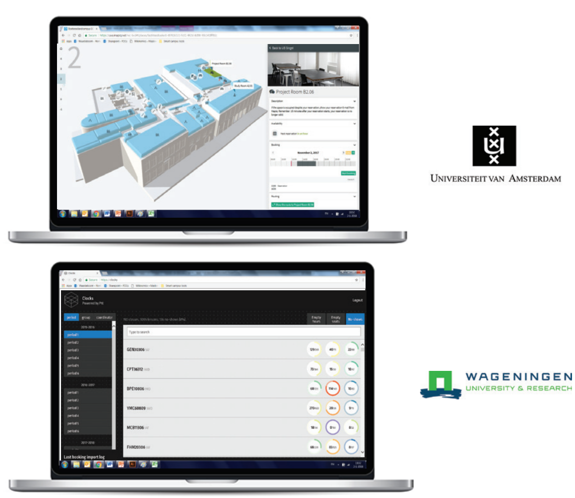


Figure 7.4 – Overview of available smart tools at organisations. Phase 1: no smart tools; phase 2: prevalent smart tools in 2016; phase 3: new smart tools in 2016; phase 4: ongoing smart tools in 2017. Arrows with bold text represent smart tools found in this study.

At **Dutch universities** smart tools are aimed at either real-time monitoring of teaching space or on smart tools that support students, in which multiple functions are brought together. Previous research concluded that by looking at all available smart tools –which includes more room booking apps and available PC apps- the focus of smart tools was for the largest part to add value by supporting students. The cases at Dutch universities are generally further along than those at international universities in terms of their implementation (time and amount of m2)

Figure 7.5 – a smart tool that support students (UvA) and a smart tool that monitors teaching space (WUR) at Dutch universities



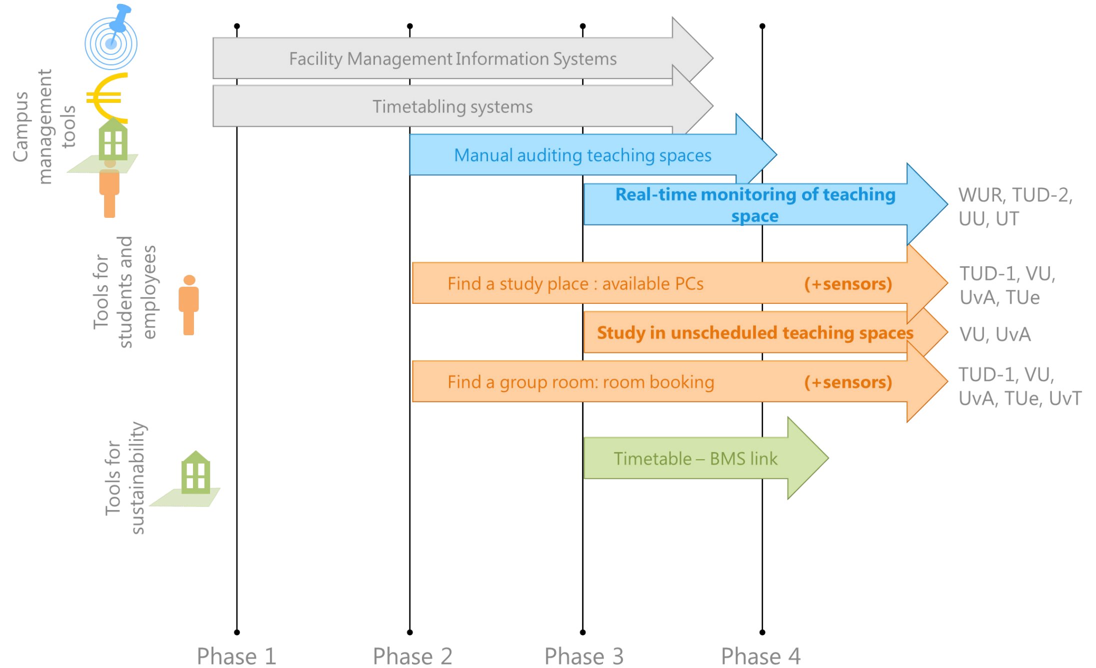


Figure 7.6 – Overview of available smart tools at Dutch universities. Phase 1: no smart tools; phase 2: prevalent smart tools in 2016; phase 3: new smart tools in 2016; phase 4: ongoing smart tools in 2017. Arrows with bold text represent smart tools found in this study.

In chapter 6 a practical guide to the subject of smart tools is given based on all cases and collected information. A framework is designed to help practitioners assess the difficulty of implementing different smart tools. Furthermore, data to support cost-benefit analyses is given. Then, generalised descriptions of types of cases are made to help practitioners find the cases that meet their demands. For each type of case, main references are suggested based largely on the same criteria: the size and duration of the implementation and its ability to report on the benefits that are achieved with the smart tool.

- Smart tools to find available study places – University of Leuven
- Smart tools to optimise teaching space use – Wageningen University
- Smart tools to share teaching space for studying – University of Amsterdam
- Smart tools to find shared workplaces – ABN AMRO
- Smart tools to improve user comfort - OVG
- Smart tools to improve meeting room use – Google and Microsoft

7.2. Recommendations

Based on the findings of the research the authors would like to make a number of recommendations for further research.

Determining current and future mismatch:
To develop a standardised method to assess the improvement of user satisfaction of smart tools, in order to more fully understand the added value of smart tools and better identify mismatches in the future.

Selecting alternatives:
To research how the determination for the type of sensor is made by different organisations. Is there data available comparing different types of sensors to determine the occupancy of teaching spaces, study places, offices, etc.? Are the results and conclusions different across organisations?

To explore the possibilities of using space use data in research. Researching the correlation between presence on campus and study performance will lead to a better understanding of the role of the university campus as a learning environment. Research might help policy makers to account for investment in the campus and help prioritise in what types of facilities to invest in the campus.

Planning transformation:
To further expand the knowledge on how to implement smart tools by studying the relation of smart tools within organisational processes. This needs to be done in-depth in a few cases that have been implemented for a longer period of time.

Chapter 8
Further insights

In this chapter a number of topics are discussed that are not necessary to answer the research question, but that do provide additional insights to the smart campus tools research.

In chapter 8.1 the issue of privacy is discussed – the content of this chapter can also be found on http://www.managingtheuniversitycampus.com

In chapter 8.2 the concept of smart campus is discussed, shedding light on what ambitions universities formulate with regard to smart campuses and how they intend to realise them.

In chapter 8.3 some practical experience in the field of smart tools is discussed, with specific attention for the evaluation of Wi-Fi as a measurement method at TU Delft.

In chapter 8.4 some of the work being done by graduate students at the Faculty of Architecture and the Built Environment is highlighted.

8. Further insights

8.1. Privacy

Because smart tools collect data (real-time) about space use, it is possible that personal information is collected. Based on our findings from last year, this is the case in some newer applications of smart tools, which use methods such as Wi-Fi and Bluetooth to collect data.

Let's start with the definition of privacy. The definition of privacy was first determined as 'the right to be left alone' in 1890 by Warren and Brandeis, and later as the 'claim of individuals, groups or institutions to determine for themselves when, how, and to what extent information about them is communicated to others' by Westin in 1967. Jan Holvast writes in an article on the History of Privacy that "at the same time it is clear that a need for privacy can never be absolute and must be balanced against other needs, for example the need for fighting terrorism, crime, and fraud" (Holvast, 2009). Because of this balance, Holvast argues that nowadays privacy is not just a legal issue, but also a political issue.

Figure 8.1 - Photo by Arvin Febry on Unsplash

This balance between privacy and other needs can be made more explicit by showing some examples of when, how and to what extent users can determine which information is communicated to others. Consider the following five examples:

- Following the terrorist attacks in Brussels last year, reports came in about a camera surveillance system on Belgian highways. This system is able to track all vehicles moving in, through and out of the country via cameras installed along highways. In addition, the system registers behaviour in traffic such as speeding, illegal passing, etc. (NOS, 2017) Users are registered without their consent and without anonymity.
- At Wageningen University Wi-Fi data on campus is used to measure frequency and occupancy rates in buildings. Here strict anonymization of this data is applied by storing data locally and encrypting IP addresses with a different encryption each day. Users are registered without their consent, but anonymously.
- Authors Lesueur, Surdu, Thion, Gripay, and Ben Ghorbel-Talbi (2014) present a method in which there is no user consent about data collection, but user consent on who accesses which data – in this model the user is able to control how other users (the controllers) of the system are able to use their data. For example, the user can determine that the controller cannot view his/her daily occupancy of his/her workplace, but that the controller is allowed to view aggregated data, showing what the occupancy was during a whole week of all the workplaces in the department.
- Multiple smart TV suppliers collect information via televisions on what people are watching, for example to collect and sell large sets of data on viewing behaviour. Willcox and Derene (2017) describe how different suppliers enable people to opt-out of this feature.
- In the Quantified Student programme, students can participate in a programme to help them improve their study results on a free basis, in which different types of data are collected to support them (Quantified Student, 2017). This is an example of an opt-in system.

From first to last, each example shows a larger degree of authority of the user in deciding what information to share: examples one and two offer no decision to the user, option three offers users a decision in the use of the data and options four and five offer the user the decision to not participate entirely. Example one is a prime example of how privacy is sacrificed to fight terrorism and crime, whereas example five is an example of how a user can share his/her information in order to receive benefits on a personal level. Smart campus tools will probably deal with privacy issues similar to the examples 2, 3 and 4. Anonymization is required by law, so example 1 is not applicable under normal circumstances – but could change in reaction to terrorism attacks. Because most smart campus tools are about measuring how many people are where at what time, example 5 would result in estimates with a higher inaccuracy because the opt-in principle would result in a lower participation rate. People fear, however, that what starts as a voluntary system (ex. 5) ends up being mandatory and all-inclusive (ex. 1): a plot line followed by novels such as Dave Eggers' The Circle.

