

Smart campus tools 2021

Gaining insights from universities and other organizations to support the back-to-campus movement following COVID-19

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Master thesis report

P5

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TU Delft

“Disaster will continue to occur and technologies will likely help us cope with them”
(Dhawan, 2020, p. 17)

COLOPHON

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PREFACE

This report is the product of the research I conducted as part of my Master of Science with the selected track Management in the Built Environment at the TU Delft. The research process started in September 2020 and took a total of ten months to complete. I was able to integrate my interests in both technology and management in this research project.

I would like to thank my three supervisors – Alexandra den Heijer, Alexander Koutamanis, and Bart Valks – for all the guidance and feedback they provided throughout the research process. During the meetings, I received useful feedback that contributed to the completion of this report. Dr. Koutamanis pointed out which aspects of the research should be emphasized more. Moreover, leading up to the brainstorming session where I presented propositions and draft results, I worked closely with Prof. Den Heijer and Ir. Valks, which was very informative and helped turn the session into a success. Ir. Valks also showed a great amount of personal care throughout the research process, which in these unprecedented times (due to COVID-19) turned out to be very valuable for me. We met on Microsoft Teams almost every Monday. During these meetings, he expressed interest and care regarding my personal situation and mental health. Finally, I would like to thank Ir. Valks for his extensive feedback on this report and while processing the interviews.

I also would like to thank all interviewees and participants in the brainstorming session for their valuable contributions to my research project. I conducted thirteen interviews in which a total of sixteen participants were present. During the brainstorming session in May, a total of thirteen candidates were present. These sessions and the participants' interests energized me, and made me realize the purpose and value of my work.

Finally, I would like to thank my family, colleagues, friends, and in these times of lockdown, especially my roommates.

For me, writing this thesis was like sailing: initially, I had to try and make sense of a wide spectrum of new terms, ways and tactics to sail the right course and at the right speed. As I put in the time, my handling speed increased, the goal became clearer, and my mistakes were reduced. In addition, just like one has to deal with environmental contingencies in sailing, a major environmental contingency that I had to adapt to during the research process was the COVID-19 pandemic. Fortunately, with the help from the people mentioned above, I was able to find the right course and speed during this research process, and eventually cross the finish line.



Figure 0-1: My analogy of writing thesis (own illustration)

Happy reading!

Lars Cazemier
TU Delft
Rotterdam, June 2021

ABSTRACT

Purpose: The purpose of this research is to gain insights from universities and other organizations to support the back-to-campus (office) movement following COVID-19.

Aim: This research aims to determine whether universities or organizations utilize SCTs due to the changes in demand and supply (as a result of COVID-19). In doing so, the goal is to contribute to the recently created gap in scientific knowledge caused by COVID-19. In addition, to map the developments in the intervening years of this and the SCT2.0 study.

Research question: What has changed in terms of type, demand, and use of SCTs addressing space utilization at universities and other organizations due to COVID-19 compared to the 'Smart Campus Tools 2.0' research?

Methodology: To reflect the changes around COVID-19 and between this and the SCT 2.0 study, the SCT 2.0 study serves as the basis. Therefore, also in order to compare data, a qualitative study was conducted again. The following methods were applied to support answering the sub and main question(s): a first brainstorming session, literature study, case study, and a second brainstorming session.

Findings: To organize a limited return to the campus and office for users, keeping in mind the maximum capacity in the campus and office, modifications have been made in the type and use of SCTs. Many reservation systems have been implemented, or SCTs display a crowding indication in the buildings, based on the maximum capacity as per COVID-19. Existing measurement methods have been deployed with a different purpose for enhancing the safety, monitoring the maximum allowable capacity rather than aiming for the highest possible occupancy.

Limitations of the research: Through COVID-19, many changes have been made in a short period in the area of SCTs, and they are now being improved or are still being expanded. Therefore, it is uncertain whether the case study results are not, still partially, or still valid after the research and the COVID-19 crisis. But also that the size of the case study is narrow for other organizations which can harm the external validity of that aspect of this research.

Value: This research provides insights into how the use of SCTs has changed due to COVID-19. Since this has been little to no research, this contributes to the literature and in practice. In addition, it also reviews the developments that have taken place between the SCT2.0 and this research. These outcomes can immediately contribute for adaptations around space utilization and SCTs for professionals in this field.

Key words: (Corporate) Real Estate Management, Internet of Things, University campus, Smart tools, Campus management, COVID-19

EXECUTIVE SUMMARY

Problem statement and proposed solution

On January 30, 2020, the WHO Emergency Committee declared a global health emergency based on increasing reports of Chinese and international cases (World Health Organization). The unprecedented impact of COVID-19 has also affected education systems around the world. This means that more than 1.6 billion students, representing 91% of all students in the world (Sharma, 2020), have felt the impact of COVID-19 on their study environments.

The Smart Campus Tools (SCTs) and SCT 2.0 research has revealed that the use of SCTs is well known among Dutch and foreign universities. But it is possible that these parties anticipated on the COVID-19 crisis by deploying existing or new SCTs. Universities are implementing or have implemented SCTs to support decision-making and add more value to their real estate and users. A brainstorming session with nine Dutch universities and one Belgian university revealed several problems due to the COVID-19 crisis and uncertainties for the period after COVID-19 (Valks, 2021). It is uncertain how the campus will be used after the COVID-19 period; due to possible hybrid forms, the campus can be used more irregularly. The teaching methods, study, and work patterns may change due to the changing demand and the type of spaces needed for it.

Research objectives and questions

Because of the COVID-19 lockdown, universities and organizations organized many events online rather than physically. These institutions organized limited visits to campus and offices during the COVID-19 period, taking a maximum capacity into account. Because the COVID-19 crisis is a recent and still current event, there is a gap in the literature with the insights on how universities and organizations have utilized SCTs during this period. This research aims to reflect the use of SCTs in the COVID-19 period at universities and other organizations. In addition, it identifies differences in the use of SCTs in the intervening years between the SCT 2.0 research and this study. Through this research, the insights will fill part of the gap in the literature where campus managers can increase short- and long-term decision-making to benefit users and campus real estate.

Furthermore, a survey by Cisco shows that the integration of smart tools into the built environment can still be perceived as difficult. 60% of the initiatives are discontinued, and 26% are considered successful (Cisco, 2017).Generating knowhow during certain phases of implementing SCTs is helpful to develop better-informed decisions.

This research addresses the following research question:

What has changed in terms of type, demand, and use of Smart campus tools addressing space utilization at universities and other organizations due to COVID-19 compared to the ‘Smart campus tools 2.0’ research?

In order to answer this main question, the following sub-questions were formulated:

1. What is campus management?
2. What are Smart Campus Tools, and what is the added value of Smart Campus Tools in a changing demand?
3. What effect does COVID-19 have on the campus?
4. What progress have Dutch universities, universities abroad, and other organizations realized on Smart (Campus) Tools addressing space utilization compared to previous research?
5. To what extent do these Smart (Campus) Tools meet the needs and use of Dutch universities, universities abroad, and the other organizations after COVID-19?

To facilitate this, the research methodology will be briefly explained.

Research methodology

To identify changes in SCTs during the COVID-19 period and the intervening years of the SCT 2.0 study on the one hand and this study on the other hand, the same research method of the SCT 2.0 study will be applied. Therefore, a qualitative research strategy will be applied. The approach to gathering information consists of a first brainstorming session, a literature study, case study, and a second brainstorming session.

To gain understanding of what the aspects surrounding campus management and smart campus tools are, the results of the literature study will be summarized.

Results from literature study

Den Heijer describes the university campus as the locations of buildings related to the university and contributes to institutional goals based on owned buildings or used (rented) or both (2011, p. 51). The campus has evolved over the years and today, a change occurs around campus in response to student and faculty demand for an attractive campus (Den Heijer, 2011; Magnini et al., 2018).

Next, campus management is an objective about aligning the real estate with the organizational goals to add value to increase the users' performance. Den Heijer defines this 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" (2011). According to De Jonge et al., this is a decision-making process in which there is a continuous search for a match between demand and supply (2009). Also, it can be concluded that during this process, three aspects belong to this process and involve adding value (den Heijer, 2008; Den Heijer, 2011). First of all, all the stakeholders involved have to be taken into account (den Heijer, 2008; Temple, 2014). Second, stakeholders must determine criteria, develop alternatives, and assign preference ratings (Arkesteijn, 2019; De Jonge et al., 2009). Third, weighting the benefits and costs against four aspects linked to the four perspectives; strategic, financial, users, and technical managers (2011). This is reflected in a conceptual model in the figure below with the thirteen objectives added that serve to add value to the campus and users, according to Den Heijer (2011).

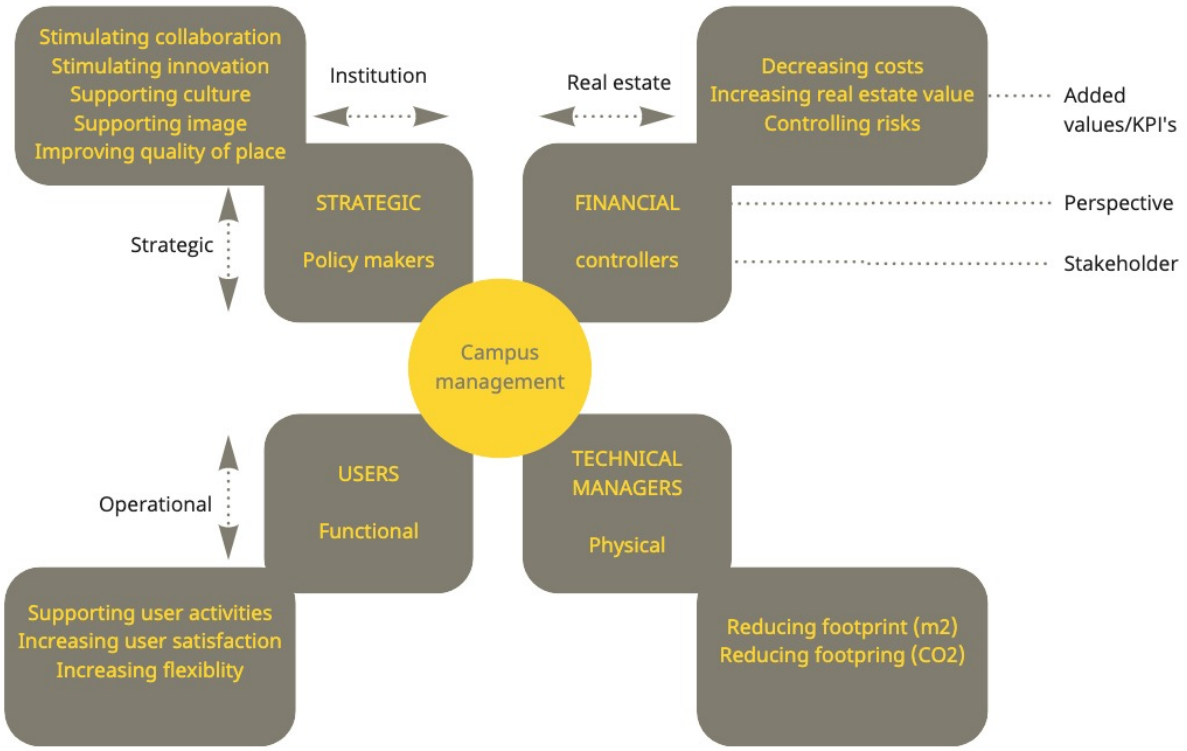


Figure 0-2: Multi-stakeholder approach linked to the four most important perspectives of campus management and their goals (from Den Heijer, 2008;2011)

Den Heijer created a model in which it is possible to position change in the use of space (at a high level). A trend has been defined in the change in use of the different spaces on campus, described by three physical states; solid, liquid, and gas (2019). These are presented in the figure below in which there will probably be a mix of the three different space uses on campus and which is reinforced by the COVID-19 situation.

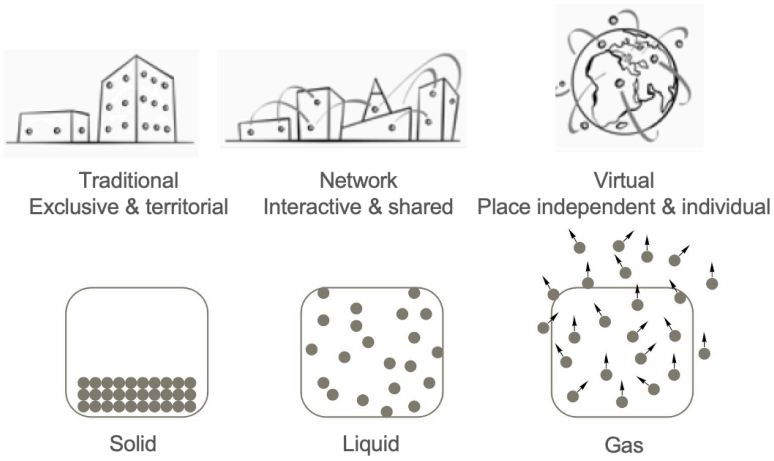


Figure 0-3: Dynamics that present how space is assigned and used (reprinted from Den Heijer, 2019)

It has become clear that SCTs can support the process of finding the match between supply and demand and users' performance. Partly because SCTs provide information that creates insights into the use of space. How this happens?

This is made clear by the following definition of a SCT; “a product or service that collects real-time data to improve space use on the current campus and decision-making about the future campus” (Valks et al., 2018).

The type of SCT is partly determined by the why, how, and what. Valks et al. (2018) describe these three aspects in which the why addresses the thirteen objectives (added values) showed in Figure 0-2. Next, the 'What' is about determining at what level space use should be measured which are shown in Figure 0-4 at occupation. Last, the how is about determining the measurement method whether this is measured on a manual, reservations, or sensor basis. Where sensors provide real-time data.

Resolution of:	→					
Time:	years	months	days	hours	minutes	seconds (real time)
Space:	campus	building	floor	space (large)	space (small)	workplace
Occupation:	frequency	occupancy		identity	activity	
Occupation description:	Yes/no	number of users		type of users	What is the user doing	

Figure 0-4: Overview of the resolution of time, space, and occupation (Own image, adapted from (Valks et al., 2016)

The aspects surrounding campus management and SCTs are described but first the impact of COVID-19 at universities will be described before the results of the case study are presented.

Results from first brainstorming session

The effect of the COVID-19 crisis on the campus has led to a mismatch between supply and demand, and the campus has hardly been used. With a consequence of physical adaptations, adapted use of SCTs, adapted way of education, impact on its users' social condition, and changes at the management level. At the university grounds, due to COVID-19 restrictions, universities have modified existing SCTs or implemented new ones. In order to ensure safety and a reduced capacity, there is an increased demand at universities to have more control over the various spaces on campus, based on crowds, occupancy, and utilization. As a first step to control the number of users present on campus, many universities implemented reservation or crowd monitoring systems. In addition to the physical adjustments, it appears that there is a growing urgency of managing (by measuring to keep control) the campus, and management support and willingness to implement smart tools have been increased (Valks, 2021).

As a result of these changes in demand for education, universities have anticipated and implemented short-term (or certain aspects possibly longer) campus supply changes. Current SCTs have been upgraded, new SCTs have been implemented, or research has been conducted to improve existing tools ’functionality. As a first step to control the number of users present on campus, many universities implemented a reservation system for education spaces (variation of systems). Several universities have applied variations of tools for crowd monitoring to identify crowds.

Finally, the future match between demand for and supply of real estate was discussed. Regarding the long-term effects of COVID-19, there are uncertainties about the right balance between face-to-face lessons and online learning, virtual exchanges, and physical mobility for the long term. Also, universities experience difficulties with no-shows, which was a problem before and during COVID-19

(Bongers, 2020). "Everything is booked, but many rooms and seats are empty" (Valks et al., 2016), even with reservations. Further, due to the possible hybrid education, there is a changing demand regarding space for education, study, and workplaces. It remains interesting to find out whether there are further developing tools and ways to use data better. Thus, it will be described what developments have taken place regarding the short-term effects of COVID-19 at the various parties interviewed.

Results from the case study

To determine the modifications in the use of SCTs during the COVID-19 lockdown period and progression at Dutch universities, universities abroad, and other Organizations, data was collected from seventeen interviews with cases of SCTs. This research concerns twenty cases for Dutch universities, five cases for universities abroad, and five cases for other organizations. The parties interviewed are shown in Tables 0.1 up to 0.3.

Table 0.1: Overview of the respondents at the Dutch universities

Universities Netherlands	Abbreviation	Function of interviewee(s)
Radboud University Nijmegen	RU	Facility management
Tilburg University	Uvt	Facility management
Twente University	UT	Campus/facility management
Delft University of Technology	TUD	Library
University of Amsterdam	UvA	Education services
VU Amsterdam	VU	Facility management
University of Utrecht	UU	Library; Library
Wageningen University	WU	Education services
Eindhoven University of Technology	TUE	Education services

Table 0.2: Overview of the respondents at the universities abroad.

Country	Universities abroad	Abbreviation	Function of interviewee(s)
Denmark	Aarhus University	AU	Campus management
Denmark	Technical University of Denmark	DTU	Library
United Kingdom	Sheffield Hallam University	SHU	Campus management
Finland	Aalto University	Aalto	Campus real estate
Belgium	KU Leuven	KL	Library

Table 0.3: Overview of the respondents at the other organizations.