In an article written last year in the Dutch Facility Management Magazine (FMM), interviewing Wilbert Thomesen of the Dutch authority for personal data, this fear is addressed (Bekkering, 2016). As far as collecting data in the workplace goes, he states that 'organisations may do what they must do' – e.g. for safety reasons a retailer can install cameras in his shop, but he cannot use them to monitor his employees. Similarly, an organisation needs to know how many people are in their buildings at what time, but not who they are and what they are doing.

The reason why privacy is such an issue nowadays is not only because people are anxious about what the organisation or government collecting the information will use the information for, but also because of potential misuse by unknown parties. Numerous Wikileaks document dumps, as well as the iCloud leaks of celebrity photos come to mind. Caviglione, Lalande, Mazurczyk, and Wendzel (2015) identify numerous hazards to applications of smart buildings, which are not necessarily related to applications which collect personal information – for example monitoring surveillance of the building, or taking over control of the automated functions in the building. Recently, a Dutch parking company was hit by the WannaCry attack, leading to an inability to enter and exit their parking structures and which led to a loss of revenues for the company. (Hoeffnagel, 2017)

Finally, sceptics of big data applications point out that big data could actually harm innovation. For organisations such as universities, whose core competence is innovation, this is especially important. Danah Boyd (2010) points out that when people know that they are monitored, their behaviour changes. To give an example of this, consider an example in the practice of a university in which the university monitors the occupancy rates of academic offices in order to optimise the climate in the offices and on the long-term to forecast how many offices are needed in their real estate portfolio. If users are aware of this technology, they could be afraid that low occupancy rates in the office will result in less accommodation for their department. In order to avoid this situation they maximise the amount of time spent in their office during the week, but as a result they avoid having coffee breaks or social interactions with their co-workers, hence impairing the process of innovation.

Intertwined with the previous point is the criticism rooted in the use of big data, which is to provide targeted services to users based on the data collection of those users. This is what Darwin Bond Graham calls the 'iron cage' of our own user-generated content (Bond Graham, 2013) - based on the term 'iron cage' as coined by Max Weber. What this development leads to is that as you use the internet more and more, the content is personalised more and more towards you and that this restricts your content to what you think, prefer or want.

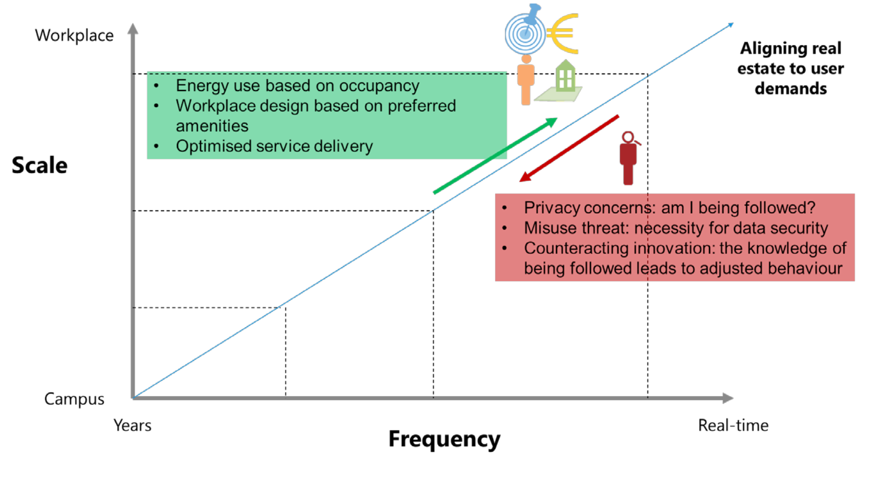


Figure 8.2 – Opportunities and threats of measuring space use real-time (own figure)

In our field, the promises of smart campus tools are that we can much better align our real estate to the needs of our users – more accurately and by responding faster to changing demand. However, we need to be aware of the potential drawbacks and threats when deciding to implement them and to address concerns of users. It seems that the benefits associated with smart tools and retaining the same amount of privacy on campus are not mutually exclusive. In our data collection we will look further at how organisations deal with this issue.

8.2. Smart campuses: ambition and strategy

During interviews with the Technical University of Denmark (DTU) and Glasgow University with regard to their use of smart tools, I discovered that both universities have formulated ambitions to realise a 'smart campus', a programme in which multiple smart tools will be researched, developed and implemented. Therefore I decided to explore the concept of a 'smart campus' and existing smart campus ambitions more in depth.

The increasing use of the term 'smart campus' might be explained from a sustainability perspective, in sustainable development there is an increasing momentum for the thesis that 'smart is the new green' (Mitchell, 2016; Singh, 2015; United Nations, 2016; Van Keulen, 2017). This differs from the meaning of the terms 'smart campus tools' or 'smart tools' in this book, which is more related to making smarter use of available space on campus (of which saving energy can be an outcome). The foreseen trend is that organisations will prioritise investment in automated systems over investment in renewable energy or waste reduction. Two aspects are put forward as reasons why this will happen. Firstly, smart solutions place more emphasis on the benefit for the individual user whereas green solutions were about doing good for the planet. Because of this lack of emphasis on the individual it is thought that green solutions did not provide enough encouragement to have individuals change their behaviour. Secondly, smart solutions have a stronger return on investment in their business cases than green solutions. This makes them more interesting from a business point of view.

Smart campus in academia

A glance at the development of scientific literature on smart campuses also displays this upward trend: a query of database Scopus shows a steady increase of papers in peer reviewed literature.

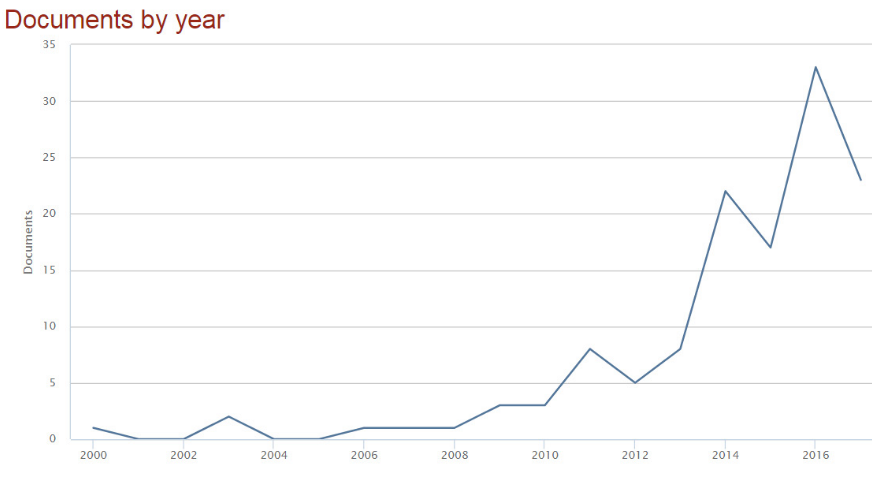


Figure 8.3 - Scopus query of "smart campus" – papers published since 2000. Query: TITLE-ABS-KEY("Smart campus"), limited to relevant subject areas

Some examples of research done related to smart campuses:

- Gomes et al. (2017) present the energy savings results and best practices in a pilot project in Lisbon (Instituto Superior Tecnico), where ICT equipment was installed in a Library, a lecture hall and a set of offices, controlling HVAC and lighting settings. The research is part of a larger Smart campus project with pilot locations in Helsinki, Lisbon, Lulea and Milan.
- Mattoni et al. (2016) present a methodology to choose strategies to develop the smart campus by evaluating strategies on the level of integration, feasibility and obtained benefits, using the University of Rome as a case study.
- Hentschel, Jacob, Singer, and Chalmers (2016) propose the development of a network of supersensors (Raspberry Pi devices) to realise Glasgow University's smart campus ambition, and demonstrate this through a small scale deployment.

These examples reflect not only the growing interest in smart campuses, but also suggest a relation to a smart campus ambition of these universities and others.

Smart campus ambitions

When searching online for smart campuses, it indeed becomes clear that some universities have formulated ambitions for their smart campus, including DTU and Glasgow University. On their website, DTU writes: "with Smart Campus, we aim to improve learning facilities, create a better and smarter campus, and ultimately test the technology that will be used to build tomorrow's smart cities. During the DTU Campus development, part of the strategy is to transform DTU into a Smart Campus, where students and researchers are able to use Campus facilities and data to test Smart City technologies." (DTU, 2018) DTU is currently realising the first smart building on campus with the renovation of their Library.

Glasgow University is in the process of further detailing its ambition and realising their Estate Strategy, which includes a large-scale expansion on a recently acquired plot adjacent to the existing campus. Glasgow University writes: "The planned expansion will provide us with a significant opportunity to exploit the development programme as a test bed for research and teaching in the smart cities field – exploring aspects of urban innovation, city systems, big data, informatics, energy management and transport policy. Through a supporting programme of research and teaching, the University and its partners will build a world-class physical environment designed around the expectations of students, academics, funders, industry and Government." (Glasgow University, 2017)

In the Netherlands the University of Twente (UT) has formulated an ambition for the Living Smart Campus. "In the Living Smart Campus programme solutions are developed for complex societal problems that require science. To explore possible solutions the campus is used in its function as living environment as a part of experiments. The campus offers a unique place to prepare solutions before they are introduced in society." (University of Twente, 2016) The University of Nottingham states the smart campus as an opportunity in their Estate Strategy and Sustainability Strategy, writing "by Smart Campus, we mean a campus that is an efficient, safe, sustainable, responsive and enjoyable place to live and work, underpinned and enhanced by digital / internet based technologies" (University of Nottingham, 2015). Arizona State University is also developing multiple tools within a smart campus strategy, but unfortunately the source does not really state what the ambition is (Whitley, 2017).

In Singapore the ambition of a smart campus has also had quite some uptake. Temasek University, Singapore Polytechnic and Republic Polytechnic have stated ambitions with regard to realising a 'smart campus.' (Basu, 2016; IMDA, 2017; Temasek Polytechnic, 2014) Temasek University announced its ambition as early as 2014, and has since partnered with NVidia[1], DBB Worldwide[2] and Philips[3] - resulting in student projects and pilots with artificial intelligence and smart lighting applications on campus. Singapore Polytechnic and Republic Polytechnic have started more recently, in 2016. Singapore Polytechnic announced a partnership with Cisco and NSC and envisions multiple tools, e.g. learning analytics, location-based tools for wayfinding and to find available study places and smart lighting. Republic Polytechnic has formulated the tools less clearly, but emphasizes the role of students in developing these tools.

Strategies – living labs and proven technology

What is interesting in these ambitions is that there is a difference in their focus. On the one hand there are universities such as Singapore Polytechnic and Nottingham University that clearly focus on the smart campus for the benefit of the university and its users. On the other hand Twente University and Temasek University focus on the smart campus as a research opportunity. Glasgow University and DTU are somewhere in the middle, both aimed at benefits for the campus itself and research opportunities.

Furthermore the way in which universities realise their ambitions differs: whilst some universities opt for a Living lab approach –leaving the formulation and development of solutions open-, others lean more towards Proven technology and predefining their solutions. Naturally a Living lab is much more suitable when the smart campus is mostly seen a research opportunity, whereas proven technology fits a focus on benefits for the institution. However, there are exceptions to this rule: Temasek University focuses on research benefits but with relatively proven technology through its partnerships, whereas Glasgow University and DTU use a living lab approach in order to also yield institutional benefits.

When viewed in relation to last year's findings in the Netherlands, this leads to an interesting (preliminary) conclusion. In the Netherlands the dominant strategy in the implementation of smart campus tools was a focus on clearly defined institutional benefits and the selection of proven technology as a solution. In contrast the examples from international universities show a less defined objective and a tendency towards the living lab strategy.

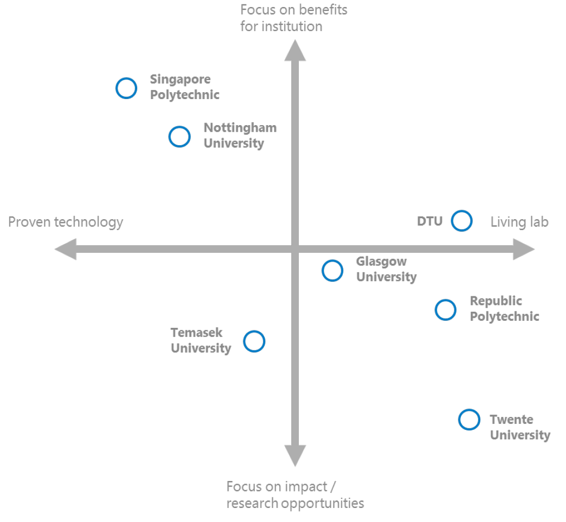


Figure 8.4 - Own figure – assessment of smart campus ambition (in focus on institutional benefits and focus on impact) and strategy (proven technology and living labs)

1 https://www.nvidia.com/blog/ntc/nvidia-technology-centre-temasek-polytehnic/
2 http://www.campaignbrief.com/asia/2016/10/temasek-polytechnic-and-ddb-wo.htm
3 https://www.dailysingapore.com/2016/08/temasek-polytechnic-and-philips-lighting-to-launch-first-connected-lighting-test-bed-in-a-tertiary-institution-in-singapore/

8.3. Evaluating the performance of Wi-Fi measurements in practice

Since the start of the research on smart campus tools I have also been involved in initiatives at TU Delft to make better use of the space on campus. This chapter summarises our findings within a pilot project to test the suitability of Wi-Fi as a measurement method. This one of the cases described in chapter 5.

In the first education period of the academic year 2017-18 TU Delft has undertaken a pilot to measure the use of the lecture halls within one building at the university with Wi-Fi (the faculty of 3mE). This pilot was done after a few proof-of-concept project in which was concluded that Wi-Fi was the preferred method for measuring space use in lecture halls. However, it was recommended that a pilot in another buildings needed to be done to confirm this conclusion, because the dependency of Wi-Fi on the characteristics of the environment turned out to be larger than expected.

In the pilot the data on the amount of time used by the booking (frequency) and the count of persons present in the room (occupancy) were compared with the findings of manual observations. In addition, the findings could be compared to the assessment made in the previous year in the proof-of-concept projects – this yielded more than 1.000 data points that could be compared.

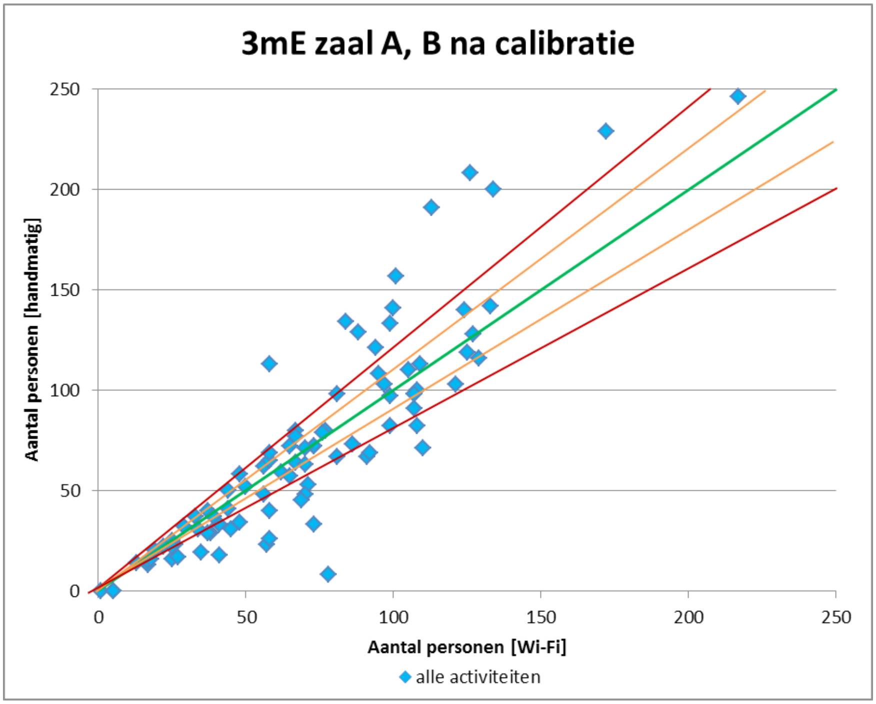
First the Wi-Fi data and manual counts were compared with regard to no-shows and empty hours. A no-show is defined as a reservation in the schedule that is not used. An empty hour is defined as a reservation in the schedule for which only a part of the reservation is used (e.g. 1 hour used out of 3 reserved).

	No-shows manual	No-shows Wi-Fi	Empty hours manual	Empty hours Wi-Fi
Zaal A,B	5	4	10	35
Zaal C,D	9	2	26	23
Zaal E,F	7	4	20	29
Zaal G-M	40	27	69	97
Zaal Emile Truijen	4	4	7	6
Linked lecture halls	2	1	0	6

Table 8.1 – Comparison of amount of no-shows and empty hours counted by manual observations and Wi-Fi

The table shows that in the manual counts a no-show is registered more often than via Wi-Fi. This is because in the manual counts the person counting observes a no-show based an observation at the start of each hour – or sometimes only one observation for a reservation of two or three hours. With Wi-Fi this is not the case, which is reflected in the registration of empty hours: here Wi-Fi observes much more partial use of reservations. This property of manual counts makes it hard to use it as 'ground truth' for frequency and occupancy measurements in comparison to a real-time measurement method.

Then the occupancy data for Wi-Fi and manual counts were compared. We compared the Wi-Fi counts to the manual counts and looked at the amount of data points that the Wi-Fi count was within +/- 20% of the manual count. Figure 8.5 displays one of the diagrams of this analysis. In this particular diagram it is visible that for these lecture halls Wi-Fi observes a higher count than Wi-Fi when a small amount of people is present, but that the manual count is higher than the Wi-Fi count when there is a large amount of people.



Figuur 8.5 – Comparison of Wi-Fi counts (x-axis) to manual counts (y-axis).

Table 8.2 shows an overview of the comparisons and the performance of Wi-Fi measurements compared to the manual observations. Based on the data in the table it is possible to conclude that the performance of the Wi-Fi measurements in the 3mE building was higher than in the IDE building in 2016 and that 58% of the Wi-Fi measurements were within +/-20% of the data points.

	Amount of data points	Data points within +/-20%	%	Data points outside +/-20%	%
(2016) IDE Arena	42	17	40%	25	60%
(2016) Joost vd Grinten	14	11	79%	3	21%
Zaal A,B*	87	52	60%	35	40%
Zaal C,D*	99	56	57%	43	43%
Zaal E,F	115	71	62%	44	38%
Zaal G-M	477	278	58%	199	42%
Zaal Emile Truijen	52	26	50%	26	50%
Gekoppeld	46	27	59%	19	41%

Table 8.2 – Comparison of occupancy data between manual and Wi-Fi counts. For lecture halls A, B, C and D the data from the first two weeks have been excluded.