Other organizations	Abbreviation	The function of the interviewee(s)
Dutch Government	NLG	Innovation management
ABN AMRO	ABN	Facility management; facility management
EDGE Technologies (former OVG)	EDGE	Innovation management

In three chapters, the situation from SCT 2.0 research and the changes at Dutch universities, universities abroad and other organizations were explained. In these chapters, cross-case analyses were performed to identify the progression and create findings on how these parties applied SCTs for space utilization in the COVID-19 period. This involves progression of the following aspects; the

timeline, foreseen developments, objectives, space use measurements, measurement methods, actuality of information, and access levels. To give an indication of the progression, Figures 0.5 through 0.7 summarize the newly applied SCTs and highlight the existing SCTs still in use.

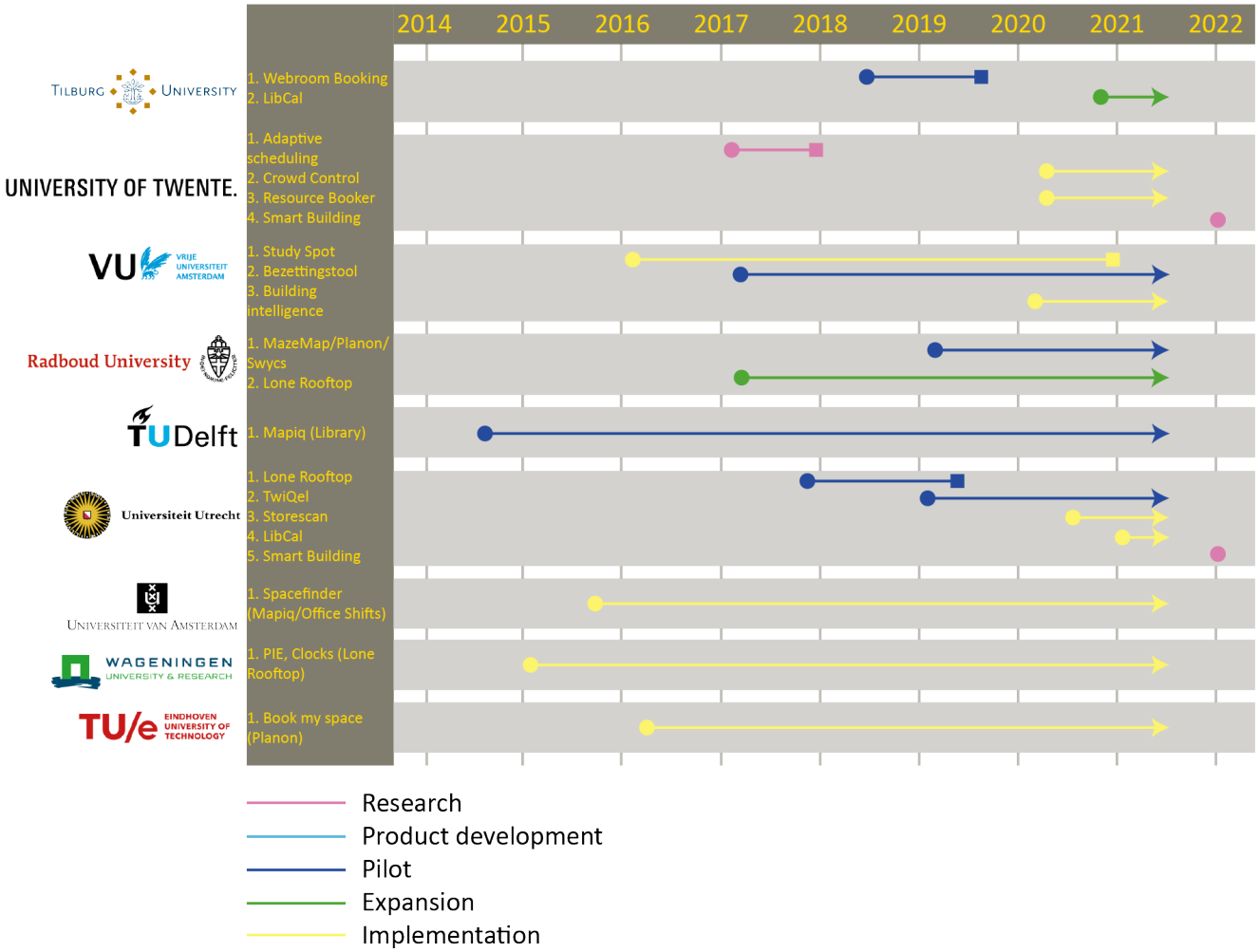


Figure 0-5: Timeline of the SCTs at Dutch universities (updated from Valks et al., 2018)

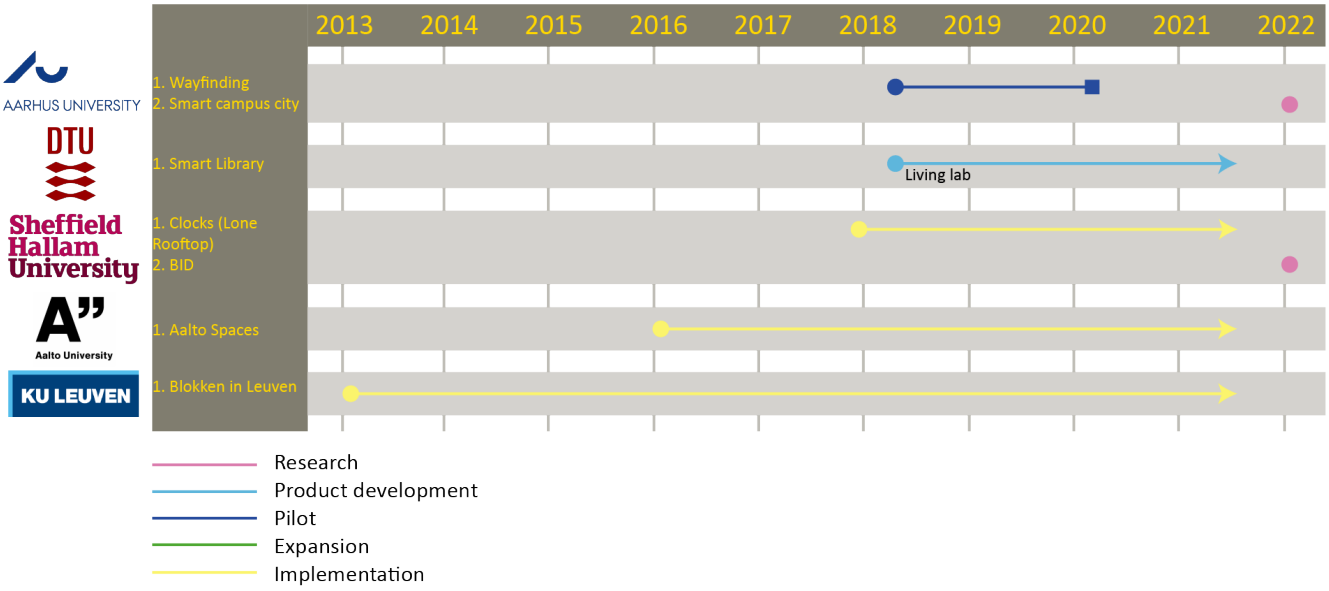


Figure 0-6: Timeline of the SCTs at universities abroad (updated from Valks et al., 2018)

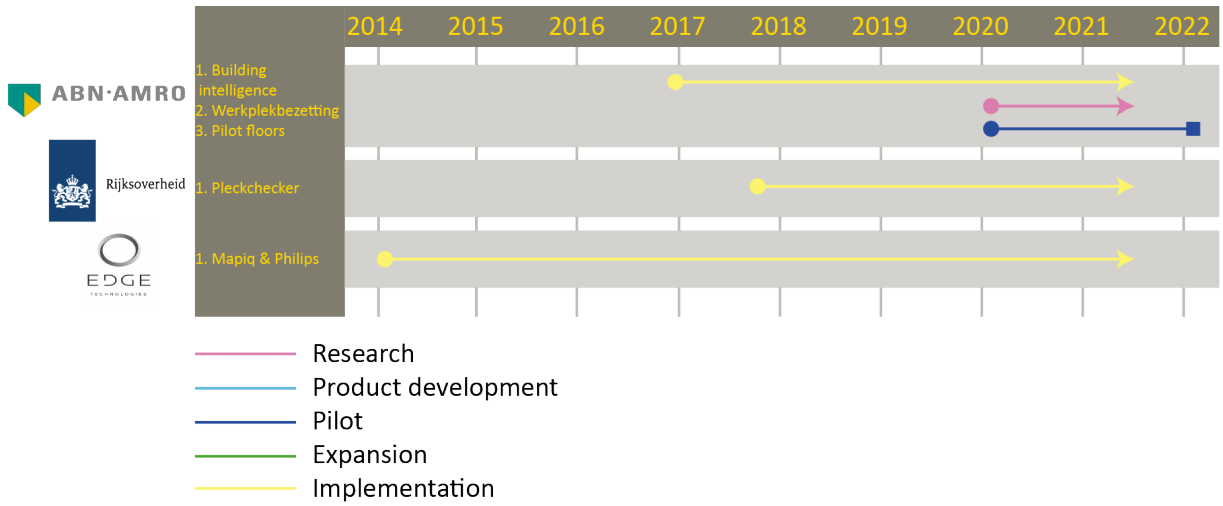


Figure 0-7: Timeline of the SCTs at the other organizations (updated from Valks et al., 2018)

At the Dutch universities it can be concluded that of the cases from nine Dutch universities, four have discontinued, nine new cases arose, and five cases are still in use. For the case of universities abroad, it can be concluded that they have achieved less progress in realizing new SCTs. One new case emerged from the interview at the Aalto. With regards to the universities abroad, it can be concluded that they have achieved less progress in realizing new SCTs. One new case emerged from the interview at the Aalto, and the case of AU is on hold. Concerning the progression at the other organizations, it can be concluded that two new cases have been initiated focused on space utilization at the ABN. In addition, the three existing SCTs are still in use and thus there has no delay or termination of SCT projects experienced.

The overviews below show the developments compared to the SCT 2.0 survey among the various parties.

- Expansion (buildings and m2) or additions
- Crowd indicator for users
- Crowd indicator for management
- Monitoring/managing capacity
- Use of sensors
- Improving safety as objective
- New Smart campus tools

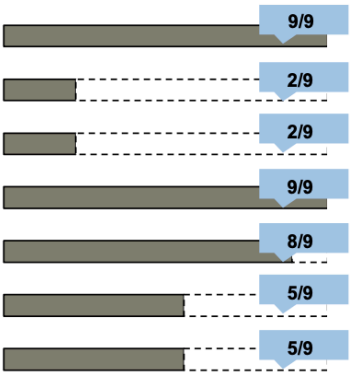
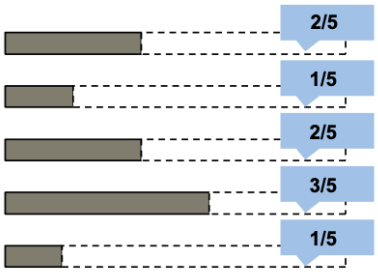




Figure 0-8: Developments in comparison with SCT 2.0 at Dutch universities and a map with their locations.

- Expansion (buildings and m2) or additions
- Crowd indicator for users
- Monitoring/managing capacity
- Improving safety as objective
- New Smart campus tools



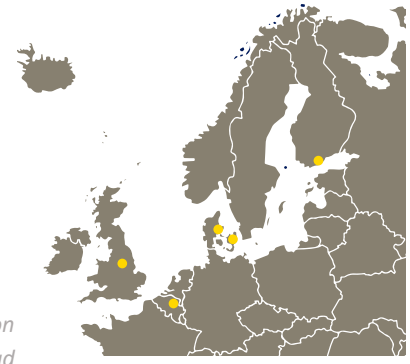


Figure 0-9: Developments in comparison with SCT 2.0 at the universities abroad and a map with their locations.

• Expansion (buildings and m2) or additions	ABN
• Crowd indicator for users	ABN & NLG
• Monitoring/managing capacity	ABN & NLG
• Improving safety as objective	ABN & NLG
• New Smart Tools	ABN



Figure 0-10: Map with the locations of the other organizations.

The overviews below show the developments compared to the SCT 2.0 survey among the various parties. Next, an explanation will be given as to whether the results from the follow-up brainstorms match or vary with those from the interviews.

Further, it has become clear from the interviews with the Dutch universities, universities abroad, and the other organizations, that it can be concluded that the existing and new SCTs have met their needs and use during COVID-19 times. It was mentioned several times that the back-to-campus (office) was partly made possible by the use of SCTs. In addition to further developing the existing and new applied SCTs, the focus is directed at better utilizing received data from SCTs for supporting users and decision-making. But also obtaining real-time information from sensors for study- and workplaces.

Results from second brainstorming session

The purpose of this chapter was to describe the main findings from the follow-up brainstorming session. This involved testing striking results and statements from the case study and gaining new insights by presenting statements and open-ended questions to the participants.

From this chapter, it can be concluded that SCTs became more relevant during the COVID-19 period than before. However, when this is compared to the hypothesis of this study, it can be derived from the changing context due to COVID-19. On the other hand, the measurement of space has been deployed differently than before COVID-19, where the safety of the users was mainly the reason rather than a hybrid form of education. This is comparable with the results from the case study. However, it has been experienced that, what is already observed with booking and no-show, that the importance with real-time information has increased. This is also evident according to the different room types where the combination of sensors and reservation were mentioned most often.

Conclusions

This research inventoried how the use of SCTs at universities and other organizations has changed by COVID-19. In addition to providing insight into these actions, the developments that have taken place between the SCT 2.0 and this research are identified. To answer the main question, data was obtained from literature, seventeen interviews regarding cases of SCTs, and two brainstorming sessions. This research concerns twenty cases at Dutch universities, five cases at universities abroad, and five cases at other organizations.

Since the changes surrounding the COVID-19 virus occured, existing or new SCTs have contributed to the 'back-to-campus/office' phase. This has been achieved through reservation tools for individual study places and/or tools that display crowding indications in the buildings. This has facilitated the monitoring of the amount of users in the buildings and the ability to regulate capacity.

Type

- Compared to the SCT 2.0 study, through the modifications caused by the COVID-19 crisis, there are cases at Dutch universities that do not depend on data from schedule/reservation systems.
- The type of existing or initiated SCT is modified in many cases to enhance safety as an objective.

Demand

- With the change in demand at the management level by COVID-19, there is a growing urgency to manage the campus based on data (measuring to keep control) during the COVID-19 period.
- To meet the demand to study on campus, two implemented approaches can be identified by employing a reservation system with which students can reserve a study place or project room or a crowding indication that creates insights for the user whether there are study places available and safe.
- From the interviews and brainstorming session, it appears that since COVID-19, the demand has increased for collaborations between facilities, management, or IT, since these departments focus on the use of SCTs too.
- New applications and foreseen developments show that the demand for real-time information for space utilization is increasing.
- With the insights of working from home, universities and other organizations have increased the demand to initiate reservation systems for workplaces.

Use

- At universities and other organizations, the use case for a SCT has mostly changed where existing sensors have been utilized to measure the occupancy in the buildings in order to monitor the capacity, instead of measuring to reach the maximum occupancy for space utilization.
- Since the introduction of reservation systems, a new form of occupying places without using them arose, which initially triggered the SCT study in 2015. This concerns reservations of study places that are not used afterwards (no-shows)(no-show) due to inefficient space usage and other students who might have preferred to reserve and use this place.

Discussion

Around the discussion, some limitations in relation to the theory were noted. Through the COVID-19 period, a frequently mentioned objective was “enhancing safety” which did not appear in the thirteen added values. In addition, optimizing the footprint (m2) also came up, which differs from the existing objective of reducing footprint (m2). Thus, the results regarding changes in the use of SCTs by COVID-19 are based on the case study and could not be compared with scientific literature. Lastly, there has been considerable use of standalone reservation systems on which opinions differ as to whether this is a SCT since most systems do not employ real-time information.

Limitations

Through COVID-19, many changes have been made in a short period in the area of SCTs, and they are now being improved or are still being expanded. Therefore, it is uncertain whether the case study results are not, partially, or still valid after the research and the COVID-19 crisis. But also that the size of the case study is narrow for international universities and other organizations, which can harm the external validity of that aspect of this research.

Recommendations for further research

New research in the areas of campus management, SCTs and space utilization can add value to the current scientific body of knowledge, with a number of aspects recommended for further research:

- Conduct a repetitive research in the future when long-term changes related to COVID-19 have been implemented.
- Conduct research with the other cases from the SCT 2.0 research that were not investigated
- Conduct a quantitative study to identify the effects the SCTs
- Conduct an empirical research component
- Conduct a detailed design study

Recommendations for practice

Through the findings gained during this research, the following recommendations for practice are described:

- Monitor progress of SCTs to determine the benefits
- Recommendations about the time period when there is a case of no-show, notifications, how much time in advance a booking can be made, and the financial consequences to reduce the no-show with reservation systems (‘het digitale handdoekje’)
- Engage users in the process of implementing SCTs make them realize the benefits of SCTs
- Share knowledge about the various issues at play at universities and other organizations
- Learning from the mistakes in unsuccessfully implementing an SCT contributes to the next implementation process.