Finally, the frequency and occupancy rates over the whole measurement period were compared to see what the differences would be when looking at the total. This comparison is displayed in table 8.3. The table reveals that there are minor differences between Wi-Fi and manual measurements, and that the differences are much smaller in this aggregated form of data than when looking at each data point separately.

	Frequency rate (scheduled)		Frequency rate (actual use)		Occupancy rate (actual use)	
	manual	Wi-Fi	manual	Wi-Fi	manual	Wi-Fi
Zaal A	83%	84%	76%	76%	35%	37%
Zaal B	95%	96%	87%	90%	32%	33%
Zaal C	75%	76%	64%	64%	33%	44%
Zaal D	85%	86%	74%	71%	41%	44%
Zaal E	57%	53%	48%	50%	45%	48%
Zaal F	48%	41%	41%	39%	43%	41%
Zaal G	49%	46%	46%	45%	38%	53%
Zaal H	51%	48%	40%	43%	51%	41%
Zaal I	74%	69%	69%	67%	53%	54%
Zaal J	55%	52%	49%	50%	60%	66%
Zaal K	79%	73%	72%	64%	51%	42%
Zaal L	60%	57%	56%	54%	44%	51%
Zaal M	64%	60%	50%	52%	42%	39%
Zaal Emile Truijen	63%	43%	55%	39%	41%	39%
Average total	**67%**	**63%**	**59%**	**57%**	**43%**	**45%**

Table 8.3 – Comparison of the average frequency and occupancy rates over a whole period with Wi-Fi and manual counts. For lecture halls A, B, C and D the data from the first two weeks have been excluded.

One of the difficulties in making the comparison in table 8.3 is that the scheduled frequency rate differs between both methods. The difference can be caused because different versions of the timetable have been used, or because in the schedule used in the manual counts also non-educational activities are included. Ideally the exact same schedule should be used. Because the actual use is derived from the scheduled use, the difference in scheduled use largely explains the difference between the actual use in the Wi-Fi data and manual data as well. Furthermore there are slight differences in the occupancy rates of teaching spaces.

Based on the findings the following conclusions were drawn up, recommending to proceed further with Wi-Fi for measurement of frequency and occupancy rates:

- With Wi-Fi it is possible to get a better (fine-grained) insight into no-shows and empty hours;
- The performance of Wi-Fi as a measurement method was better in the faculty building of 3mE than in the previous experiment in the faculty building of IDE. 58% of the Wi-Fi measurements were within +/-20% of the data points.
- When a report is made for the average frequency and occupancy rates over a whole period the results are barely different; the conclusions made would be the same irrespective of the method used.

An important issue for discussion is how to determine when the observed accuracy is accurate enough. Here we compare Wi-Fi data or other data to the existing practice of manual observations. In such a comparison it is visible that Wi-Fi is not completely accurate; however, the same is true for the traditional practice of manual observation. We hope that this analysis is helpful to practitioners who have to answer similar questions.

8.4. Student work

Since the start of our research on smart campus tools the topic has found its place in the graduation labs of Management in the Built Environment. Furthermore graduate students of the Geomatics education programme are doing research on the subject.

Designing a Wi-Fi positioning system for use on campus

Within Rob Braggaar's research the focus is on the development of a non-intrusive network-based indoor positioning system using Wi-Fi. Wi-Fi has clear advantages over other measuring techniques in that these systems are ubiquitous, cost-effective and their use is multi-faceted. Now over 85% of the users carry a smartphone. These off-the-shelf, unmodified smartphones and other Wi-Fi-enabled mobile devices can be used as mobile stations to indicate user locations through an iterative positioning process. Besides the mobile stations, existing Wi-Fi infrastructures and networking equipment can be re-used with minor adaptations. The following research question was addressed in this research: 'To what extent can indoor Wi-Fi positioning be used for indoor localisation in order to determine occupancy rhythms and movement patterns within and between rooms to support campus management?'.

The research question was approached starting with exploring the different techniques and methods suited for indoor positioning or localisation. A case study at the TU Delft faculty of Architecture building was used to review and develop a system suitable for indoor campus environments. Reviewing and developing the system includes design and decisions on the collection of Wi-Fi data, how to position devices, how to filter data and how to convert mobile devices to user counts.

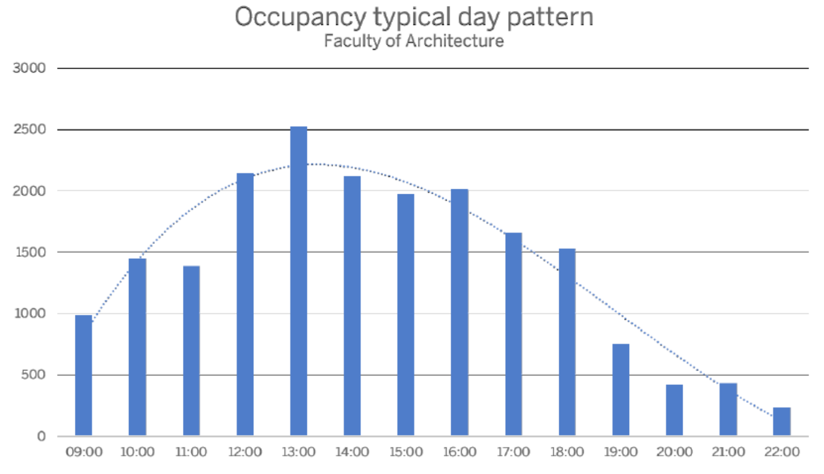


Figure 8.6 Occupancy pattern in the faculty of Architecture during a typical day (by Rob Braggaar).

The system was deployed at the faculty to monitor occupancy and movement patterns before, during and after a fire drill. Ground truth was acquired using BLE wrist bands and manual counting. The fire drill had different elements: counting the number of users per m^2 and per room, the occupancy rhythms over time and the movement patterns. In addition to providing this data, overall close to a 90% match between BLE wrist band equipped user counts and Wi-Fi counts was achieved. In conclusion, with this localisation system the occupancy rhythms and movement patterns of users can be measured to a large extent to aid in the various tasks of campus management, e.g. planning and safety evacuations.

Researching the possibilities for smart tools to support the user of the campus workplace

The increasing availability of technology around us and the possibilities of these innovations at the workplace are the starting points of this research. Besides the cost reductions and efficiency increases that can be reached by connecting devices, there is also a possibility to increase customer experience according to Cisco (2013). This user focus is the base line of Linda Supheert's research. Although it is known that in a broader sense the use of technology at workplaces has its benefits, it is often difficult to decide which tool is actually preferred by both management and users.

The ongoing digitisation of the work environment and wide variety of different work spaces employees' use during their work, create much potential for the use of smart tools. At the same time organisations are focusing more and more on the preferences of their employees by creating a pleasant work environment, like implementing ABW principles, instead of only focussing on reducing cost and increasing efficiency (Harris, 2016). The real estate manager needs to collect specific information to provide the smart tool functionalities which support the user as well as the organisational goals at the best of their abilities. Therefore the aim of this research is to gather a deeper understanding of the problems new users encounter during their day at the workplace and to connect these problems to specific functions of smart tools.

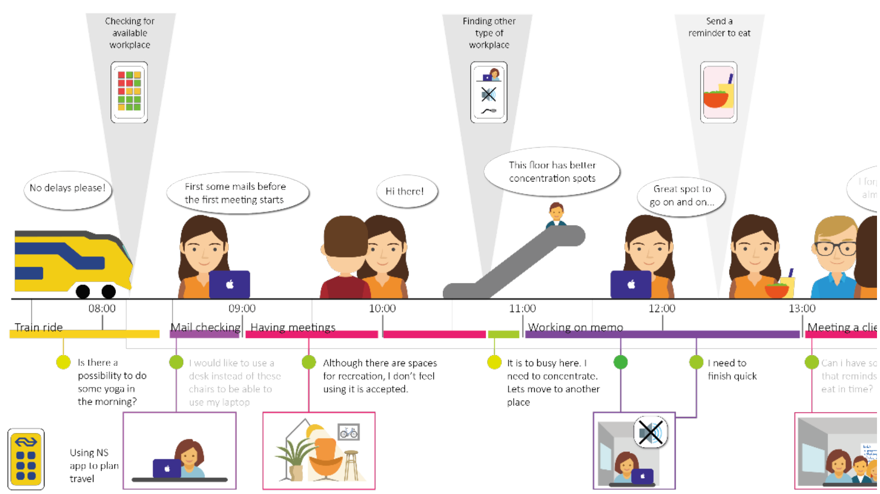


Figure 8.7: Redesigned journey of one interviewee. At the top new tools are implemented to optimize the journey (by Linda Supheert)

By showing the connection between problem and smart tool, insight is given on how the working experience can be optimized during the day on campus and what the role of already available tools in this process can be. These findings can help the campus manager in making plans for the implementation of smart tools in the workplace. The main research question is: Which functions of smart tools are needed to assist new campus users in choosing an appropriate work place throughout the day?

To gather in-depth insights in the problems users encounter during their day, a user journey will be composed based on interviews with workplace users. By comparing these insights to the vision on real estate management and smart tools, envisioned in an assumed journey, inconsistencies can be identified. By doing this, the possibilities of different functionalities of smart tools will be highlighted and can be used to optimize the user journey of a working-day. It gives insight into the preferences of users on the campus of a specific organisation. A redesigned journey will be composed to show the improvement that smart tools can offer for the specific user, see below for image of the redesigned journey.

Although it is too early to formulate conclusions and the case study approach makes it hard to generalise, it can be stated that there is not one size fits all approach for the implementation of smart tools. There are different functions tools can offer but also the preferences among users reveal strong differences. This is also highly dependent on contextual aspects like the workplace approach: do people have a flexible workplace or one assigned spot?

Smart tools should not be limited to the workplace only, productivity can also be improved by offering collaboration tools, people finders or by giving insight into different functions surrounding the workplace. The connection between domains like HR, IT, CREM and FM becomes even more important to be able to show the benefits of smart tools, as they cross the boundaries of these different fields.

Making a user journey gives an alternative method to find smart tools that can turn the problems and annoyances users encounter into better experiences. Not by asking them what they want, but by asking what goes wrong and matching this to specific functions of smart tools.

Developing a smart tool for campus-user alignment in pursuance of a real estate intelligence system (REIS)

Recent research on Dutch campuses (Campus NL, 2016) shows several conclusions were drawn regarding space use. Even though digitisation enables students to study virtually everywhere, demand for study space on the campus remains high and is even increasing. Additionally, students place higher demands on the quality and availability of facilities (Campus NL, 2016, p. 15).

Sven ter Veer is researching how to solve the described space use problem by providing information about available study spaces with the use of Smart Tools (Campus NL, 2016, p. 18). With regard to the use of the university campus or real estate, the objective is to increase both the effectiveness of the alignment of supply and demand while optimizing the efficiency of space use. Hence, the main research question of this research is: "How can a Smart Tool provide information to support the alignment of dynamic user demand with campus space supply more effectively and efficiently on both the long and short term?".

The process surrounding the Smart Tool is visualized in Figure 8.8. Starting with the users who have a certain demand for a study space at a certain time. The Smart Tool enables the interaction between real estate (supply) and the user (demand). By providing information on available spaces and requesting the users' preferences the smart tool is able to help the user find a suitable study space. This supports the alignment of demand with supply in the short term. Meanwhile, this interaction generates data which is stored into the Real Estate Intelligence System (REIS) as management data.

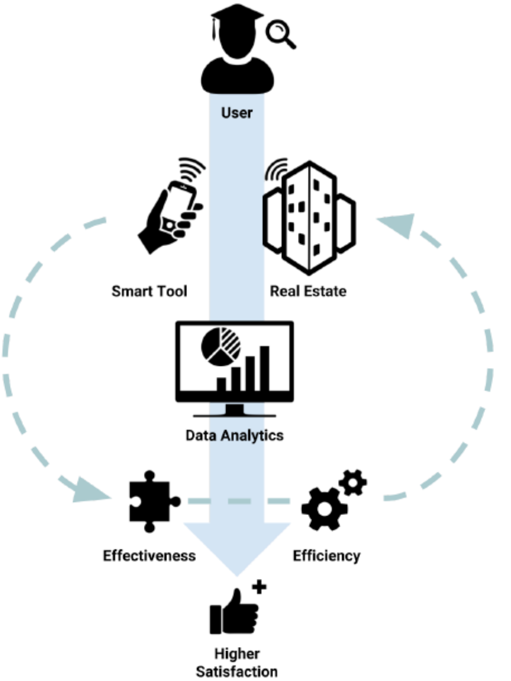


Figure 8.8: Visualization of Smart Tool process (by Sven ter Veer)

This data serves the purpose to quantify the dynamic demand of the users which can be analysed over the long (or short) term by the campus management. This data can be used to increase the effectiveness of the real estate by making changes to optimally accommodate its users while considering its preferences. The utilization data can also be used to make its real estate more efficient by maximizing utilization. Hence, the feedback loop signifies the changes made to the real estate on the basis of the generated data leading to improved efficiency and effectiveness. Ultimately, this should also lead to higher user satisfaction in general over the long term.

Expected Results:
A Smart Tool that helps users to find an available study space according to their preferences.
A mobile application User Interface (UI) mockup.
A Real Estate Intelligence System (REIS) Dashboard which stores and displays the data generated by the Smart Tool for analysis.

Predicting the added value of smart systems on a building

A relatively new concept for building upgrade measures is the concept of smart buildings. An academic view is given by Wang et al. (2012), agreeing that smart buildings are part of the next generation building industry, suggesting that they address both intelligence and sustainability issues by utilising computer and intelligent technologies to achieve an optimal combination. It has the potential to add value to an organisation, but there are many different solutions to consider, and different stakeholders with different preferences. Identifying what criteria are important and therefore determining what smart system will optimally add value to the building can be a difficult task.
Niels Dijkstra's research focuses on this issue. The research question is: How can a decision model predict the added value of a smart system, based on the preferences of the stakeholders?

The research will focus on the design of a decision model. This model is based on Preference Based Design, which scales and weights the values of each stakeholder in order to find the highest preference score (the optimum solution). Both quantitative and qualitative values can be transformed into preference scores suitable for mathematical modelling. With the use of repeating interviews and workshops the preferences will be established and the stakeholders are able to alter their input until a satisfied model of reality is achieved.

The research will be completed at Schiphol Airport. Schiphol Real Estate stated that they want to transform their Central Business District into a Smart Airport City. The aim of the research is to create the best solution to transform an office building into a smart building.

Smart systems are able to provide excellent tailor-made solutions. Therefore the expectation of the research is that smart systems have the potential to add a lot of value to the office building. Moreover, the model is expected to provide a scientific way to match smart systems and preferences of stakeholders.

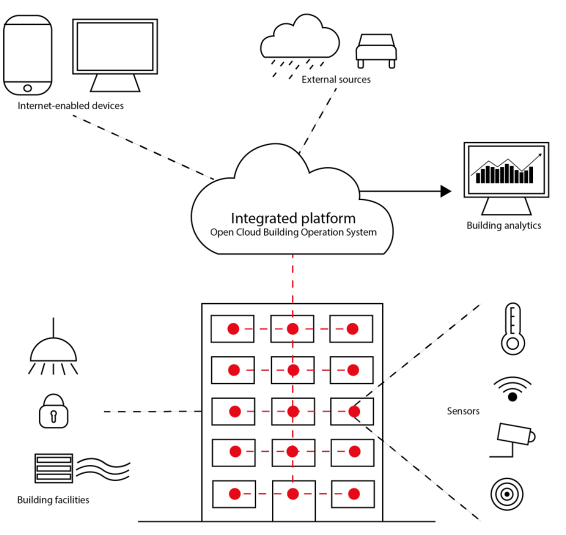


Figure 8.9: Components of a smart building (by Niels Dijkstra)

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Figure 0.2	Photos via Unsplash (top: Geraldine Lewa, middle: Justin Main), Dutch universities
Figure 0.3	Own illustration
Figure 0.4	Own illustration
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Figure 0.6	Left: University of Leuven, Right: Cambridge University
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Figure 1.9	Own illustration
Figure 1.10	Own illustration

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Chapter 3

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Chapter 4

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Figure 4.7	Own illustration
Figure 4.8	Jeroen van den Heuvel
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Chapter 5

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Figure 5.6	Own illustration
Figure 5.7	Own illustration
Figure 5.8	Linda Supheert
Figure 5.9	Top: TU Eindhoven / Planon, bottom: University of Amsterdam / Mapiq
Figure 5.10	Wageningen University / Lone Rooftop
Figure 5.11	Own illustration

Chapter 6

Figure 6.1	Own illustration
Figure 6.2	Own illustration
Figure 6.3	Own illustration
Figure 6.4	University of Leuven
Table 6.6	Own illustration (initial figures by Den Heijer, Arkesteijn and De Jonge)
Figure 6.5	Wageningen University / Lone Rooftop
Table 6.8	Own illustration (initial figures by Den Heijer, Arkesteijn and De Jonge)
Figure 6.6	University of Amsterdam
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Table 6.16	Own illustration (initial figures by Den Heijer, Arkesteijn and De Jonge)

Chapter 7

Cover photo	Beppe Giardino
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Figure 7.5	Left: University of Amsterdam / Mapiq ; Right: Wageningen University/Lone Rooftop
Figure 7.6	Own illustration

Chapter 8

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Figure 8.7	Linda Supheert
Figure 8.8	Sven ter Veer
Figure 8.9	Niels Dijkstra

Appendices

Appendix 1 List of terms and abbreviations

Definitions

Actual space use
The use of space in reality (in contrast to predicted space use). Alternatively terms such as 'surveyed space use' can be used

Campus management
The process of attuning the university campus (real estate and services) on the changing context and stakeholder perspectives, which adds value to the performance of the university

Data
Numbers, words, symbols etc. devoid of context

Effective space use
The extent to which a space is used to achieve an intended result. For example: to help students learn and study. (Qualitative)

Efficient space use
The extent to which the waste of available resources is prevented – in this case to maximise the use of space. (Quantitative)

Occupancy
The use of a space in relation to the capacity of that space. A space is occupied by an x amount of people.

Occupancy rate
The formula for the occupancy rate is: amount of people in the space / maximum capacity of the space * 100%

Frequency
The use of a space in relation to the availability of that space. A space is frequented for an x amount of time

Frequency rate
The formula for the frequency rate is: amount of time that the space is used / maximum available time of that space * 100%

FTE
Full-time equivalent, a unit of measurement to express the size of the workforce of an organisation

GFA
Gross floor area, related to NEN2580. The total floor area contained within the building measured to the external face of the external walls.