DEFINITIONS & ABBREVIATIONS

This section lists the main definitions and abbreviations that will be employed in the research, with the intention of assisting readers in understanding the subjects addressed.

Term	Description	Source
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	(Den Heijer, 2011)
Community spaces	Spaces in which a bond is created between individuals and groups involved in a communal experience. The defining characteristic of communities is the shared sense of purpose, responsibility, commitment, the sense of inclusion, and relationships (McDonald, 2002)	(McDonald, 2002; Roberts, 1989)
Data	Numbers, words, symbols etc. devoid of context	(Valks et al., 2018)
Education spaces	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, lecture halls and meeting rooms.	(Valks et al., 2018)
Frequency	Frequency is the number of hours a room is in use as a proportion of total availability (the timetabled week).	(NAO, 1996)
Laboratories	A room or (part of a) building containing scientific equipment for conducting scientific experiments or for the education of science, or a place where medicines or chemicals are produced	
Measurement method	The technology used to collect real-time data as a component of “smart campus” tools. This information can be obtained from sensors, reservation systems or manually.	(Valks et al., 2018)
Meeting rooms	These rooms are used for meetings between employees	
No-show	The event in which a reservation is made but not actually used.	(Valks et al., 2018)
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 organizational objectives.	(Valks et al., 2018)
Occupancy	Occupancy is the average group size as a proportion of total capacity for the hours the room is in use.	(NAO, 1996)
Office space	Spaces with one or more workplaces –individual or shared- where employees work individually	(Valks et al., 2016)
Project rooms	Intended for student collaboration. Spaces (or parts of spaces) that are reserved for one project group during an entire teaching period, or spaces that can be reserved by project groups themselves.	(Valks et al., 2016)
Previous Research	Smart campus tools & Smart campus tools 2.0	

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.	(Valks et al., 2018)
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.).	(Valks et al., 2018)
Space utilization rate	$\frac{\% \text{ Frequency} * \% \text{ occupancy}}{100}$	(NAO, 1996)
Study places	Spaces that are set up for students to study individually. These spaces usually consist of a collection of workstations or individual rooms, with or without a fixed computer or set up for laptop use.	
University	Academic institution for higher education and research where there is a focus on universities rather than also University of Applied Sciences	
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	(Valks et al., 2018)
Users	Students, academic, and supporting staff connected to the university	
Workplace	The place (flexible or fixed) in a building or room where someone practices his/her work.	

LIST OF ABBREVIATIONS

BMS	Building Management System
CRE	Corporate Real Estate
CREM	Corporate Real Estate Management
FM	Facility Management
FTE	Full-time equivalent
IoT	Internet of Things
KPI(s)	Key Performance Indicator(s)
REM	Real Estate Management
SCT(s)	Smart Campus Tool(s)
SCT2.0	Smart campus tools 2.0

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PART I

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NORDICS 16 NOV 2020

Swedish universities brace for second lockdown

By Paul Connolly in Skellefteå

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09 juni 2020 13:32
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deVolkskrant

Voorpagina Nieuws & Achtergrond Columns & Opinie Uitgelicht

ACHTERGROND TERUG NAAR KANTOOR

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VAN NEDERLAND

middelbare scholen weer open, maar '1,5 meter afstand is een uitdaging'

2 JUN 2020, 09:46 / **UPDATE:** 2 JUN 2020, 22:22

NOS NIEUWS · ECONOMIE · 06-04-2020, 18:27 · AANGEPAST 06-04-2020, 20:46

Sectoren maken plannen voor 'anderhalve-meter-economie'

NOS NIEUWS · BINNENLAND · 08-04-2020, 19:20

1,5-meter-samenleving als nieuwe normaal? 'Blijf updaten en wees duidelijk'

Coronavirus lockdown means some US college students are paying US$70,000 for Zoom classes

- One student says the shift to distance learning due to stay-at-home orders has resulted in a loss of structure and supervision
- Some students have taken their grievances to court. At least 50 US colleges and universities have been sued by students

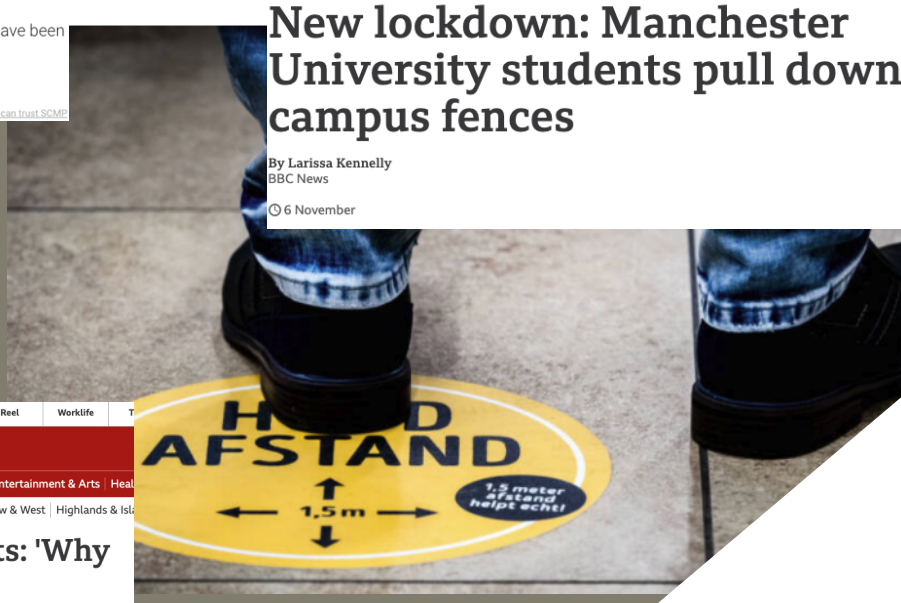
Agence France-Presse
Published: 2:20pm, 10 May, 2020

Why you can trust SCMP

New lockdown: Manchester University students pull down campus fences

By Larissa Kennelly
BBC News

6 November



Het 1,5 meterkantoor dreigt een onwerkbare werkplek te worden

COLUMN Neem plaats op de sofa van Irene van den Berg. Zij analyseert iedere week ons economisch gedrag.

Irene van den Berg 18-07-20, 12:30

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Covid-hit university students: 'Why have they sent us here?'

25 September

News › UK & World News › Schools

Government issues rule update for schools and universities under second lockdown

The Government has now issued fresh guidance

SHARE 4 COMMENTS By Lottie Gibbons 05:00, 3 NOV 2020

NEWS

News › Bristol News › Coronavirus

How students and staff at the ' about staying open during '

'I think I would feel safer and more comfortable a

SHARE By Estel Farell Roig Se 20:57, 2 NOV 2020 UPD

NIEUWS GEDRAGSONDERZOEK

RIVM: meer mensen hebben moeite om 1,5 meter afstand te bewaren

Update: Universities Minis Address

Covid-19 News News Univers

3rd November 2020 New

CONCEPTS

1 INTRODUCTION

1.1 Problem statement

On January 30, 2020, the World Health Organization Emergency Committee declared a global health emergency based on increasing reports of COVID-19 cases in China and other parts of the world (World Health Organization). The emergence of COVID-19 and the ensuing pandemic disrupted the world as we knew it. As the pandemic spread across the world, governments instated lockdowns, closing office buildings, education institutions, sport facilities and various public facilities. Ever since, the world has moved in and out of lockdowns with different intensities. On April 4, 2020, over 3.9 billion people in over more than 90 countries were in a lockdown, and in December the AFP confirmed over 60 million confirmed COVID-19 cases and almost 1,5 million fatalities (World Health Organization). As a result of the above, organizations have (had) to continuously adapt to the most recent regulations (e.g., 1,5-meter distance between people, ventilation regulations) to facilitate students, employees, and people in general to engage in all kinds of work- and leisure activities.

University campuses have been similarly affected. It is estimated that more than 1.6 billion students, representing 91% of all students worldwide, are affected by the COVID-19 pandemic (Sharma, 2020a). Universities have been forcibly adapting their teaching methods and facilities to switch to online learning (Rijksoverheid, 2020). Depending on government regulations, education takes place in a hybrid model with classes both on-campus and online (NOS, 2020). Similarly, research activities have also been affected: several types of research are now conducted virtually or face capacity constraints in laboratories (Radecki & Schonfeld, 2020). Public events on campus, such as graduations, PhD defenses, inaugural speeches, conferences, and study-related activities, are organized online or in a very limited on-campus setting. Thus, it can be concluded that the space use on the university campus is radically different than it was before March 12, 2020.

Previous studies have identified the importance and added values of space and campus management. In particular, De Jonge et al. (2009), with the DAS framework to anticipate the demanded changes, determine the match between supply and demand of campus real estate. Moreover, Den Heijer (2008) has demonstrated the importance of the multi-stakeholder approach which supports the DAS frame to retrieve the match. Furthermore, in recent years there has been more research into smart tools or IoT in real estate, which has shown that SCTs can support campus decisions (Valks et al., 2018; Valks et al., 2020). According to Valks et al., “a smart campus tool is a product or service that collects real-time data to improve space use on the current campus and decision-making about the future campus” (2019, p. 5) SCT and SCT 2.0 show that several universities have already implemented Smart tools, which indicates that SCTs contribute to more effective space use and support campus decisions.

Despite the accumulation of literature, there is an absence of research that examines the contextual effects of the recent COVID-19 at universities and other organizations. The content of this research builds upon the results presented in SCT 2.0 (Valks et al., 2018).

1.2 Research objectives

Because of the COVID-19 lockdown, universities and organizations organized many events online rather than physically. A limited return to campus and office was organized by these institutions during the COVID-19 period taking into account maximum capacity. Because the COVID-19 crisis is a recent and still a current event, there is a gap in the literature with the insights of how universities and organizations acted in terms of space utilization and SCTs. The purpose of this research is to update the SCT2.0 research to reflect the use of SCTs in the COVID-19 period. In addition, to also identify the developments that have taken place in the intervening years. Through this research, the insights will fill part of the gap in the literature where campus managers can increase short- and long-term decision-making to benefit users and campus real estate.

Furthermore, a study by Cisco shows that the integration of smart tools into the built environment can still be perceived as difficult. However, 60% of the initiatives are discontinued, and 26% are considered successful (Cisco, 2017). Thus, generating insights during certain phases of implementing SCTs is helpful to develop better-informed decisions.

1.3 Research questions

To facilitate this goal, this research addresses the following research question:

> *What has changed in terms of type, demand, and use of Smart campus tools addressing space utilization at universities and other organizations due to COVID-19 compared to the 'Smart campus tools 2.0' research?*

1.3.1 Sub questions

To answer the main question of this study, the sub-questions will be answered first. The research covers the following sub-questions, which are presented in the table below. In addition, for each sub-question, the objective is defined.

Table 1-1: Overview of sub-questions and their objectives

SQ	Research question	Research Objectives
1.	What is campus management?	Understanding the aspects of campus management
2.	What are Smart campus tools, and what is the added value of Smart campus tools in a changing demand?	Defining the concept of a Smart campus tool and how they can support campus management during a changing demand.
3.	What effect does COVID-19 have on the campus?	Defining the impact of COVID-19 to date. Also, ascertaining the suggestions of universities about the effect of the COVID-19 period in the short and long term

4.	What progress have Dutch universities, universities abroad, and other organizations realized on Smart (campus) tools addressing space utilization compared to previous research?	Updating the information from previous research. Figuring out modifications to existing cases and newly initiated cases. To subsequently identify the progress and modifications to type, demand, and use of Smart campus tools
5.	To what extent do these Smart (campus) tools meet the needs and use of the Dutch universities, universities abroad, and the other organizations after COVID-19?	Defining the contribution of the Smart campus tools during the COVID-19 crisis. Also, identify the improvements regarding the use and needs for the period after the COVID-19 period

Based on the problem statement, it can be assumed that space on the university campus is radically different due to the changed context. The situation has changed compared to the SCT 2.0 research, resulting in a lack of shared knowledge in practice and science. This research's hypothesis is: Due to the changed context resulting from COVID-19, increased demand for a hybrid form of education, research, and working has been generated, the measurement of space use will become more critical after COVID-19 than before.

1.4 Scientific relevance

This research focuses on universities and organizations that, due to the COVID-19 crisis, have experienced a rapid change in their way of education, work, and research due to which the supply of campus or office real estate is hardly or not used. Since this is a current situation, little or no research has yet been conducted into the choices made in SCTs, experiences, developments, and problems.

Since COVID-19, several studies have been conducted to support and create insights. Most of these studies have focused on the approach or a form of hybrid learning (Brammer & Clark, 2020; Daniel, 2020; Tesar, 2020). Dorn et al. raise a problem whereby a post-COVID-19 strategy will be required to convergence physical and digital education (2020a). Cheng et al. describes several steps to reopen universities where the main focus is on ventilation and sanitization practices and general hygiene (2020). De Boer addresses more the soft side, such as the impact of COVID-19 on users and its consequences on education and work (2021). These studies focus on the impact on students, how digital education is perceived, and the academic post-COVID-19 approach. There is little to no discussion of universities' actions regarding technologies as support for space use.

With regard to the other organizations. A scarce amount of research has been conducted on the insights of the effect of COVID-19 on CREM. Conducted Research mainly focuses on the possible reduction of office space due to the increase in hybrid working. Boland et al., indicate that technology will play an essential role in enabling the back-to-office in the future office (2020). In addition, the transformational approach to analyzing space requirements, where technology is not addressed as a solution. Parker describes that technology-based strategies have applied sensors at offices to reduce the number of common surfaces touched by employees (2020). He also provides improvements for building management systems, such as improved air ventilation and occupancy indicators.
These studies briefly discuss applied technologies or potential improvements for office use after the COVID-19 situation.

This research contributes to a recently created gap in scientific knowledge caused by COVID-19. This study aims to examine whether universities or organizations use SCTs due to changes in demand and supply (caused by the COVID-19 pandemic). Furthermore, it investigates whether the demand for SCTs is changing and whether SCTs have added value, and if so, in which way. It also contributes to increasing knowledge on this topic from a CREM perspective. In this field, the utilized Smart tools are still sparsely researched.

1.5 Societal relevance

As a result of the extremely rapidly changing situation due to COVID-19, education has had to take other forms, but this also impacts social relevance. There are psychological problems, social isolation, and study delay (Dartmouth College, 2020; NOS, 2020 ; Remie & Veldhuis, 2020; ScienceGuide, 2020).

Research shows that universities are more than a place to learn and play an important role in providing nutrition and providing care about the student's physical safety, social and mental health, and well-being (Dorn et al., 2020a). In a hybrid form of education, it is therefore important that these aspects continue to exist and that it continues to encourage learning (Dorn et al., 2020b). Teachers and students have experienced that online alone does not work well in the lockdown period (NOS, 2020b; Omroepwest, 2020a). In addition, there is a lack of learning through social context by observing and learning from others (Herzog et al., 2020). Thus, it appears that campus education is important, and to enable this, it is becoming clear that the use of SCTs contributes to the back-to-campus.

In addition to these users, this research is also relevant to the CREM or campus managers. The application of SCTs emerge from strategy decisions where technology has been shown to contribute to decision making (Corenet Global, 2015). Based on this research, these professionals can make better choices about SCTS for the back-to-campus/office phase to regulate the number of users in the buildings.

The following aspects will be explained in the report. First, the research methodology will be described. Next, the results of the literature review will be explained. Then the results of the first brainstorming session, the case studies and the second brainstorming session will be discussed. Lastly, the research question will be answered and additional findings and recommendations will be discussed.

READERS' GUIDE

Apart from the textual explanations described for the readers' guide, Figure 1.1 visualizes the chapters of this research. The first phase of the report consists of a description of the introduction and the concepts. The introduction is the first chapter in which the problem definition, scientific and societal relevance, research goals, research method, and research questions are explained. Then in the second chapter, the methodology of this research is presented. In this chapter, the following aspects are explained: research strategy, research method, data collection, data analysis and plan, and ethical considerations.

In the second phase, the findings from the literature are outlined. In the third chapter, three aspects are described; Campus management, the campus of the future, and SCTs. The following chapter,

Chapter 4, discusses the impact of COVID-19 on universities. Information from an initial brainstorming session with universities was consulted as a basis for this chapter.

From the third phase, the results from the interviews during the case study are presented. Changes and progress regarding different aspects between the SCT 2.0 and this research can be analyzed. This concerns the following parties: Dutch universities (chapter 5), foreign universities (chapter 6), and other organizations (chapter 7).

During the fourth phase, the results of the second brainstorming session are discussed in chapter 8. In this session, striking results from the interviews were transformed into propositions presented and answered by respondents from the universities present.

The fifth phase is the final phase in which the conclusion, recommendations, and reflection of this research are explained. The ninth chapter is aimed at answering the main question. Also, by a discussion in which theoretical and practical implications and limitations of this research are outlined. Finally, recommendations for further research and practice are provided based on the conclusion. The research will conclude with a reflection on the entire research process.