HVAC systems
Heating, ventilation and air conditioning systems

Information
Data to which context has been added.

Laboratories
Spaces designed to conduct a specific type of research, and which is used for research and not for education practicals.

Measurement method
The technology used to collect real-time data as a component of smart campus tools. Alternatively the word 'sensors' is used.

Meeting rooms
Rooms designed for meetings between employees.

No-show
The event in which a reservation is made but not actually used.

Objective
That what needs to be achieved through use of the smart tool. The objectives are described by using Den Heijer's framework describing ways in which real estate adds value to organisational objectives.

Office environment
Offices and meeting rooms

Offices
Spaces with one or more workplaces –individual or shared- where employees work individually

Predicted space use
The use of space according to scheduling systems, booking systems or forecasts (in contrast to actual space use). Alternatively 'scheduled space use' can be used.

Self-booking system
A system in which the user is able to make a booking without any intervention of a third party.

Smart tool
A smart tool is a service or product that collects information on space use real-time to improve space use on the current campus on the one hand, and to improve decision-making on the future campus on the other hand.

Space use
Generic term for the occupation of a space by a person. Space use can be measured on the resolutions of frequency, occupancy, identity and activity (based on Christensen et al.).

Study space
All spaces on campus that are used by students to study in. This includes spaces designed for such a purpose, e.g. study places, carrels, PC halls, libraries, project rooms; it can also include spaces designed for other purposes, e.g. canteens, classrooms and meeting rooms.

Teaching space
All spaces on campus that are specifically designed for teaching purposes. This can include lecture halls, classrooms, practical rooms, PC halls, etc. Alternatively education space can be used.

University campus
All the land and buildings that are in use by university functions or functions related to the campus, whether leased or owned by the university, and not bound to a single location

Utilisation survey
General term for a survey of the space use (utilisation) by an organisation. Traditionally surveys are administered manually

Abbreviations

International universities (chapter 3)

AU	Aarhus University
CAM	Cambridge University
CMU	Carnegie Mellon University
DTU	Technical University of Denmark
KUL	University of Leuven
OSBS	Oxford Said Business School
OXF	Oxford University
SHU	Sheffield Hallam University

Organisations (chapter 4)

ABN	ABN AMRO
AGF	Agnelli Foundation / Carlo Ratti Associati
EMC	Erasmus Medical Centre
ERI	Ericsson
GGL	Google
MIC	Microsoft
NLG	Dutch government
OVG	OVG

Dutch universities

EUR	Erasmus University Rotterdam
LEI	Leiden University
MU	Maastricht University
OU	Open University
RU	Radboud University Nijmegen
RUG	University of Groningen
TUD	TU Delft
TUE	TU Eindhoven
TiU	Tilburg University
UvA	University of Amsterdam
UU	University of Utrecht
UT	University of Twente
VU	VU Amsterdam
WU	Wageningen University

Appendix 2 Data collection

Participants

The following participants have contributed to the data collection in chapters 3, 4 and 5 by responding to enquiries, participating in interviews and/or by filling in the data collection format.

Smart tools at international universities (chapter 3)

Aarhus University	Henrik Friis Bach, Andreas Stilling Heuwinkel
Cambridge University	David Marshall
Carnegie Mellon University	Yuvraj Agarwal
Denmark University of Technology	Lars Binau
University of Leuven	Peter Verbist
Oxford Said Business School	Mat Davies
Oxford University	Emma Spencer
Sheffield Hallam University	Donna Cooper

Additionally, interviews were conducted with Dominik Brem of ETH Zurich, Sandra Henrich of EPFL, Fiona Bradley and Eleanor Macgennis of Glasgow University. Alastair Adair of Ulster University and Pat McAllister of Reading University responded to the enquiry for their universities.

Smart tools at organisations (chapter 4)

ABN AMRO	Marleen de Haan, Sander ten Have
Agnelli Foundation (Carlo Ratti Associati)	Giulia Maccagli
Erasmuc Medical Centre	Arjan Windhorst, Huib Maclean
Ericsson	Richa Singh, Tommy Korhonen
Google	Frans van Eersel
Microsoft	Brian Collins
Government of the Netherlands	Frank van Linden, John Rosema
OVG	Erik Ubels

Additionally, information obtained in the previous research project was used in chapter 4.4: an interview with Jeroen van den Heuvel of Dutch Railways.

Dutch universities

TU Delft	Arjan van der Meijde, Sabine Kunst, Linda Heemskerk
TU Eindhoven	Bregje van der Steijn, Erwin Spanjaards
Tilburg University	Marloes Peeters
University of Amsterdam	David Quainoo
Utrecht University	René den Houting
University of Twente	Rudy Oude Vrielink
VU Amsterdam	Carin van der Wal
Wageningen University	Joris Fortuin

Joint meeting Dutch universities

Additional information on the use of smart tools at Dutch universities was collected at the joint meeting. The participants of this meeting are listed below.

TU Eindhoven
Lotte Kester
Annemieke Pelt-Thissen
Bregje van der Steijn
Monique Kuyck
Anne van Dortmont
Erwin Spanjaards

University of Amsterdam
David Quainoo
Marij Veugelers
Tom Verhoek
Astrid Ens

VU Amsterdam
Marjan Oliehoek
Carin van der Wal

Leiden University
Rogier de Bruin
Maarten Kruizinga

Utrecht University
Rene den Houting
Jan-Willem Moerkerk
Willem Huijgens

Tilburg University
Maurice Paas
Marloes Peeters
Janny de Knegt

Maastricht University
Jacques Knoppen
Daniel Rienties
Olaf ten Have

University of Groningen
Walter Timmermans
Ruben van der Leij
Leon van der Meulen

TU Delft
Catelijne Elissen
Kelvin Berghorst
Iljoesja Berdowski
Arjan van der Meijde
Sabine Kunst

Researchers MBE
Bart Valks
Alexandra den Heijer
Monique Arkesteijn
Linda Supheert

Interview protocol

General questions

#	Topic	Question / subject
1	Context	Organisational development, CRE portfolio development
2	Smart tools	Which smart tools / examples of use of real-time data are currently applied at [university]
3	Decision-making	How is the data from smart tools used at [university] in decision-making processes? Has it led to the redesign of offices, adjustments to the CRE strategy, etc.?
4	Privacy	How does [university] deal with privacy in the use of sensitive information?
5	Interest in smart campus tools research	How can we keep [university] updated during the research and with which results?

Template questions

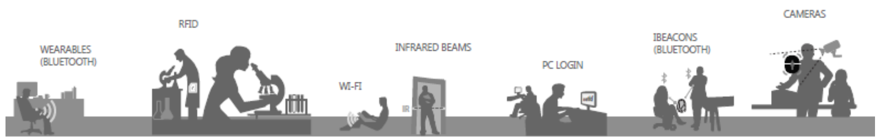
Interview	Fields in template
	Organisation-#
	Fill in the abbreviated name of the organisation and a number to distinguish multiple smart tools at the same university.
answer	
	Project description
question	Could you indicate how the initiative for this smart tool was taken (problem) and why this smart tool has been chosen (solution)
answer	
	Phase
question	In which phase of implementation is the smart tool?
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 Implementation – If the smart tool has been implemented and is now part of the regular operation
answer	
	Scale
question	Could you indicate how large the application area of the smart tool is, in m2 Gross Floor Area and amount of buildings?
answer	
	Duration
question	Since when is the tool in use at your organisation?
answer	
	Functions
question	Which functions does the smart tool have?
options	Wayfinding, room booking, find a workplace, monitoring space use, linking systems, optimising workplace comfort. Other options can apply
answer	
	Space types
question	For which space types is the smart tool used?
options	Education spaces, study places, project rooms, laboratories, offices, meeting rooms, whole building
answer	
	Foreseen developments
question	Are there foreseen developments in the near future - amendments or improvements to the existing tool, replacement, etc.?
answer	
	Investment costs (per m2 GFA)
question	Could you indicate what the investment costs of the smart tool are, in € per m2 gross floor area?
explanation	Investment costs are costs that have to be made once, e.g. to develop the smart tool, do a pilot, make start-up costs to adjust floor plans
answer	
	Operating costs (per m2 GFA)
question	Could you indicate what the operating costs of the smart tool are, in € per m2 gross floor area?
explanation	Operating costs are costs that have to be made annually for the smart tool, e.g. software licences, maintenance of sensor infrastructure, extra server space.
answer	

	Benefits
question	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 ...
answer	
	User information
question	Could you indicate what information is available to the user and how the tool works?
explanation	
answer	
	Management information
question	Could you indicate what information is available to the campus manager and how the tool works?
explanation	
answer	
	Why: Objectives
question	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	
	Why: Objectives
question	Which goals have priority? How are they achieved?
answer	
	What: Measurement
question	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	
	What: Measurement
question	What exactly is measured? How is privacy addressed?
answer	
	How: measurement method
question	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	
	How: measurement method
question	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	
	Actuality of the information
question	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	
	Actuality of the information

	Actuality of the information
question	Could you further specify how up-to-date the information in the smart tool is? Are there differences between functions?
answer	
	Access levels
question	Who has access to the smart tool?
options	managers, support, users, open access.
answer	
	Access levels
question	Who has access to which function of the smart tool?
answer	
	Side notes
question	Could you share some of the experiences with the smart tool, or other information which you think could be of interest for campus managers?
answer	
	Images
question	Could you send a number of images of the smart tool?
	1 general image, 2 user information, 3 management information
answer	

Appendix 3 – Overview of sensors

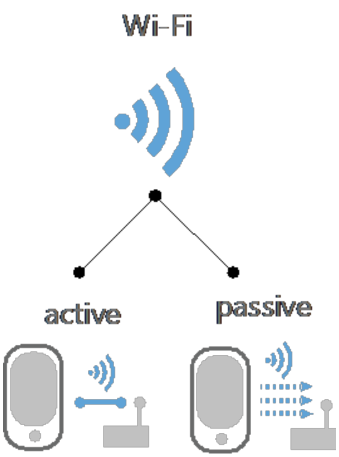
This appendix provides a further elaboration on all the different ways observed over the course of this year's research and the research previously done. This overview of sensors was originally based on a survey on indoor positioning methods done by Mautz (2012), a white paper on utilisation collection technologies by Serraview (2015). Then, during the interviews information on sensors gradually expanded and the overview was adapted.



different sensors are used to determine how space is used

Determining space use with sensors

First, the different types of sensors used to determine the use of space and the various methods to measure space use with these sensors are discussed.