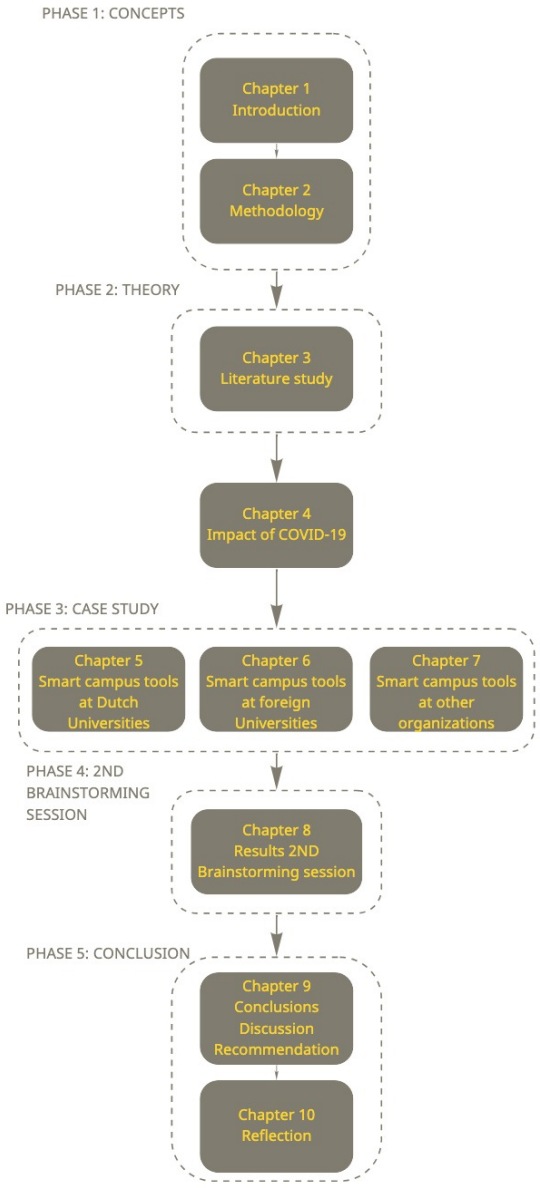


Figure 1-1: Readers guide (own figure)

2 METHODOLOGY

This chapter describes the research method used. With this chosen method, the information can be collected in order to answer the main question. Elements outlined are strategy, methods, and techniques will be applied, how data will be collected, how this data will be analyzed and used, and how ethical considerations will be dealt with.

2.1 Research Strategy

In the SCT2.0 research, a qualitative research method was applied since quantitative research was not appropriate (Valks et al., 2018). To assess the changes to SCTs by COVID-19 and between this and the SCT 2.0 study, the same research method is applied. The approach to gathering information for the qualitative research consists of a first brainstorming session, a literature study, case study interviews, and a follow-up brainstorming session. The approach to the various methods will be clarified.

The brainstorming session created insights into the impact of the COVID-19 period at universities. In parallel, it contributed to formulating the introduction with the problem statement and the objective of this research.

The literature review's primary goal is to understand campus management regarding space utilization, understand what Smart (campus) tools are, and how they can contribute to changing demand. The data will be collected by studying existing literature.

The main focus of this research is on conducting the interviews at several of the same Dutch Universities, universities abroad, and other conducted organizations during the SCT2.0 research. Through these case studies, insight is gained into current practices in the field of SCTs. As a strategy, an interview protocol is created with questions surrounding current use, whether the SCT meets the demand and use during COVID-19, the use and approach of a reservation system, changes to existing templates, and whether new SCTs have been initiated. In the latter case, the same interview protocol and template are used to obtain and process information as in the SCT 2.0 research. In addition, changes to existing templates are indicated in italics in the existing templates. In order to compare information in a structured way, and to conclude if progress has been made. Furthermore, the reason is identified if cases experience little or no success in implementing a SCT. This will contribute to better-informed decisions for integrating or expanding SCTs at universities or other organizations.

The second brainstorming session serves to review salient statements and results from the first brainstorming session and case study. This is achieved through statements and questions per theme that are presented to which the participants could respond.

2.2 Research Method

According to Bryman (2012, p. 384), a used sequence in qualitative research starts with a general research question, then selecting relevant site(s) and data, collecting relevant data, and interpreting data. This is continued with a conceptual and theoretical work from which it can be concluded if further data is needed and finally the conclusion and findings. This process will also be maintained in this research, and to answer the abovementioned research questions, several different research methods are used. These are:

1. Brainstorming session
2. Literature study
3. Semi-structured interviews with case studies
4. A follow-up brainstorming session

These methods will be explained in the following sections for each phase.

2.2.1 Phase 1: Concepts

In the first phase, the main focus is to define the reason, problem statement, and objective. To support this phase, a brainstorming session (Organized by Ir.Valks) is applied to create insights into the challenges by COVID-19. This allowed the identification of the impact of COVID-19, thought for the longer term, and how universities have coped with COVID-19. This session also indicated that the majority of the universities that attended were interested in doing follow-up research. This also contributed to the selection of the cases during the case study. The following sub-question can be answered based on the brainstorming session which will be answered at Chapter 4:

- What effect does COVID-19 have on the campus?

2.2.2 Phase 2: Literature study

The next step of the research is the second phase. It will conduct a literature study to discover more in-depth information to understand the theory of Campus management, the campus of the future, SCTs,

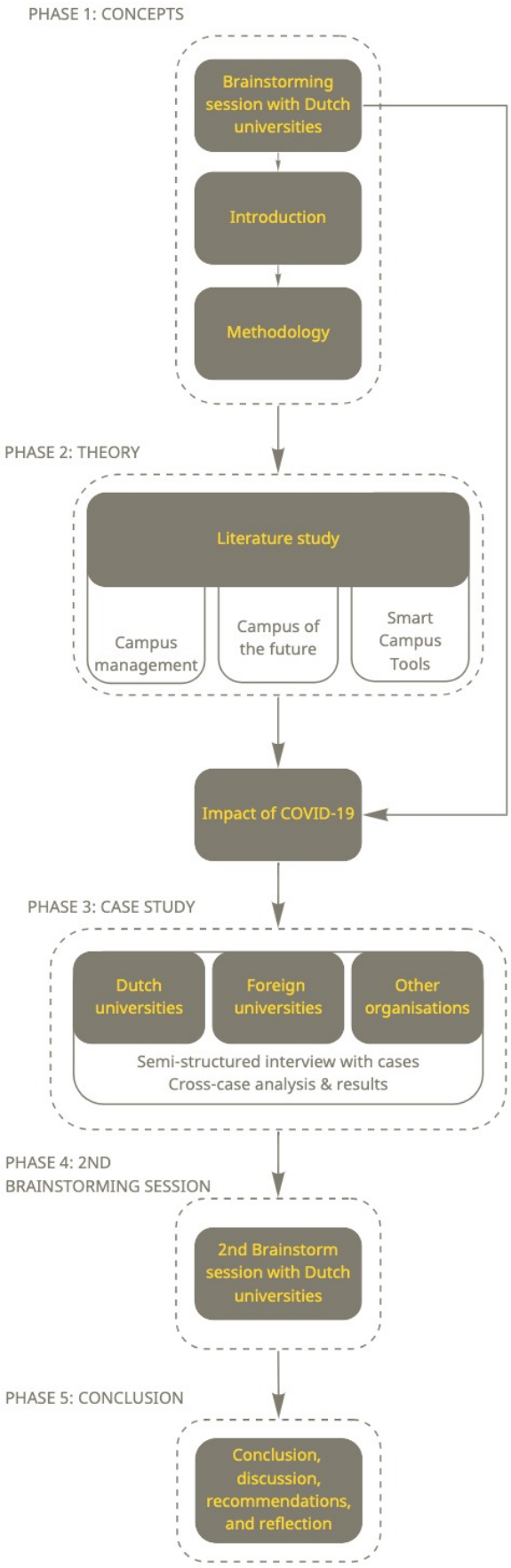


Figure 2-1: Research framework (own illustration)

the organizational context, and results from the SCT and SCT2.0 research. The information sources utilized to obtain existing literature are Google Scholar, Internet sources, Repository, and the TU Delft library. Table 2-1 displays a list of sources that provide information per theme that served as a basis in the literature study. Below will be described the sub-questions that can be answered employing literature study.

- What is campus management?
- What are Smart Campus Tools, and what is the added value of Smart Campus Tools in a changing demand?

Table 2-1: Literature study (own table)

Title	Search terms	Literature
Research method/strategy	"qualitative research", "social research methods", "architecture research methods"	Bryman (2016), Valks et al. (2016; 2018), Dorst & Cross (2001), Newman (2011), Design Council UK (2005 & 2011)
(Smart) Campus management	"Supply and demand real estate", "smart tools management", "campus management", "decision-making supply and demand" "Public Real Estate Management", "Corporate Real Estate Management", "Trends education", "Management education spaces", "Management user space", "space management"	Den Heijer (2008; 2011), De Jonge et al. (2009), Ibrahim, Yusoff, & Bilal (2012), Valks et al. (2014), van der Voordt (2017), Van Der Voordt et al., (2016), Temple (2014), Space management group (2006), Rondeau et al., (2012), Abdullah et al., (2012), Lindholm et al., (2006)
Smart campus tools / smart tools	"Sensor technology", "Campus internet of things", " smart real estate", "Smart tools" "smart technologies real estate", "Smart building", "Technology real estate", "Occupancy measurement"	Valks et al. (2016; 2018; 2019;2020), Labeodan et al. (2015), Brena et al. (2017), Mautz (2012), Salimi & Hammad (2019), Space management group (2006), Serraview (2015), Melfi et al., (2011), Erickson et al., (2014)

2.2.3 Phase 3: Semi-structured interviews from case study

The method in the third phase is obtaining data on cases by in-depth interviews. These are the identical cases adopted in SCT 2.0. An overview of the results from SCT 2.0 of these universities has been created in Appendix I. The information obtained per case will be documented standardized in terms of layout with short, long textual answers/ descriptions and images to clarify the results. For the steps followed for this purpose with an indication of the open and closed questions, please refer to Appendix II. An overview of the parties interviewed is shown in Table 2-2.

By applying an established interview protocol, information is obtained in a structured and uniform manner during the interviews. To ascertain whether the interviewed parties are satisfied with the current or new SCTs during the COVID-19 crisis, the reason in case of no success during the SCT implementation process, modifications at the existing templates, and the approach to reservation systems, a new interview protocol is established. The purpose of the additional questions to the interview protocol is whether universities or organizations use SCTs due to the changes in demand and supply (as a result of COVID-19) also, whether COVID-19 confirms the added value of smart tools even more or not, and to identify the progression of existing SCTs. When a new SCT is initiated at a university or organization, the same interview protocol is applied as in the SCT 2.0 study. This information is presented in templates created during the SCT 2.0 study. By receiving and similarly

processing the information, it is able to determine whether progress has been made on new SCTs added at universities and other organizations.

Using this method, the following sub-questions are addressed

- What progress have Dutch universities, universities abroad, and other organizations realized on Smart (campus) tools addressing space utilization compared to previous research?
- To what extent do these Smart (campus) tools meet the needs and use of the Dutch universities, universities abroad, and the other organizations after COVID-19?

Table 2-2: Case studies (Reproduced from (Valks et al., 2018)

Country	Universities abroad	Abbreviation	Dutch universities	Abbreviation	Other organisations	Abbreviation
Denmark	Aarhus University	AU	Radboud University Nijmegen	RU	Dutch Government	NLG
Denmark	Technical University of Denmark	DTU	Tilburg University	Uvt	ABN AMRO	ABN
United Kingdom	Sheffield Hallam University	SHU	Twente University	UT	EDGE Technologies (former OVG)	EDGE
Finland	Aalto University	Aalto	Delft University of Technology	TUD		
Belgium	KU Leuven	KL	University of Amsterdam	UvA		
			VU Amsterdam	VU		
			University of Utrecht	UU		
			Wageningen University	WU		
			Eindhoven University of Technology	TUE		

2.2.4 Phase 4: 2nd brainstorming session

In the fourth fase, the second brainstorming session, serves to review salient statements and results from the case study. In addition, it can also be analyzed here whether there are already differences in responses between the initial brainstorming session and the follow up. This is achieved through statements and questions per theme that are presented to which the participants from Dutch universities could respond via Mentimeter. In addition, there was room for discussion which brought out interesting findings. For the report is referred to Appendix III.

2.2.5 Phase 5: Conclusion

In the fifth phase, in the synthesis, the findings of the literature study on SCTs and cases will be combined in a cross-case analysis to formulate statements for the campus manager.

From the synthesis, it should be revealed what the progression is concerning the parties among themselves, corresponding reasons of delay or no use of pre-conceived SCT, corresponding methods of reservation use. Also, whether there are comparisons in the changes to information needs and the use of SCTs for this purpose.

Subsequently, a conclusion, discussion, and recommendation will be made. This last part will also reflect on the findings and recommendations that offer the potential for further research.

2.3 Data collection

The research has four parts: the concepts (1), theories (2), the analysis and results of the cases (3), and the analysis and results of the second brainstorming session (4). Table 2-3 shows how data is retrieved per phase/sub-question.

Table 2-3: Data collection (Own table)

Phase / Question	Research question	Research method	Data collection
2.1	What is campus management?	Literature study	Existing literature
2.2	What are Smart campus tools, and what is the added value of Smart campus tools in a changing demand?	Literature study	Existing literature
1.3	What effect does COVID-19 have on the campus?	Brainstorming session	First brainstorming session with statements presented and opportunity for discussion.
3.4	What progress have Dutch universities, universities abroad, and other organizations realized on Smart (campus) tools addressing space utilization compared to previous research?	Case-study: in-depth interviews & follow-up brainstorming session	Semi-structured interviews according to the interview protocol and questions and statements presented at the follow up brainstorming session
3.5	To what extent do these Smart (campus) tools meet the needs and use of the Dutch universities, universities abroad, and the other organizations after COVID-19?	Case-study: in-depth interviews & follow-up brainstorming session	Semi-structured interviews according to the interview protocol questions and statements presented at the follow up brainstorming session

2.4 Data analysis & plan

This section will describe how data is handled and how it will be analyzed. First, the plan of action will be described to process as carefully and systematically as possible data obtained. Then, the approach for securely storing the received data. The data analyzed and retrieved in this research is derived from the different research methods, as shown in

When an interview is scheduled, the participant is notified in advance, allowing the participant to prepare. For this interview, the interview protocol and template from SCT2.0 were used to structure the interview and visualize the results. The preparation files are the interview protocol, the template from SCT2.0, and the consent form. After the semi-structured interview, the outcomes are then processed in the interview protocol. Changes are made to the existing template, or in the case when a new smart campus tool is applied, a new template is created. Next, the participant is allowed to verify the outcomes, after which these can be used as final files in the report. To maintain structure and overview during the graduation process, these steps are tracked in an overview.

According to the TU Delft, the FAIR guidelines should be followed regarding the data during and after the research. Research shows that these guiding principles imply that data must be findable, accessible, interoperable, and reusable (Wilkinson et al., 2016, p. 4).
When writing the thesis, data will be received in different ways as shown in Table 2-3. This will be stored on a personal computer, iCloud, where it will be logically documented in folders (findable) that are only accessible with a private 2-step verification (accessible). Also, the data is stored on SURFdrive (recommended platform from the TU Delft), where a supervisor is granted access to the data. In order to minimize the chance of data loss but to ensure privacy. Programs and file formats that are interoperable will be used, and after the graduation process, the data will be published on the TU Delft repository (reusable).

2.5 Ethical considerations

During the research, it is important to protect human beings with the help of appropriate ethical principles. Especially in qualitative research, this is even more evident since the character of qualitative research is to find out in-depth information employing, for example, interviews. Polonsky and Waller (2010) divided ethical considerations into five different areas, which are:

1. Voluntary participation
2. Informed consent
3. Confidentiality and anonymity
4. Potential for harm
5. Communication results

This section will explain how ethical considerations will be respected and dealt with during this research.

Voluntary participation

For data collection, participation in the study must be a voluntary choice. The respondent should also be well informed about what he or she will be asked and what the agreements are regarding the questions and answers. Another important aspect of voluntary participation is that there are the possibility and respect that the potential participant can withdraw from the study if they no longer feel comfortable with it. Finally, when it is necessary to record an interview, permission should be requested beforehand. The possibility should be given to removing parts afterward (if this is requested) and the whole recording after transcription.

Informed consent

This is important to inform the respondent so that no unexpected situations arise in the field of information. It is first important to describe the subject of the research or session and whether there are any negative consequences. You inform the respondent who you are, why you are conducting this research, and the desired outcomes. Finally, it is useful to offer the respondent the opportunity to give feedback.

Confidentiality and anonymity

The anonymity and confidentiality, which are often confused, of respondents should be treated with respect. Anonymity is about the researcher not knowing who the respondents are. In confidentiality, the researcher is aware of the participant, but this information should not be exposed in the report or other files. In this way, it should be considered how the information and identity of respondents are protected. The last aspect is that detailed information should be handled with care to not reveal the participant after all.

Potential for harm

In this aspect, the researcher should put himself in the respondent's shoes to assess whether the respondent can be hurt physically, emotionally, or psychologically. In focus groups or interviews, in the scenario that there is potential for harm, it can be useful to have the participant sign that they are participating. With smart tools and the potential for harm, the privacy aspect should be taken into account. Given COVID-19, all interviews will be conducted in an online environment, which also has to consider the potential for harm.

Communication results

In terms of communication results, plagiarism should be monitored by respecting and referring to someone else's work rather than pretending to be their own. Second, in the case of academic fraud, data obtained, interpretations, and analyses must not be deliberately misrepresented. Finally, when research is carried out at a company, there is a chance that a researcher will be too eager to misrepresent the results. To impress the company and thus deliberately misrepresent the results may not occur.

Ethics of smart buildings / smart campus

Smart tools functions are used and implemented more and more often, and the benefits of smart tools such as increasing students' experience, reducing environmental impact, optimizing the energy performance of campus, and increasing the use of valuable resources bring risks (Jisc, 2018). In particular, that people feel followed, surveilled, and checked.

Valks et al. (2019) describe that smart tools can better respond to the changing demand, but conscious thought must be given to users' potential disadvantages and threats when implementing them. Assuming it is implemented, Cormack (2019) indicates that transparency is very important. This is reinforced by Leong (2018) that indicates that involving occupants in smart cities' decision-making has more advantages. This also emerged from a brainstorming session (Valks, 2021), which showed that it makes a difference if users are well informed about what the sensors measure, what happens to the information, and who has access to it. Since parts of society are reluctant to do this, partly due to the current economy in which organizations collect (personal) data and resell it for secondary purposes. A second example is when a site or database is hacked into, and personal data is subsequently stolen.

PART II



THEORY

3 THEORIES

This chapter introduces the various theories of campus management, SCTs, and the campus of the future. The purpose of this chapter is to answer the sub-questions what are smart (campus) tools? (1) What is campus management, and what is the added value of Smart campus tools in a changing demand? (2). Accordingly, this will contribute to the emphasized part of the main question: "What has changed **in terms of type, demand, and use of Smart campus tools** at universities and other organizations due to COVID-19 compared to the 'Smart campus tools 2.0' research?". A literature review is conducted to answer these questions.

3.1 Campus Management

To understand campus management, firstly, a description will be given of what a campus is, why managing the campus is important, and how it should be managed.

Campus

First of all, there has been investigated what the campus' definition is, two clear descriptions have been determined. Den Heijer describes the university campus as the locations of buildings related to the university and contributes to institutional goals based on owned buildings or used (rented) or both (2011, p. 51). University real estate can also be considered as a campus. This term represents the land and buildings and other objects that cannot be moved on this land where the university is the owner of the buildings and uses them, rents buildings, or owns them but does not use them (Den Heijer, 2011, p. 51).

About the land and buildings of a campus, the campus has evolved over the years. From the earlier 1900, there are campus examples of university buildings divided in the city (integrated) (Den Heijer, 2011, p. 61). According to Hoeger and Christiaanse (2007), the demand for coherently designed campuses arose after WWII in the US, resulting in more individual and open concepts (greenfield, outside the city). Meanwhile, in Germany, students' user perspective grew, and awareness of the campus's social responsibility grew, leading to the architecture considering users' performance. It can also be concluded that the boundaries of the campus were more concrete at the time as protection against the ordinary citizen, but that the boundaries are now more blurred for interaction with the city and business; the campus is part of the city (Den Heijer, 2011, p. 61). These different spatial configurations for campuses are also shown in Figure 3-1.

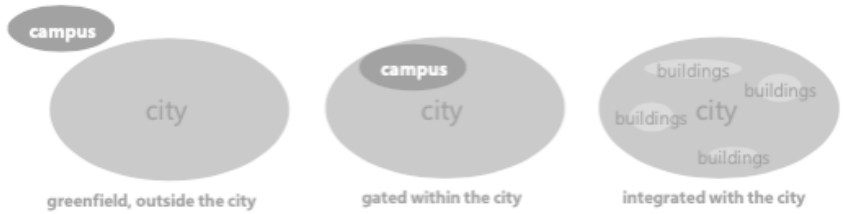


Figure 3-1: Spatial configurations for a campus (Retrieved from (Den Heijer, 2011, p. 53)

Den Heijer complements the campuses' different characteristics on different levels, namely from the city, campus, or building level, and influences the performance level and different stakeholders around and in these universities (2011). Studies have been conducted on various physical characteristics for designing university spaces. Barrett et al. (2015), indicate that three design principles, shown in Figure 3-2, support good space design and are each important for academic progress. These are the sound, light, temperature, and air quality (1), the flexibility, connection, and ownership (2), and the appropriate level of color and complexity (3).

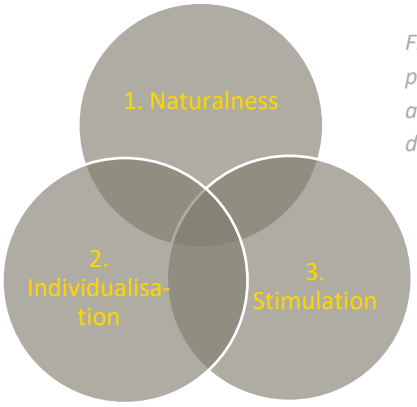


Figure 3-2: The design principles of good academic space design (own figure).



Figure 3-3: Functions on the campus (Den Heijer, 2011)

Today, the campus can be seen as a city unto itself with infrastructure, services, and complete buildings like microcosms of cities and towns. A change occurs around campus in response to student and faculty demand for an attractive campus (Den Heijer, 2011; Magnini et al., 2018). Sports, cafes, supermarkets, festivals, and various events have become intrinsic to the campus's identity. The functional and physical contact is improved with the city, which ensures increasing support from citizens for stimulating a part of the economy of skills, ideas, and resources. Thus, the campus as a knowledge city makes it attractive for companies to establish themselves on and around the campus. Figure 3-3, displays the different functions on campus to support these demands: not only academic functions but also residential, related businesses, retail & leisure, and infrastructure.

Campus management

Users of the campus (originally) need real estate to carry out their work and study in preferably an environment according to their needs. In order to offer real estate that better suits these users, choices need to be made regarding the Real Estate Management. In addition, it appears that real estate can have a positive or negative effect on the performance of its users, an aspect why campus management is important.

Den Heijer's (2011) research shows Campus Management to have an overlap with Public Real Estate Management (PREM) and Corporate Real Estate Management (CREM). In general, both forms of management have the goal of aligning the real estate with the organizational goals in order to add value to increase the performance of the users. The two forms can be distinguished by the type of owner/manager. In CREM a private company or organization directs the real estate management and in PREM a public organization where the core objective is not financially grounded (De Jonge et al., 2009). On a campus there are private and public interests, however, Den Heijer indicates that the

emphasis is greater on CREM since the growing dependency on private funding and the growing economic objectives (2011).

Added value

Beside user performance, according to Den Heijer (2011, pp. 98-100) and De Vries (2007), it appears that real estate has a qualitative and quantitative influence on organizational goals that then directly or indirectly affect productivity (users), profitability, and competitive advantage. These three components are described by De Vries as the performance. It also affects the performance of organizations and society as a whole. Also, by continuing to search for the match between supply and demand, productivity and flexibility can be increased (Den Heijer, 2011; Lindholm & Leväinen Kari, 2006). Abdullah et al. confirm that through effective and efficient management as a resource, a reduction in operating costs can be achieved and support spaces' physical and function (2012). Since real estate is about the third-highest cost of an organization, energy-saving, effective use of buildings and space optimization can contribute to the achievement of organizations' goals (Corenet Global, 2015). An overview of the added values of the campus for the university was described by Den Heijer by means of thirteen added values (2011, pp. 97-98).

> *"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" (Den Heijer, 2011).*

The management of corporate or public real estate is a continuous process, in which the campus manager is in charge of and responsible for managing the facilities and/or estate (Den Heijer, 2011). This is a decision-making process in which there is a continuous search for a match between demand and supply. This process is represented in the DAS (Design Accommodation Strategy) framework of De Jonge et al. (2009), shown in the figure below. The model consists of two dimensions based on the market and on time and consists of four perspectives: current demand, future demand, current supply, and future supply. Based on this framework, by using four intermediate stages as a planning cycle and an evaluation cycle, the match can be identified.

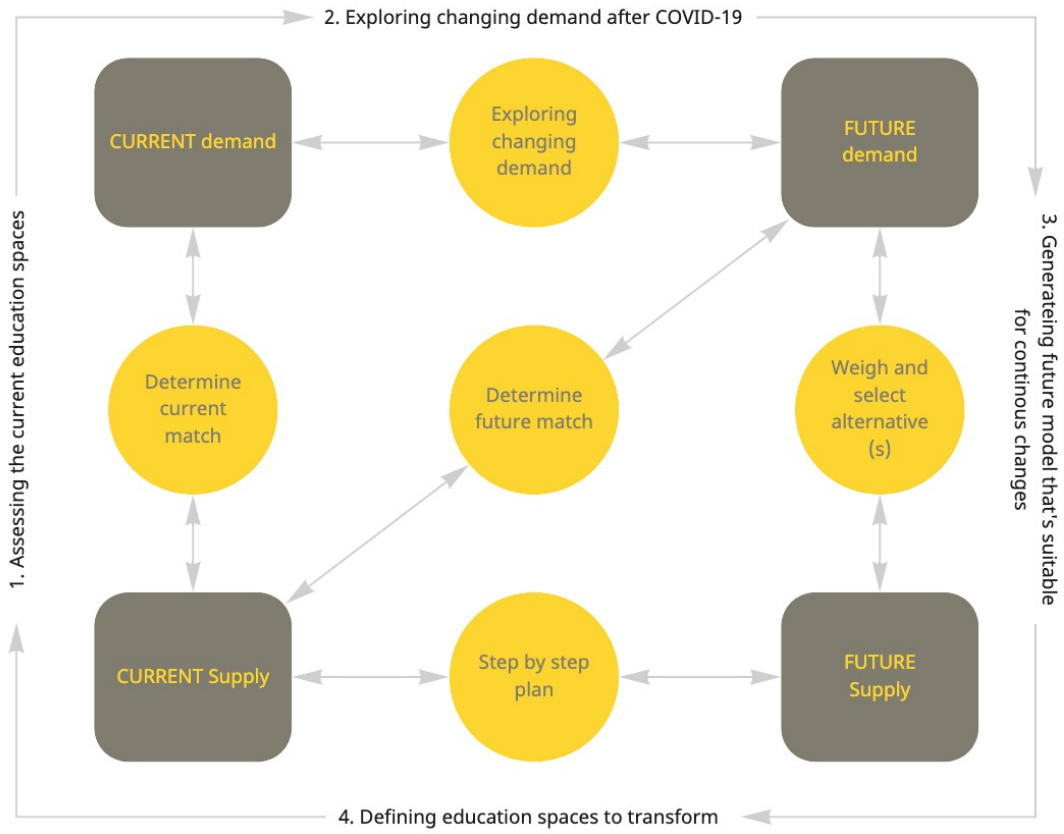


Figure 3-4: Framework matching demand and supply of education spaces (De Jonge et al., 2009)

'The demand of the different stakeholder groups'

During this process of the DAS frame, three aspects belong to this process and involve adding value (den Heijer, 2008; Den Heijer, 2011). First of all, all the stakeholders involved have to be taken into account (den Heijer, 2008; Temple, 2014), and this concerns the demand side (left) and supply-side (right) of the real estate and from strategic to the operational level. This is a design process in which stakeholders must determine criteria, develop alternatives, and assign preference ratings (Arkesteijn, 2019; De Jonge et al., 2009). Also, weighing the benefits and costs against four aspects linked to the four perspectives (Den Heijer, 2011). She appoints them as the user demands, strategic goals, physical aspects of the campus, and the financial resources. This is reflected in a conceptual model in Figure 3-5. The thirteen goals distributed for each stakeholder/perspective that serve to add value to the campus and users, according to Den Heijer (2011), have been added. Beckers et al. describe the same goals without dividing them into perspectives but focused on CRE (2015).

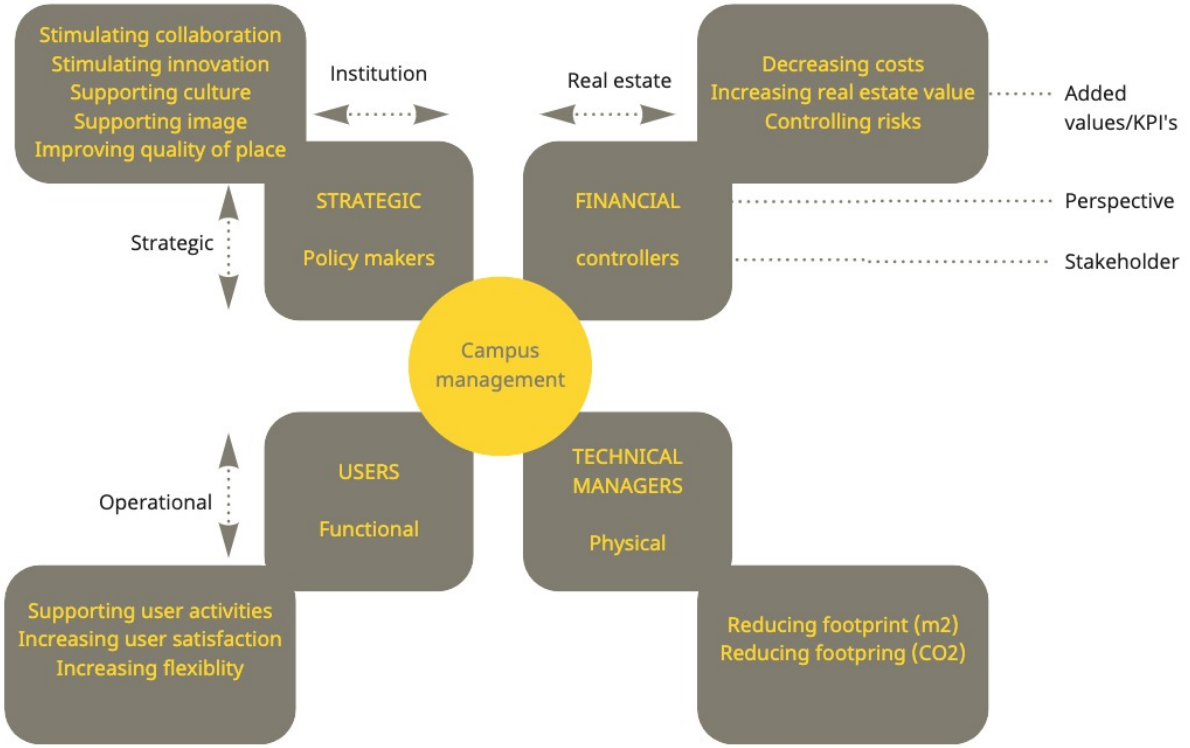


Figure 3-5: Multi-stakeholder approach linked to the four most important perspectives of campus management and their goals (Adapted from (den Heijer, 2008; Den Heijer, 2011)

Campus managers need management information for these tasks, focused on the multi-stakeholder approach, connecting the four perspectives and the matching variables (KPIs). According to Den Heijer, these are based on a solid set of definitions for benchmarking universities and their floor area, student numbers, investment costs, facility costs, carbon footprint, cost of ownership, user satisfaction, occupancy rates, and the number of users per m2 (2011).

Space management

Space utilization is a focus of this research, so the literature is reviewed to determine the aspects of space management. Universities are unique places where people come together, cultural, economic, and intellectual areas created in spaces with material consequences. These consequences can be seen as temporary. Like furniture, the interior design could still be adapted, but the location will be permanent. These spaces in a faculty have a permanent effect on the actions that occur, such as research, inclusiveness, education, and social connections. However, Temple indicates that it is not easy to imagine how space affects output (2014).

Space management for universities has been in place since 1960, realizing that not systematically using spaces leads to unnecessarily higher costs for cleaning, maintenance, and energy (Ibrahim et al., 2012). Leonard and Warner indicate that it was already thought that there was a lack of space at universities (1992). Also, then and still space management is not yet optimized well enough, which has recently been confirmed (Space Management Group, 2006).

According to Abdullah et al., the main goal of space management is to effectively manage a dynamic and limited resource to support institutional academic activity, reduce costs to a minimum, and obtain maximum and efficient design, planning and use of the organization's space (2012). Further, beside the benefits of reducing operational costs effective space management can also contribute to maintaining the physical and function of space (Abdullah et al., 2012).

To address planning, space planning has traditionally been applied using space norms (Space Management Group, 2006a) In addition, Space Management Group described that this is accomplished based on coefficients such as for example the size of the teaching group or the staff:student ratios to determine the suitability of the type of space (2006a). In this way, the predicted frequency and occupancy rates for the type of space for space utilization are determined.