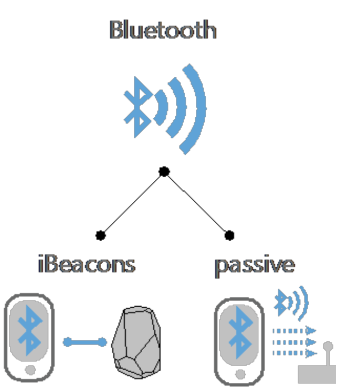
Wi-Fi

The Wi-Fi network can be used to estimate the amount of occupants in a building. As the demand for Wi-Fi in buildings has increased, so has the infrastructure present in buildings: the amount of access points and their performance. The amount of users present and connected to the network via their smartphone, laptop or tablet is so high that it has become of interest to use this technology to measure the frequency and occupancy rates in buildings.

Two different ways to use the Wi-Fi network to measure space use are distinguished. The first method is to collect the data on the amount of devices connected to each access point located in the building. This generates data that is quite coarse, as it shows which access points have users connected to them but not on which floor. Furthermore, it does not recognise devices that cannot connect to the network.

The second method is to collect the data on the attempts that devices make to connect to all access points in the building. This obviously generates far more data than the first method, but comes with an RSSI value (received signal strength indicator). Comparing the RSSI values of connection attempts that a device makes with different access points makes it possible to estimate more accurately what the location of the user is.

Aside from the use of Wi-Fi data to measure space use, it can also be used to localise users within buildings. This technology is used in some wayfinding apps and colleague finding apps.



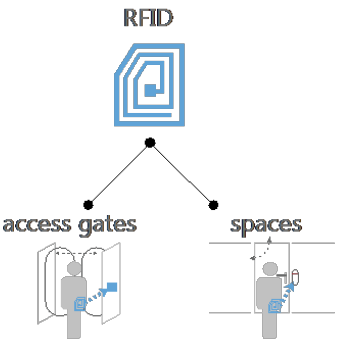
Bluetooth

Bluetooth is a form of wireless connection that can be used to transmit data over short distances (when compared to Wi-Fi); also the amount of data that is transmitted is usually smaller than with Wi-Fi. Similar to Wi-Fi, the use of Bluetooth for the purpose of measuring space use has become interesting because of the increasing amount building occupants using devices. An important condition of using Bluetooth is that the user has Bluetooth enabled on his/her device. This condition makes that by default a smaller amount of users is observed when measuring space use.

One method is observed in which Bluetooth is used to measure space use. The first type is iBeacons, which are small devices that are placed in each space and to which devices present with active Bluetooth connect. This works similar to the way in which you would connect to a Bluetooth device. In order to maximise the amount of users that connect with the iBeacons (and thus the accuracy of the space use measurement) it is common to develop an app that activates Bluetooth and automatic connection with iBeacons with permission of the user. This method is also used for localisation in indoor environments. Alternatively, methods exist to collect space use data via Bluetooth in a similar way as with Wi-Fi; i.e. measuring the periodic attempts of a device to search Bluetooth devices in the environment. This method is used in various scientific studies. Here the extent to which users are detected depends on if their Bluetooth is active. Research shows that the percentage of total users detected by Bluetooth scanners is estimated to be between 5 to 11 percent (see for example Daamen et al. (2015) or Versichele 2012)).

RFID

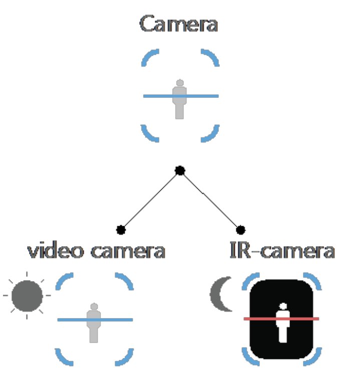
RFID, which stands for Radio Frequency Identification, is a system that consists of (1) a chip with information and an antenna and (2) a reading device. In passive RFID systems the chip is activated by the reading device. This system is commonly used in libraries and retail outlets for theft prevention, but also in warehouses or hospitals to track the location of assets.



Two different methods that have been identified to measure space use with RFID. The first method is access control: by using systems that grant access to buildings or restricted sections. These systems grant access per person. The use of access gates to restrict entrance to buildings is quite common at corporations. Because all users need to pass through these access gates, it gives an accurate measurement of the amount of people present in a building. Another example of the use of access gates is at Dutch Railways, where passengers gain access to most station terminals via the use of smart cards.
The second method considered is the use of reading devices in doors of meeting rooms, offices etc. that are activated via a campus card. The difference between this system and the access control is that access is not restricted per person: one person can allow a group entrance to a space. That makes this method unsuitable to accurately measure space use.

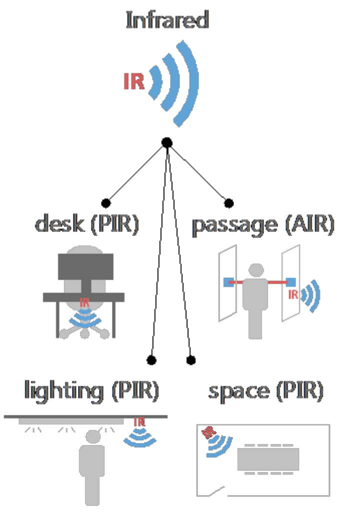
Cameras

The application of cameras to measure space use can be done in many ways, that are dependent on the placement of the camera, the type of camera and the software installed to process the images. Camera footage is usually not saved, but analysed real-time via the use of software.



Two main methods are distinguished: video cameras and infrared cameras. Video cameras are used in situations when there is sufficient light. Depending on the software, video cameras can measure e.g. the amount of users in the view of the camera, the amount of persons in a predefined zone, the amount of incoming and outgoing persons at an exit.

Infrared cameras register an image based on infrared radiation (heat) of objects. By adding software to the cameras they also be used for people counting. Infrared cameras are mainly used for security purposes in outdoor environments.



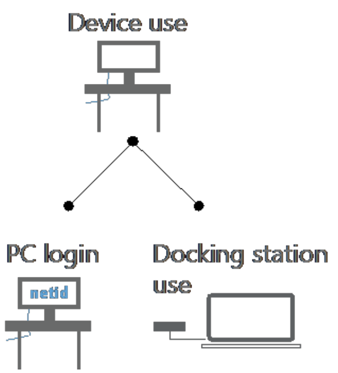
Infrared

The application of infrared to measure space use can be done in multiple ways. Within infrared applications active infrared (AIR) and passive infrared (PIR) are distinguished. AIR works with a transmitter and a receiver, in which the breach of an infrared beam is registered. PIR systems sense energy variances in the environment within range of the sensor.

Four different methods of PIR sensors to (potentially) measure space use have been identified, but many more might exist. The first is using an AIR to measure the amount of entries and exits at an entrance. These sensors are maybe even used already on campus to automatically open and close doors when a person approaches them. However, no applications of this method to measure space use have been found during the study.

The second method is the use of PIR sensors that are integrated in lighting systems. Here the PIR sensor triggers the lighting based on the presence of one or more persons in the area beneath the lighting. The use of these systems to measure space use is limited. Firstly, they measure frequency and not occupancy; secondly, they are prone to false positives e.g. a person passing through the space and not occupying it and to false negatives e.g. a person that is stationary for a long period and thereby not registered.

A method using PIR sensors that is often used for measuring space use is sensors underneath desks. This sensor determines for each workplace when the desk is occupied or not. The accuracy of these sensors is very high – however, they are also very costly. Finally, the fourth method is the use of PIR sensors to measure the space use in meeting rooms. Here the PIR sensor registers the presence of people. This method is perhaps most commonly used – it is cost efficient and helps to effectively determine if meeting rooms are actually used.



Use of devices

The application of registering device use to measure space use is also found in some cases. Here the use of workplaces can be determined by logging if the personal computer (PC) on that workplace is in use. Alternatively, if users make use of laptops, the use of the docking station on the workplace can be monitored. Of course the accuracy of these solutions depend on the extent to which these facilities are used: for PCs if everyone makes use of PCs or not; for docking stations if everyone has laptops that are compatible with the docking stations.

Ultra-wideband

Ultra-wideband (UWB) is a technology similar to Bluetooth and Wi-Fi that enables the wireless transmission of data between devices. The advantage of UWB is that it can transport large amounts of data over a relatively large distance, whilst using a low amount of energy. UWB is also not hindered much by obstacles such as doors and walls. Therefore in some scientific studies it has been tested for use in safety applications – e.g. to detect if there are users inside a building in case of a fire (Thiel 2011).