According to Best et al., the way a space is effective and efficiently managed as a service is space management (premises) (2003). According to Abdullah et al., (2012) three comparable concepts are essential for managing space in university buildings. These are measuring utilization, space inventory, and before carrying further analysis, the future space needs must be defined. This are also corresponding aspects from the DAS frame of De Jonge et al. (2009). Besides Abdullah et al., provide five criteria items for effective space management; (1) Staff involvement and competency, (2) classroom arrangement, (3) use of software, (4) managing space during the break, and (5) space management evaluation.

Whereby the last one is extra explained because this is now a current topic by COVID-19, to identify how much space an organization or university needs and what kind of quality this should be. This is an evaluation of the current space use with future projections to plan new construction, renovation, or disposal (Valks et al., 2021). Besides, Arkesteijn et al. present an example to align educational spaces and users' needs (2015). According to Space Management Group space utilization can be estimated based on planned use, an expectation of how the space will be used (2006a). This expectation can be supplied by history from timetables or on the basis of measuring actual space usage. According to Valks et al, there are four levels (variables) that can be measured on; (1) scheduled frequency, (2) scheduled occupancy, (3) actual frequency, and (4) actual occupancy (2021).

Regarding space that is not used. Ibrahim et al., addresses an aspect that spaces that were booked but not used contribute to wastage of lamps, electricity, fans or air conditioning, and therefore cost money (2011). This research also presents the space charging model at the University Tun Hussein as a solution to raise awareness among users and reduce the thinking that space is considered a free resource. The construction of the space charging model is illustrated in Figure 3-6.

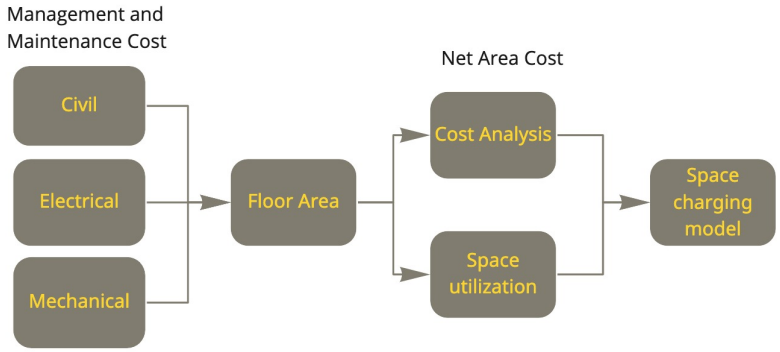


Figure 3-6: Space Charging Model at the University Tun Hussein Onn Malaysia (adopted from (Ibrahim et al., 2011).

The different type of maintenance and management is divided into three main components, which are among planned and unplanned maintenance. Next, all components are assigned in an area for each classroom along with an analysis to the cost per classroom. For the classrooms without optimal space utilization, costs are charged or made transparent. Then the cost for type of lecture halls is calculated by: Total cost ($) / floor area used (m2) (Massey University, 2007), and to measure the effectiveness by; Unused booked hours / booked hours * 100% (Ibrahim et al., 2011).

3.2 The campus of the future

This paragraph describes the developments surrounding the future campus. The change in types of spaces and their use. Since COVID-19, the future of the campus is still uncertain also partly because space is partly the root of this crisis. Possibly already described aspects that seem to have become more relevant due to the COVID-19 crisis.

Since the emergence of varied learning methods, the spatial requirements for campus buildings are being reshaped (Magnini et al., 2018). The traditional way of transmitting information in a traditional lecture hall is changing towards collaborative or transdisciplinary workspaces, quiet rooms, laboratories, and innovation hubs. As curricula frequently change over a short time, the demand for more flexible layouts to be regularly adapted to the users' needs is also increasing (Magnini et al., 2018). Den Heijer already described the pressure on universities due to declining government funding. This allows for more efficient and effective use with more flexible spaces (2011). This is one reason why there has been a growing awareness to ensure the long-term viability of faculty through design strategies (Magnini et al., 2018).

One trend Den Heijer describes is the change in the use of different spaces on campus, described by a physical state (2019). In a traditional campus, everyone used their faculty (solid). In a network-like campus, all faculties become partial (liquid), and finally, the virtual campus where the student is even less dependent on the location (gas). According to Valks et al., office, and laboratories are characterized as solid. Whereas lecture halls, meeting rooms, classrooms are characterized as liquid, and study places as gas (2018, p. 28). This dynamic how space is assigned and used is shown in Figure 3-7. Den Heijer expects that there will be a mix of physical states, but because of COVID-19 the situation changed extremely quickly to a virtual environment (Den Heijer, 2019).

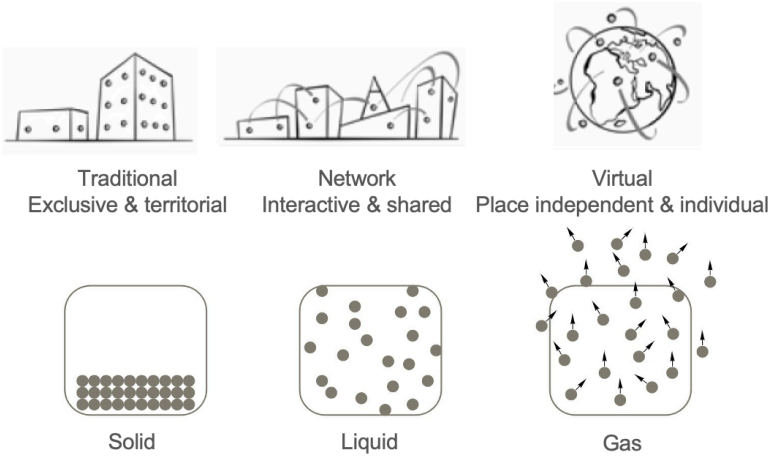


Figure 3-7: Dynamics that present how space is assigned and used (Den Heijer, 2019)

Den Heijer's thought links up with Deshmukh's visualization where it is thought that in the future campus, there is more focus on collaboration, the learning experience, and quality of life (2021).

With the potential for hybrid (reinforced by COVID-19) education and the trend toward a city campus, universities may differentiate themselves more by focusing on the spaces between colleges. Deshmukh (2021) describes that it is precisely in the spaces between colleges that lifelong friendships are made. Students discover themselves and become independent there.

The concept of space lies at the heart of the COVID-19 crisis, which previously has had the importance of being filled above all else. (Potentially meaningful) Focus on attendance, group size, etc. Sudarshan indicates that (appropriate) spaces exist in the service of human interactions, in which case education is a human activity (2020). Universities need to "reimagining campuses as a series of agile, multifunctional spaces with robust, scalable, flexible, tech-enabled infrastructure which can be refashioned owing to sequential or disruptive changes" (Deshmukh, 2021). This should include variation in occupancy.

3.3 Smart campus tools

Universities increasingly implement SCTs to improve the resource-efficient use of the campus. SCTs are defined as: "a product or service that collects real-time data to improve space use on the current campus and decision-making about the future campus"(2019). This definition has been further expanded using a conceptual model to elaborate the why, the what, and how by Valks et al. (2018).

Why

When implementing a smart tool, the goal mainly depends on whether it is accompanied by adding value to the campus. Figure 3-5 shows an adaption of Den Heijer's (2011) model with its most important stakeholders, perspectives on campus management, and in which its objectives are defined. This can be used to determine the added value and so, the why.

How

It is essential to know what kind of data is needed and what is done with it. However, several Dutch universities have experienced that last aspect as difficult, as shown by a brainstorming session (Valks, 2021). This shows that universities experience that sensors generate data, but then? This seems a gap in practice at several universities.

The 'what' is also shown in Figure 3-8 what Melfi et al. have developed. This represents the concept of presence over three different dimensions and is called 'occupancy resolutions' (2011). Labeodan et al. use six spatial-temporal properties of which one can be merged, but 'track' is still interesting to follow the currents and crowds in the campus (2015).

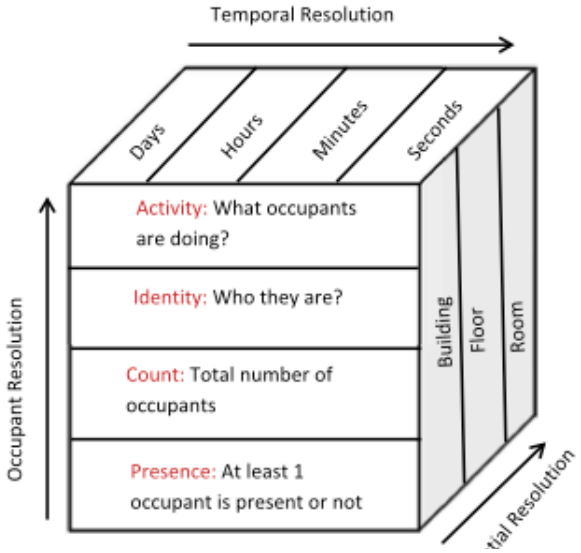


Figure 3-8: Occupancy resolutions, retrieved from (Melfi et al., 2011)

Valks et al. have broken down several resolutions even further, shown in Figure 3-9, and they use frequency instead of presence (2018). Remarkably, different terms and definitions are used in literature: presence, location, count, occupancy, frequency, activity, identity, identify, and track.

Resolution of:						
Time:	years	months	days	hours	minutes	seconds (real time)
Space:	campus	building	floor	space (large)	space (small)	workplace
Occupation:	frequency	occupancy		identity	activity	
Occupation description:	Yes/no	number of users		type of users	What is the user doing	

Figure 3-9: Overview of the resolution of time, space, and occupation (Own image, adapted from (Valks et al., 2016)

What

The last step is to determine which sensor will determine how that sensor can measure the 'What' to meet the 'why'. For the implementation of occupancy and utilization measurements, three grades defined in SCT were used to obtain data in the first-grade existing hardware. In the second grade, the existing hardware is obtained but with new software data, and in the third grade, new hardware and software need to be applied (Valks et al., 2016). These levels depend on the 'what' data is to be measured.

In various studies, it is written which tools there are, how they are used, their advantages and limitations. NAO(1996) and Space management(2006) research describes how frequency and occupancy can be measured using manual measurements. Literature that describes sensoring methods to collect real-time data is Mautz (2012) and Serraview (2015). Mautz surveyed indoor positioning methods, and Serraview researched utilization collection technologies.

The table below describes the different space utilization measurement methods by sensors. The description explains the operation of each sensor and how it can be used to measure space usage. Based on Valks et al. (2016), the sensors are described. In addition, radar is attached since it is considered as an emerging measurement method in the literature (Li et al., 2018).

Table 3-1: Different sensing techniques for measuring space utilization (information obtained from Valks et al., 2016 and completed).

Method	Description
Radio Frequency Identification (RFID)	RFID is a method where there is a chip (with an antenna) that contains information (transmitter) and a reading device (receiver). This chip can provide access to buildings or, for example, at the room level. In this way, an estimate can be made of the number of people in the building.
Cameras	With the camera as a tool, there are two methods that can be used to measure space utilization. The video camera can be used if there is sufficient light. Otherwise, the infrared camera should be used. In the latter version, an estimate is made on objects on the basis of infrared rays. Cameras are generally pricey, and the software influences the possibilities of measurements.
Wi-Fi	Using the Wi-Fi network, an estimate can be given of how many users are present in the building or certain area (Range of the access point). There are two methods that can be applied for this. One is to discover how often devices try to connect to all access points. In addition, information can be obtained from the number of connected devices per access point. A margin should be used with both options because users, for example, use a phone and laptop.
InfraRed	In the infrared, passive (PIR) and active (AIR) measurements can be taken. AIR can be used at passages to measure passersby. PIR methods are integrated into lighting systems and serve as activation of the light. AIR methods are used more often because PIR only measures the frequency and AIR the presence of people.
Ultra-wideband (UWB)	Ultra-Wideband is similar to Wi-Fi and BT. Only UWB is more accurate and is not hindered by objects in buildings such as doors and walls. The advantage of this is that the location of the device (the user) can be better ascertained only this application is less used in practice.
Bluetooth	Bluetooth is similar to Wi-Fi as a short-range information provider. A recognizable use is iBeacons which are small devices placed in rooms and then connected to devices (which are equipped with BT).
Device Use	It estimates the number of users using a device—for example, computers or QR-codes.
CO2 Sensors	Based on a CO2 concentration, an estimate can be made of the number of users in a room or area. However, this system is not tremendously accurate for measuring space usage due to the number of variables that affect accuracy.
Energy	Similar to CO2 sensors, energy consumption also indicates the number of users in a room. However, the reliability of this method is low.
Radar (Li et al., 2018)	Radar is an emerging technology that is similar to PIR. The advantage of Radar is that it can see through objects, just like the UWB. This is a reliable way due to the very small (radio) waves.

The above table shows that the sensors are very different from each other in terms of functions. This is also evident in Figure 3-10 which presents the relationship between the quality of the data and its cost for different sensors. From this, it can be concluded that it varies reasonably, but it does not consider existing structures that may already be implemented in the buildings.

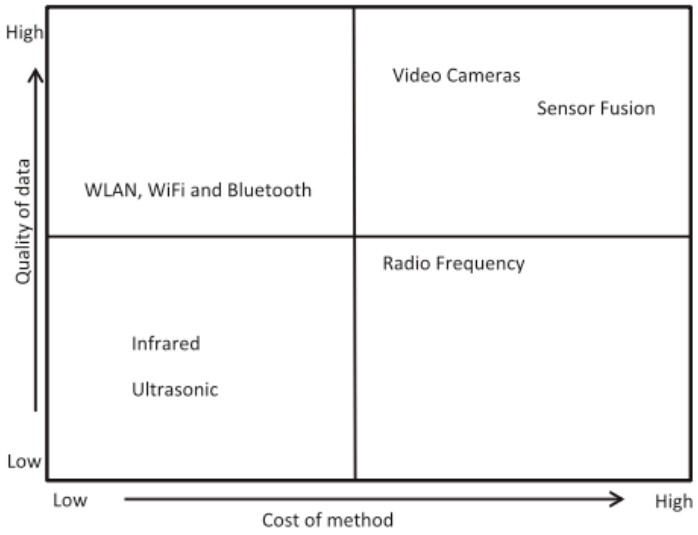


Figure 3-10: Occupancy measuring methods with an indication of strengths and weaknesses. acquired from (Ahmad et al., 2020).

Privacy and Support

Literature shows around the privacy aspect of designing an accurate system for monitoring occupancy is a challenging task. measuring occupancy is not easy because it legislates about privacy and accuracy (Ahmad et al., 2021). Where in non-residential buildings privacy is more challenging, such as universities. It even appears that people behave differently when they know they are being monitored (Boyd, 2010)

In terms of measurement, cameras appear to be the most sensitive in terms of privacy. Zou et al. indicate that Passive infra-red-based offers better privacy protection (2018). The SCT2.0 survey shows Wi-fi to be described as a problem in terms of privacy (Valks et al., 2018). Also, the municipality of Enschede here recently experienced privacy issues with measuring crowds based on Wi-Fi (Autoriteit Persoonsgegevens, 2021). However, the literature also explains Wi-Fi as partial privacy concern of the occupants (Zou et al., 2017; Zou et al., 2018). Where examples are given for a Wi-Fi fine-grained Channel State Information (CSI) approaches to solve the privacy concerns (Ma et al., 2019; Zou et al., 2017; Zou et al., 2018). Ma et al. indicates to make progression in the field of Wi-Fi measurements, new policies, protocols, algorithms and architecture must be developed for the privacy and security of Wi-Fi sensing (2019). For processing data, Ahmed et al. indicate that binary output plays an important role with privacy (2021).

The literature indicates that support is an important component for trust and how users will adapt to using a new study or work environment. Brunia et al. describe user involvement as important in the initial phase, but also during the process for successful implementation (2016). Thereby, Dery et al. indicate that users should perceive the benefits by providing platforms or technology to increase the connectedness of users. But also involving users, handling various data sources (2017).

Smartness

It is interesting to read when a tool, service or building is 'Smart'. This is briefly explained because there are doubts about the 'smartness' of reservation systems. Part of the definition of a SCT is described as; when the tool can gather real-time information to improve space utilization and decision-making (Valks et al., 2018). Gil-garcia et al. describe the degree and nature of "smartness" in a smart city. They do not make a distinction between not being smart and being smart, but they describe smartness as a continuous process in which users conceive and carry out initiatives to create a better place to work and live (2015).
In addition, the term Smart Building appears as the next step of SCTs in foreseen developments. Buckman see a smart building as a complete system which communicate rather than a collection of small tools together (2014). Sinopoli confirms this and is about integration, where the design and systems of the building are also important (2009). Also, these technologies must be integrated vertically as well as horizontally in the building. From this you create information about the operation of the building that can be used and managed by multiple users.

SCTs in a changing demand

In recent years, technology has grown as a support in terms of decision-making for management. CoreNet Global describes that management with integration between technology and communication systems adds value in adapting to changing needs (2015). Trends such as IoT or other integrated digital systems (Smart tools) make it easier to efficiently use energy, space, and money. It can also contribute to analyzing and enhancing user experience (Magnini et al., 2018). Unless the brainstorming session showed that this is still challenging (Valks, 2021). Furthermore, in recent years there has been more research into smart tools or IoT in real estate, which has shown that SCTs can support campus decisions (Valks et al., 2018; Valks et al., 2020). Den Heijer describes campus needs to stimulate optimal solutions decision-making with evidence-based management big data (2011).