CO2 sensors

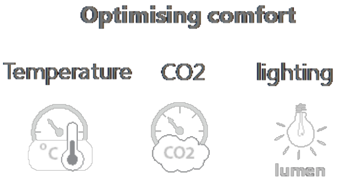
By measuring the CO2 concentration of the air in a space an estimation can be given of the amount of users present in a space. Frequency can certainly be detected, but estimating occupancy is difficult due to the variables that influence the CO2 concentration: i.e. the CO2 concentrations of incoming and outgoing air, the air refresh rate, and the activity level of the people present. CO2 sensors are commonly present in public buildings to steer HVAC systems.

Related uses of sensors

Aside from the purpose of measuring space use, the various cases reveal that sensors are also used in the built environment for other purposes. These purposes and the sensors used are discussed shortly.

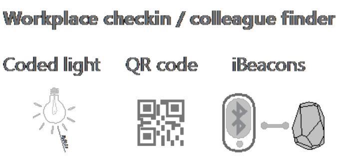
Optimising comfort

In order to optimise the comfort of employees or students, various aspects of the study or work environment are measured. Employees or students can submit their preferences and a system can (a) help them to find a place that matches their preferences, (b) enable them to adapt a workplace to their preferences or (c) automatically adjust the environment to their set preferences. Temperature, lighting and CO2 sensors are the main sensors used.



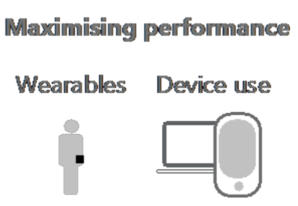
Workplace check-in / colleague finder

In order to help people find an available work place or study place, some organisations work with reservation and check-in systems rather than sensors. In these systems the challenge is to make sure that people always mark their space in use when they come and similarly, mark it as available when they leave. Various methods are observed to do this. Furthermore, because users check-in to a location this method can also be used for applications such as a colleague finder.



Maximising performance

In order to support students or employees in maximising their performance, some applications have been observed in which data is collected that is analysed to provide users with advice that helps them to optimise their performance. For example, by monitoring the sleep levels and activity levels users can be advised on their health or the presence of students on campus can be used to advise them based on the average presence on campus. In one case in this research the use of devices is monitored to gain insight into the productivity of meetings – i.e. if users are using their devices during the meetings to send e-mails, they are probably not using the meeting productively. Also, the insights gained via monitoring collaborations via mail and messenger programs can be used to inform the design of the workplace.



Appendix 4 – GDPR Summary

This appendix summarises the main contents of the EU's General Data Protection Regulation (GDPR) in order to assess the efforts that need to be taken to comply to regulations for certain smart tools. The GDPR is a strengthening and expansion of privacy rights and leads to an increased responsibility for commissioning parties. The GDPR will go into effect on May 25th 2018. It states (in summary) the following[1]:

Personal data may be collected on the following grounds:

1 It is permitted by the user

- Permission must be given freely;
- Permission must be given verbally or in writing;
- The user must be informed about the identity of the organisation, the specific aim of the data collection, what exactly is collected and how to retract permissions
- Permission only pertains to a specific use and a specific objective. For every objective specific permission is required
- Permission and retraction must be equally simple

2 Vital concern (not applicable to smart tools)

3 Required by law (not applicable to smart tools)

4 An agreement – e.g. in order to deliver post, you need the recipient's address (not applicable to smart tools)

5 Required for public interest or public authority

- Universities have a responsibility for the safety on campus[2] – hence personal data may be collected if necessary to fulfil this task

6 Legitimate interest

- Prove that the interest is legitimate: that is it necessary to fulfil organisational activities
- The use of personal data must be necessary to achieve the legitimate interest. Assess if (1) the breach of privacy is proportionate to use of data and if (2) the objective can be achieved in a way that is less disadvantageous for the people involved.
- Consider how your legitimate interest weighs against that of the interests of the involved people

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1 Contents based on https://autoriteitpersoonsgegevens.nl/nl/onderwerpen/avg-nieuwe-europese-privacywetgeving/algemene-informatie-avg

2 https://www.rijksoverheid.nl/onderwerpen/veilig-leren-en-werken-in-het-onderwijs/veiligheid-op-school

In order to ensure thoroughness:

- Public organisations are required to hire an official for data protection
- The standard for personal data collection is to design solutions that protect personal data and that not more personal data is collected than necessary; and that only the personal data necessary to achieve the objective is used
- Necessity to conduct Data Protection Impact Assessments (DPIAs)
  - If personal aspects are thoroughly evaluated, e.g. in profiling
  - If special personal data is collected on a large scale
  - If personal data is collected on a large scale in public areas, e.g. camera observation

Organisations are required to:

- Compose a register with all data processing of personal data
- To write an organisational privacy policy
- To secure personal data
  - The measures taken must be in proportion to the risk of a breach
  - In cases that data processing is done by third parties to sign data processing agreements.

Involved people have the right to:

- See the data
- Rectification of incorrect (use of) data
- Right to be forgotten
  - Circumstantial, e.g. if data is not necessary anymore, after retracting permissions, in case of objection
- Right to receive the collected personal data from organisations
- Right to be informed (via privacy statement)

Data processing agreements:
In cases where data processing is done by a third party, an agreement needs to be signed by both parties that satisfies numerous requirements. Primarily it states matters of data use and data security.

Accountability requirement:
Is it really necessary to collect personal data in order to fulfil this task?

Based on these requirements the following table has been filled in, which can also be found in the report. Four categories of smart tools are distinguished –based on the extent to which personal data is collected- and for each of these categories the activities required to comply with the GDPR are listed, with references to the aforementioned requirements.

Categories	Activities
0 – GDPR requirements that in any case need to be fulfilled	• Hire a data protection official (2a) • Compose a registry with all processing of personal data (3a) • Write an organisational privacy policy (3b) • Secure personal data (3c, in relation to 3a) • Enable users to easily enforce their rights stated in (4a-e)
1 - Minor. Personal data is used, e.g. login data to gain access to smart tool	(In addition to 0) • Argue the need to collect this data based on an agreement (1d) – in order to restrict access to the application for users, a login portal is needed • Even in minor cases of personal data use by third parties (i.e. login data), a data processing agreement with the supplier of the smart tool is necessary. (3c, 4a-e) • Add case to existing documents (3a, 3b)
2 – Uncertain. Personal data is collected, but anonymised.	(In addition to 0) • Justify if the need to collect the data applies via user permission or legitimate interest (1a or 1f); In case of user permission, ensure that the conditions are met • Assess whether privacy by design (2b) is met • (Optional) Conduct a DPIA (2c) • Sign a data processing agreement with the supplier of the smart tool (3c) • Add case to existing documents (3a, 3b)
3 – Extensive. Personal data is collected and used.	(In addition to 0) • Justify if the need to collect the data applies via user permission or legitimate interest (1a or 1f); In case of user permission, ensure that the conditions are met • Assess whether privacy by design (2b) is met • Conduct a DPIA (2c) • Sign a data processing agreement with the supplier of the smart tool (3c) • Add case to existing documents (3a, 3b)

Table – Assessment matrix of legal effort (N.B. this matrix is drafted to give an indication of the workload associated with the implementation of certain smart tools. For exact instructions consult a legal expert)

Appendix 5 About the authors

The authors are all employed by the department of Real Estate Management at the Faculty of Architecture and the Built Environment, TU Delft.

Bart Valks

Bart Valks, MSc, is Ph.D Candidate and Policy Officer at the dept. of Campus and Real Estate, TU Delft. He has a background in Architecture (BSc) and Management (MSc). In his minor at TU Vienna he started to focus on research of the built environment in three different theses. For his Master's thesis –aimed at the design of a real estate portfolio of lecture halls of TU Delft based on stakeholder preferences- he received an honourable mention from the university and a second place in the 2013 CoreNet Student Award for best MSc thesis.

Since graduating he has been working as a policy officer and been aimed at the application of decision-making models and generating management information in practice. He has worked on different policy subjects, i.e. the university's campus strategy, policies on education spaces and international student housing. Since the fall of 2015 he has combined this position with the research on smart campus tools.

Monique Arkesteijn

Monique Arkesteijn, MSc, MBA, is Assitant Professor and Head of the Dept. of Real Estate Management. She has a background in Architecture (BSc) and Management (MSc). Her specialisation is real estate strategies in both the public and private sector. Her PhD research is aimed at the alignment of demand and supply in real estate strategies. She has developed a new method to achieve this: preference-based design of a real estate portfolio.

In the past she has worked as a project manager and consultant at Arcadis, G&P and Diephuis Stevens and completed an MBA degree at TSM Business School. Next to her appointment at TU Delft she is connected to CoreNet Global, the largest worldwide network of professionals in real estate, as member of the CoreNet Global board.

Alexandra den Heijer

Alexandra den Heijer, MSc, PhD is a Professor of Public Real Estate. She has a background in Architecture (BSc) and Management (MSc). Her specialisation is planning, design and management of university campuses and buildings. She is aimed at generating management information for decision-making in real estate. The past decennium she has developed models and theories that help universities to design and implement their campus strategies and which contribute to the creation of knowledge cities. All Dutch universities have supported her research from its inception.

In addition to her research on the Dutch context she has explored international context and written many reports, articles and papers on the university and the campus of the future, trends and changing concepts and campus strategies. After the fire that destroyed the Faculty of Architecture in 2008, she applied her theories in practice as part of the team that realised the new faculty (BK City) for students and staff in a monumental building, given an extremely tight schedule. Alexandra operates within an extensive network of national and international campus management experts, both in academia and in practice.

www.managingtheuniversitycampus.nl