3.4 The organizational context of universities

The fourth chapter will describe the changing organizational context of universities by COVID-19. Before this period, there were trends that also affected campus management. This will be briefly explained.
The first aspect is about the growth of the number of students. Due to the rapid growth in the number of students in recent years and the ever-wider range of education on offers, such as private schools and online teaching such as MOOCs (HOP, 2020) and the decreasing national contribution (VSNU, 2018, june) have put universities under pressure (Barber et al., 2013; Zwaan, 2016, p. 13).

In addition, the use of space was already a focus issue before the crisis. Earlier research by Valks et al. shows that it is essential for Dutch and European campuses to use existing space more effectively and efficiently. It appears that universities are struggling with too many square meters, which is due to obsolescence, and that there has been a change in the use of campus spaces (Valks et al., 2016). The workplace has already been used in an increasingly dynamic way, and the value of ownership is increasing, need for own study- and work places. It is important to offer different types of these spaces to different users on campus. Due to the increased digitalization, users need to be less on campus.

However, this COVID-19 crisis shows that only working from home does not work, but this will possibly impact the future demand for university spaces.

Six trends have been defined by Magnini et al. that affect the campus and its management and that it is essential for management to respond to this (2018). The value of the third trend has increased after the COVID-19 crisis (Valks, 2021). These are diverse student demographics (1), rising demand for lifelong learning (2), on-campus experiences remain key (3), lifecycle-driven design and automation improve sustainability (4), a greater understanding of user needs enhances productivity (5), and internal and externals synergies drive innovation (6). These trends arise from changing demand, and these affect campus management. Aspects surrounding campus management are now being defined.

In addition to these trends, the problems that have arisen from COVID-19 (outlined in the problem definition) play a major role (Valks, 2021).

3.5 Previous research

The current information from previous research is used as a point of departure, in which they will be updated to reflect the changes due to COVID-19. This concerns the results of SCT 2.0 of 14 Dutch and 13 foreign universities and eight other organizations. The following aspects are presented for each of these cases: Project description, phase, scale, duration, foreseen developments, why, what, how, functionalities, space types, user information, management information, benefits, the actuality of information, and access levels. The most important conclusions are presented in Table 3-2 and the first appendix is an overview of the results concerning the university, and other organization cases that will be interviewed in this study.

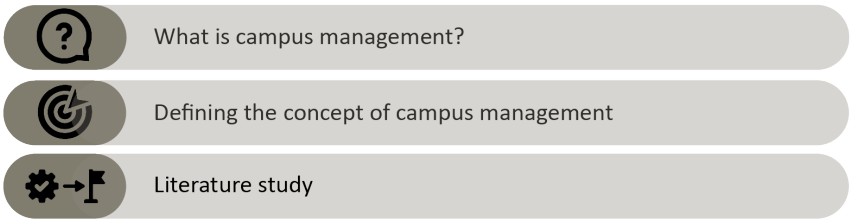
Table 3-2: Textual conclusions from previous research (Information retrieved from (Valks et al., 2018; Valks et al., 2016)

Type:	SCT (2015-2016)	Type:	SCT2.0 (2018)
Dutch university	University buildings have many different spaces. Where these spaces are offered differently but also used differently by users.	Dutch university How	Measurement methods is used differently at universities (Bluetooth, iBeacons, WI-FI, active connections, cameras, infrared, CO2, temperature, RFID, acces gates, doorways and desks)
Dutch university	The way in which spaces are offered and used determines whether and how data on space usage is retrieved. There is a difference in spaces that are hardly measured, either manually or tools to support users.	Dutch university What	Space use measurement is used differently at universities (frequency, occupancy, identity, activity) Smart tools are used for real-time monitoring of teaching space and are also focused on the value added in terms of support for students.
Dutch university Why, what and how	The use of smart tools was still focused on using spaces more effectively and still little on the basis of efficiency. Wifi, cameras or infrared could collect real-time data but still real-time data was only used for teaching space or supporting students.	Dutch university Why	Now, also in terms of value addition, the aspect for physical objective is more mentioned next to the functional objectives.
Dutch university What	In relation to privacy, the demand from universities is not yet for higher resolution of utilization but for measuring utilization and occupancy.	Dutch university How	Information for users is available via the webiste or apps near real-time.
		Dutch university	Benefits (goals) for smart tools to monitor the use of educational spaces can be reported but the goals to support the student are more difficult to define and report.
Other organizations Why	These are more advanced than universities in terms of implementations. Emphasis is placed on supporting the employees with finding a workplace or meeting room. In addition, also the monitoring of space usage and 2 of the 8 organizations that used smart tools for alignen energy use to building use.	Other organizations Why, what and how	Similair focus on supporting the employees by frequency and occupancy on find available workplaces by Wi-fi, check-in at workplace, and docking station or pc use. In addition, 3 out of 9 focus on available meeting rooms with real-time information by passive infrared. Besides, there are 2 more cases that improve user comfort by offering an application that can regulate temperature and light as an exception.
Other organizations Why	It also turns out that other organizations already use smart tools from multiple perspectives compared to universities where the focus is more on the goals from the functional perspective.	Other organizations Why	In these researched organizations, the focus for adding value is again on functional objectives but almost all cases also focus on strategic objectives and a little less on physical objectives.
		Other organizations Why	In these researched organizations, the focus for adding value is again on functional objectives but almost all cases also focus on strategic objectives and a little less on physical objectives.
		Other organizations	Type of sensors: Reservation systems, occupancy by workplace check-in. Wi-Fi for wayfinding and space use

3.6 Conclusions

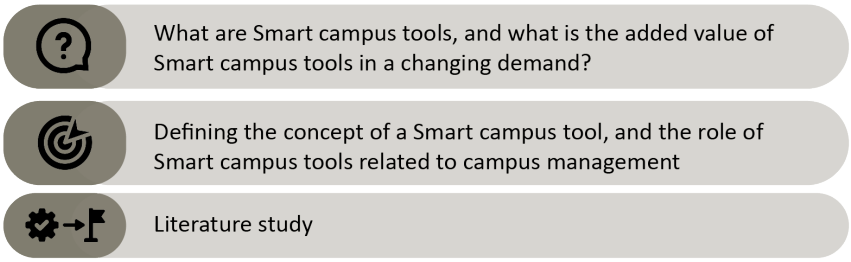
In this conclusion, based on the literature review, the following two sub-questions are answered.

3.6.1 First sub-question of the research



The literature shows that campus management involves managing the buildings related to the university and contributes to institutional goals based on owned buildings or used (rented) or both (Den Heijer, 2011, p. 51). This campus management is considered a process of aligning the demands and requirements of the users with the changing context of the university, supporting the university's performance. This process consists of four repetitive steps striving to match supply and demand (De Jonge et al., 2009). The four stakeholder perspectives, the corresponding objectives, and variables to be measured need to be involved (Den Heijer, 2011). The key is to add value to the campus for the university and its users. Future campus management will thereby focus on a mix of space use of the three physical states described by Den Heijer (2019).

3.6.2 Second sub-question of the research



A SCT is a service or product that collects real-time information about space usage and provides this information to the user, contributing to better space utilization on campus. Second, this obtained real-time information can contribute to the user's decision-making for improving space utilization in the short and long term. The same applies to the contribution to the thirteen added values described by Den Heijer (2011).

The type of SCT is partly determined by the why, how, and what. Valks et al. (2018) describe these three aspects in which the why addresses the thirteen objectives (added values) just mentioned. Next, the 'What' is about determining at what level to use of space should be measured such as frequency, occupancy, identity, and activity. Last, the how is about determining the measurement method whether this is measured on a manual, reservations, or sensor basis. Where sensors provide real-time data.

The role of SCTs is to support decision-making for management, where the integration between technology and communication system adds value in adapting to changing needs (Corenet Global, 2015). In addition, real-time information can create insights into the use and performance of buildings, which contributes to decision-making. Finally, from the brainstorming sessions and the case study, it can be concluded that space utilization by COVID-19 has become even more important.

4 IMPACT OF COVID-19

This chapter describes the impact of COVID-19 on universities, what has changed, how universities have responded, and what the suggestions are in the short and long term. The purpose of this chapter is to answer the sub-question; What effect does COVID-19 have on the campus? Accordingly, this will contribute to the emphasized part of the main question: "**What has changed** in terms of type, demand, and use of Smart campus tools **at universities** and other organizations **due to COVID-19** compared to the 'Smart campus tools 2.0' research?". This chapter is primarily based on a brainstorming session with support from the literature.

4.1 Main findings

A year ago, the COVID-19 pandemic started and had an impact on the university and its users. Based on a brainstorming session with ten universities in November 2020, focused on SCTs. During this session, issues and experiences were discussed COVID-19 in the short term, back to campus, and in the long term. With the intention that interviews with the cases can be conducted based on this information obtained. This chapter will first describe what has changed, then how universities have dealt with it.

Through the COVID-19 virus, in a short period, education has changed from physical to digital environment. At the university grounds, circumstances have changed, and campus management has made adjustments using SCTs. In addition to physical adjustments, change was also noticeable at the management level. This appears from a brainstorming session with ten universities, from which it appears that there is a growing urgency of managing (by measuring to keep control) the campus (Valks, 2021). Furthermore, management support and willingness to implement smart tools have been increased (as appears from increased interests in reporting to external parties), but attention to the privacy concerns of employees and students. In the meantime, the decision-making process of the campus management seems to go faster than before COVID-19, and decisions are carried out quicker. Opinions and shared thoughts are less unambiguous about the privacy aspect of the smart tools. A part is still hesitant. However, the awareness has increased that the campus management needs to think more from the user's perspective, which needs to be explained before acceptance.

As described in the previous chapter, campus management is a continues process to find the match between demand and supply. Through the COVID-19 pandemic, a match needs to be sought to anticipate the demanded changes by matching the supply and demand of campus real estate. As a result of these changes in demand for education, universities have anticipated and implemented campus supply changes. Research at the brainstorming session shows that most universities have been taking action. Current smart tools have been upgraded, new smart tools have been implemented, or research has been conducted to improve existing tools 'functionality. As a first step to control the number of users present on campus, many universities implemented a reservation system (variation of systems). These concerns study places (chair level), education spaces, or even office spaces. Several universities have applied variations of crowd control to make the crowd levels transparent. This has been applied at different levels, such as the floor, building, campus level, and distinction in access information per user type. Furthermore, to manage crowd control, registrations

are made of incoming and outgoing usage flows per building, and the expectation versus reality is compared (per day) and in a dashboard. This also gives a picture of the no-shows, with which many problems are still encountered among universities (Valks, 2021). Besides, the knowledge of actual traffic (and possibly comparison with reservations) can assist in spreading users across the campus and is used as input for conversations with public transport.

The COVID-19 crisis has brought uncertainties that universities are facing now. Selected alternatives such as smart tools that have been proven effective during the crisis will probably continue to be used, depending on the campus and users 'added value. The brainstorming session revealed several problems (Valks, 2021). There is uncertainty about the future supply as the right balance between face-to-face lessons and online learning, virtual exchanges, and physical mobility has yet to be found. It has been experienced that studying at home only is not preferred and that users still feel the benefits of going 'back to campus'(Omroepwest, 2020a)(Future Demand). Regardless of what this form will look like, universities experience difficulties with no-shows, which was a problem before and during COVID-19 (Bongers, 2020). "Everything is booked, but many rooms and seats are empty" (Valks et al., 2016) even with reservations. Universities are also searching what to do with certain information obtained with the help of SCTs. It appeared to be desired to manage crowded situations and predict capacity because they vary from week to week (this was no different before the crisis).

Because of COVID-19 and possible hybrid education, there is a changing demand for education, study, and office spaces. Possibly large lecture halls are less needed, there is a higher demand for collaborative spaces for students and employees. Finally, the number of users on campus will fluctuate more than before the crisis, reducing the use of space and bringing new opportunities. As a result, the universities have increased demand of more control over the various spaces on campus, based on crowds, occupancy, and utilization.

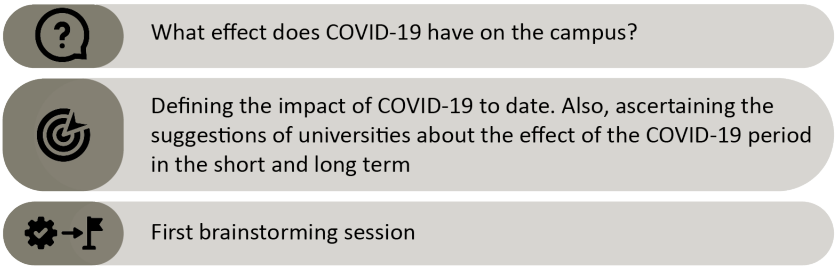
The coronavirus has shown an unexpected impact on the demand for campus space, and this may remain for an extended period (Valks, 2021). These issues result in questions and possible changes in how to manage, buildings, and spaces. SCTs may be used differently because COVID-19's changing demand result in a need for different information. New insights or interests can be retrieved in use and needs of SCTs in measuring frequency, occupancy identity, and activity. In the brainstorming session(Valks, 2021), the universities indicated that SCT developments are made or that research to develop new possibilities/methods is conducted. Besides, it is thought that more use will be made to manage education spaces with scheduled occupancy and deployment as study places outside teaching hours. This also shows that more thought is being given to real-time occupancy and utilization than before and that reservation data and sensor data are still promising. The SCT 2.0 research concludes that the expected developments aim to link existing solutions to building management systems or planning systems and extend sensors to existing solutions. Also, certain benefits such as user experience are still challenging to measure, and new entries may be found (Valks et al., 2018).

It is interesting to see whether these SCTs may have or will play an even more important role in reusing the campus and decision-making after the COVID-19 crisis. It remains interesting to find out whether there are further developing tools and ways to better use data (Determine Future Match). With this research, results can be achieved that are immediately usable and support follow-up choices for smart tools for campuses and other organizations and professions.

4.2 Conclusions

The purpose of this chapter is to provide an answer to the third sub-question.

4.2.1 Third sub-question of the research



The effect of the COVID-19 crisis on the campus has led to a mismatch between supply and demand. With a consequence of physical adaptations, adapted use of SCTs, adapted way of education, impact on its users' social condition, and changes at the management level. From the first brainstorming session, it appears that there is a growing urgency of managing (by measuring to keep control) the campus, and management support and willingness to implement smart tools have been increased (Valks, 2021).

As a result of these changes in demand for education, universities have anticipated and implemented short-term (or certain aspects possibly longer) campus supply changes. Current SCTs have been upgraded, new SCTs have been implemented, or research has been conducted to improve existing tools ’functionality. As a first step to control the number of users present on campus, many universities implemented a reservation system for education spaces (variation of systems). Several universities have applied variations of tools for crowd monitoring to identify crowds.

Regarding the long-term, there are uncertainties about the right balance between face-to-face lessons and online learning, virtual exchanges, and physical mobility for the long term. Also, universities experience difficulties with no-shows, which was a problem before and during COVID-19 (Bongers, 2020). "Everything is booked, but many rooms and seats are empty" (Valks et al., 2016), even with reservations. Lastly, due to the possible hybrid education, there is a changing demand regarding space for education, study, and workplaces.

PART III



CASE STUDY

5 Smart tools at Dutch universities

As the first part of the case studies, this chapter start with exploring the use and progression of SCTs at Dutch universities. The purpose of this chapter is to answer the sub-questions
'What progress have Dutch universities, universities abroad, and other organizations realized on Smart (campus) tools addressing space utilization compared to previous research? (4)', and 'to what extent do these Smart (campus) tools meet the needs and use of the Dutch universities, universities abroad, and the other organizations after COVID-19? (5)' Accordingly, this will contribute to the emphasized part of the main question: "**What has changed in terms of type, demand, and use of Smart campus tools at universities** and other organizations **due to COVID-19 compared to the 'Smart campus tools 2.0' research?".** A case study and a follow-up brainstorming session is conducted to answer these questions.

This chapter will first describe the selection process of the cases, and for each case, it will give a brief description. Subsequently, the templates will be displayed with the collected data of the cases. These templates serve as a basis to analyze the properties of the cases, but also to be able to conclude what the progression and modifications are with respect to the SCT 2.0 research

5.1 Cases

For this study, nine Dutch universities were selected as cases. The cases were selected because they participated in the first brainstorming session and because these cases were also examined during previous research. Due to time constraints, it was not possible to interview all Dutch universities. The map on the right shows the locations of the universities that were interviewed. In 2018, all Dutch universities were interviewed for the SCT 2.0, and in this study, a large proportion was re-interviewed. These are nine of the fourteen universities in the Netherlands.
In the table below, an overview has been included, identifying the interviewed universities, along with the function of the interviewee(s).



Figure 5-1: Map of the interviewed cases of the Dutch universities

Table 5-1: Overview of the universities interviewed, the abbreviation, and the position of the interviewee

Universities Netherlands	Abbreviation	Function of interviewee(s)
Radboud University Nijmegen	RU	Facility management
Tilburg University	Uvt	Facility management
Twente University	UT	Campus/facility management
Delft University of Technology	TUD	Library
University of Amsterdam	UvA	Education services
VU Amsterdam	VU	Facility management
University of Utrecht	UU	Library; Library
Wageningen University	WU	Education services
Eindhoven University of Technology	TUE	Education services

5.2 Case description

This section briefly explains the context for each university. This information derives from the interviews with the universities. In addition, general information for each university is presented in an image. The general information is extracted from annual reports and/or websites of the universities.

Tilburg University continues to have an upward trend in student and employee growth, demanding more efficient use of space. Tilburg University has the ambition to start preliminary research to enable the measurement of occupancy and utilization in lecture halls. Because of COVID-19, the demand to reserve study places emerged to gain insight into which students are/were on campus and in what location. Web Room booking is no longer in use due to changing scope, time, and data quality.

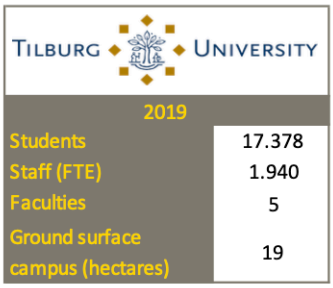


Figure 5-2: General information about the UvT (own figure, info from annual reports)

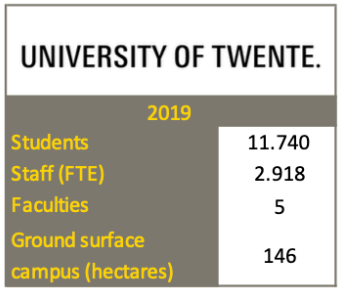


Figure 5-3: General information about the UT (own figure, info from annual reports)

Because of the new Twents onderwijsmodel, the focus of the University of Twente is focuses on contact hours, therefore the rooms are more occupied. Adaptive scheduling is no longer in use because of the collaboration between IT and the organization and its smart tool expertise. A new approach is to start measuring frequency/occupancy in education spaces in the Ravelijn building by implementing sensors. In addition, the ambition is to adaptive scheduling if this succeeds with a collaboration between a developer and the university.

The VU, implemented the Bezettingstool shortly before COVID-19, as a result of the students' desire to gain insight into free study places. Studyspot is no longer in use, becauseof different expectations regarding the data and the system. Furthermore, in Amsterdam, a map to show available study places is being developed through collaboration between the VU, UvA, InHolland, Amsterdam University of Applied Sciencesand public libraries. Finally, it emerged that the library of the VU has a broad vision to share as much as possible. This limits travel and give the flexibility for students to study anywhere.

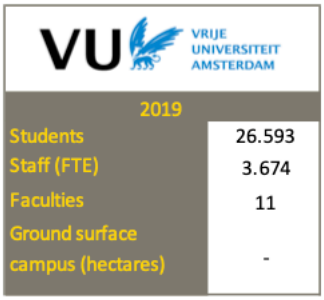


Figure 5-4: General information about the VU (own figure, info from annual reports)

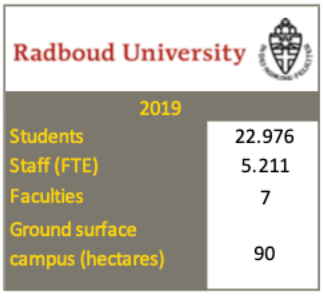


Figure 5-5: General information about the RU (own figure, info from annual reports)

The RU focuses focus on creating a structure that is able to withstand market developments, contributing to the continued development of a smart campus. This view is consistent with applying sensors that do not depend on one type of developer, to avoid the use of different sensors and methods. Finally, the experience of utilizing the halls of associations and theaters during COVID-19 also proved to be a valuable solution.

At the TUD, movement research is being conducted for the 'Back-to-campus' strategy as a field lab for Delft mobility innovation center. This focuses on the outside of the buildings on the campus, and recently also inside the library. Furthermore, there are several developments concerning the sensors in the library. Since the batteries need to be replaced regularly, they are looking for an environmentally friendly sensor for all study places.

TU Delft	2020
Students	26.480
Staff (FTE)	8.971
Faculties	8
Ground surface campus (hectares)	161

Figure 5-6: General information about the TUD. (own figure, info from annual reports)

Universiteit Utrecht	2019
Students	32.360
Staff (FTE)	5.865
Faculties	7
Ground surface campus (hectares)	260

Figure 5-7: General information about the UU (own figure, info from annual reports)

At the UU, Lone Rooftop is no longer in use due to the different expectations of the data. On the other hand, three new SCTs have been deployed. In addition, COVID-19 has put forward the strategic goal of reducing the strategic stock of education m2 as to the extent possible through more digital education. Finally, a program to create complete smart buildings for new construction or major renovations is currently being considered.

At the UvA, it turned out that the use of Mapiq was conditional on being able to go 'back-to-campus' at all. Also, partly due to the update of Office Shifts since it is possible to reserve individual study places. Furthermore, no new SCTs have been developed but continue to improve Mapiq. In addition, the ambition is to commissionn a reservation system for office places as well.

Universiteit van Amsterdam	2019
Students	35.413
Staff (FTE)	5.130
Faculties	7
Ground surface campus (hectares)	-

Figure 5-8: General information about the UvA (own figure, info from annual reports)

WAGENINGEN UNIVERSITY & RESEARCH	2019
Students	12.847
Staff (FTE)	5.400
Faculties	1
Ground surface campus (hectares)	60

Figure 5-9: General information about the WU (own figure, info from annual reports)

At the WU, there are several research institutes where research at home cannot be conducted due to the need of laboratories. However, in many laboratories the ventilation rate is not a problem, and the 1,5-meter regulation can be met. That means that many laboratories can be used with little to no restrictions. During the initial phase of the COVID-19 period, Lone Rooftop was not applied but an update allows the capacity to be adjusted and warnings to be received when the capacity is exceeded. The demand at the WU has changed since they are confronted with a huge capacity reduction in education and shortage of space, whereas the departments are not using the offices to the full capacity.

At the TUE, since COVID-19, it has been possible for students to reserve study spaces in Planon, similar to the meeting spaces for employees. Such spaces can still be reserved, even though they have a reduced capacity. Employees check manually on-site for the whole buildings whether users comply with the restrictions. Besides, access is not restricted, but is constantly monitored to keep an eye on the amount of people.

TU/e Eindhoven University of Technology	2019
Students	12.251
Staff (FTE)	2.035
Faculties	9
Ground surface campus (hectares)	75

Figure 5-10: General information about the TUE (own figure, info from annual reports)

The last two universities were interviewed by Ir. Valks around August 2020 as input for the first brainstorming session. From these interviews, the progression and aspects around COVID-19 at the universities can be outlined but the approach for reservations will be explained to a limited extent.

The following section displays the templates of the existing and new SCTs at the Dutch universities.

5.3 Templates

Based on the interviews, it is revealed that universities have discontinued or further developed the tools from the previous study, or are active with new SCTs. The table below shows an overview of which tools from previous research were examined as cases included in this research. In addition, other SCTs were not included in the study because there was not enough information available or not enough time in the interview. After the table, the templates that are still in use but have been further developed will be shown first. Most of the information in these templates was inventoried during the SCT 2.0 research. During the interviews, it became apparent that adjustments had been made. Such adjustments are identified in the template in *italic*. In addition, it shows the templates that have been developed since new SCTs were initiated relative to previous research.

Table 5-2: SCTs at Dutch universities from previous research and SCTs attached as case in this research (updated from Valks et al., 2018)

University	Previously surveyed SCTs (2016)	Previously surveyed SCTs (2018)	Other Known cases of SCTs (2018)	Included as case	Other Known cases of SCTs
		Past research		Present research	Future research
Tilburg University	PC Availability, Web Room Booking, Planon	Design brief		Web Room Booking (no succes), and LibCal	
University of Twente	Indoor maps, Facility Scheduler, Nedap, Smart Signs	Research on adaptive scheduling		Adaptive scheduling (on hold), Resource Booker, and Crowd Control	Smart building development
VU Amsterdam	Studyspot	StudySpot	Lone Rooftop	StudySpot (no succes), Bezettingstool, and Building intelligence	
Radboud University Nijmegen	Web Room Booking, Availability for students, Planon			Mazemap/Planon /Swycs	Lone Rooftop
TU Delft	Mapiq, Workplace Availability Service	Mapiq, Lone Rooftop		Mapiq	Outdoor mobility dashboard
University of Utrecht	Studyspot	Design brief		Lone Rooftop (no succes), LibCal, Crowd control, TwiQel	Business case for Smart building
University of Amsterdam	Mapiq	Mapiq		Mapiq (Office Shifts)	
Wageningen University	Lone Rooftop, Available PC app, Avaiable PCs in PC halls, Web Room Booking	Lone Rooftop		PIE, Clocks (Lone Rooftop)	
TU Eindhoven	Book my space, Manual occupancy measurement with cameras, Evoko	Book my space		Book my space (Planon)	

5.3.1 Existing templates

As of the following page, the templates created during the SCT 2.0 research are displayed including the modifications that arose during the period between the SCT 2.0 study and this study. Of the nine universities interviewed in this research, four existing cases are still in use, and four cases experience delay or termination of a SCT Project. The modifications to the existing templates of the SCT 2.0 research are shown in italics. This involves the cases still in use at the TUD, UvA, WU, and TUE. First, the situation prior to this research at those universities is described. The cases with a delay or termination of a SCT project concern the UT, UvT, UU, and VU. The cases with new SCTs are explained at the Paragraph 0.

Existing situation

As of 2014, after conducting a pilot with Mapiq on a faculty, the library of TUD received 100 infrared sensors to display the use of places in the library in Mapiq. With the aim of contributing to the services offered from the library to students. In Mapiq, the availability of places with PC and project spaces can be viewed and project spaces can be reserved.

The UvA also utilized Mapiq as of 2015 because of the demand that arose from the student council to provide students with access to classrooms outside of timetabled hours and to provide insight into free study places with PC, and project rooms (reservable).

At the WU, the demand arose to identify how the newly constructed educational buildings were actually being used. Starting in 2015, Lone Rooftop was applied as a SCT to measure the use of lecture halls based on Wi-Fi and (un)scheduled hours.

At the TUE, Planon has been utilized since 2016 because of the increasing student population due to which an increased efficient use of space had to be realized with the available m2s. With this SCT, the availability of study, meeting, and/or project rooms is made transparent. Also, students can reserve project rooms and employees can reserve meeting rooms, for which usage is controlled by infrared sensors. For the large lecture rooms the usage is monitored manually.

The other cases not included in this study but inventoried during the SCT 2.0 study were similar types of SCTs such as for real-time monitoring of teaching space, find a study place (available PCs), or find a group room (room booking), and to study in unscheduled teaching spaces (Valks et al., 2018).

TUD-1 TU Delft Mapiq - Blinq Systems



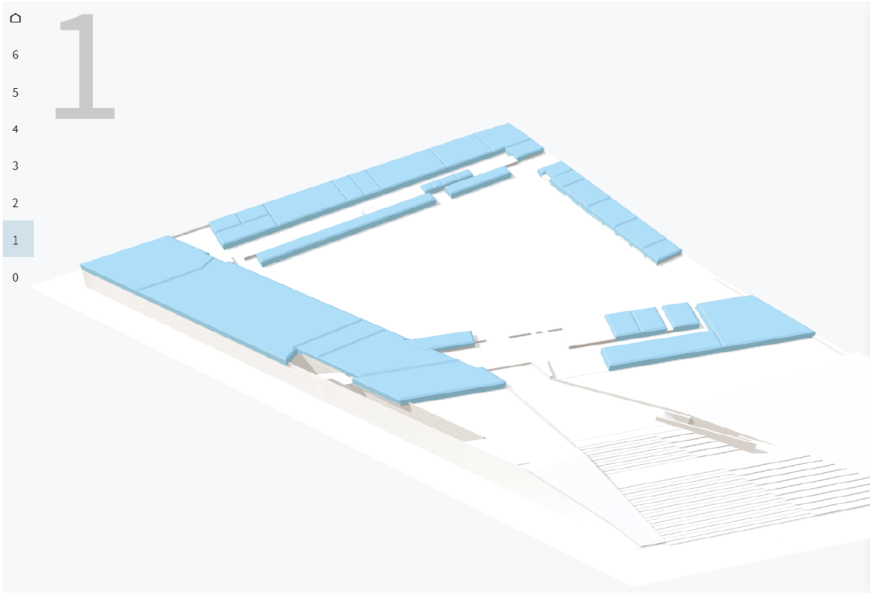
phase
Implementation
Library: Pilot

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.

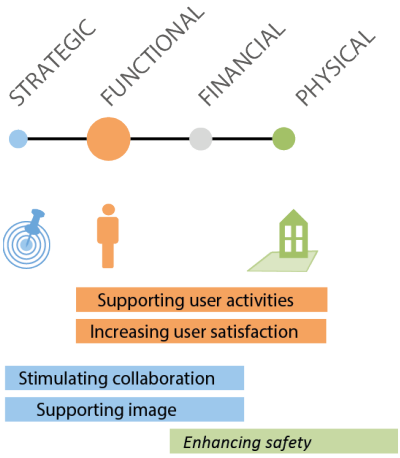


Foreseen developments

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.
We want to improve the insight into available individual study places. We are now researching the best way to do this.

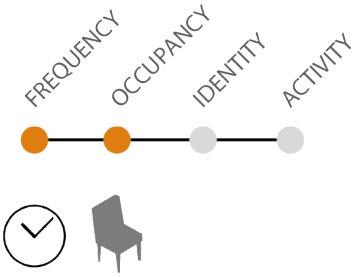
Profile

Why: Objective



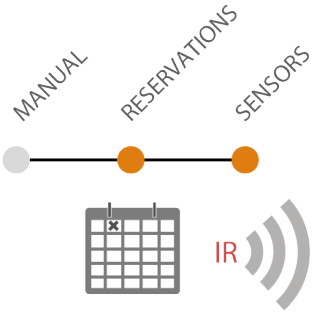
Mapiq supports user activities by offering information with regard to the amenities in the Library and by enabling reservation of project rooms. That indirectly stimulates collaboration.

What: Measurement



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

How: Measurement method



The data source used is reservations, from the reservation system of Mapiq. Infrared sensors have been added on 100 study places; they measure activity on that study place. 10 infrared sensors have been added to meeting rooms; they measure activity in the room.

TUD-1 TU Delft Mapiq - Blinq Systems

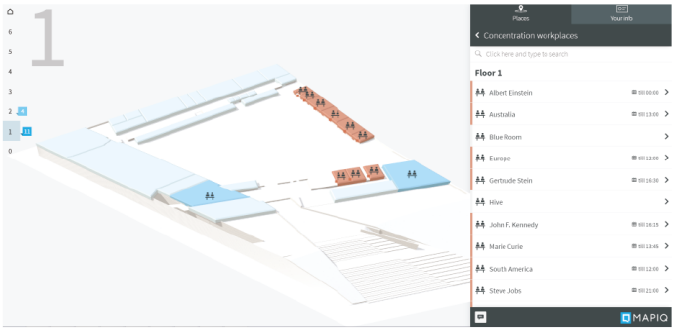
functionalities
Wayfinding, find a study place, book a project room and study place

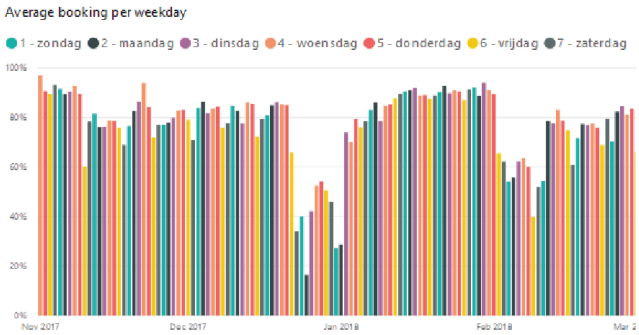
space types
study places, project rooms



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.



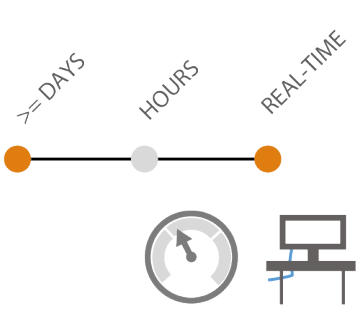


Management information

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

The reports from the PowerBi dashboards are hardly used yet. We actually don't take the time to analyze the reports properly yet. Besides, we are not using the sensors at the moment because of COVID-19.

Actuality of the information

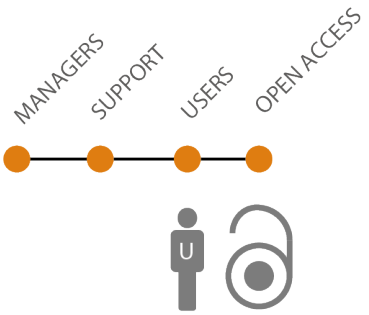


De displayed information on the webpage and in the PowerBI dashboard is (near) real-time.



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.

A disadvantage of the sensors is that the batteries need to be replaced often. Thus, from the sustainability point of view, we are not in favor of 1250 places with this sensor, so we are looking at another sensor/method.

UvA

Universiteit van Amsterdam - UvA Spacefinder (Mapiq)



phase
Expansion
Implementation (2019)

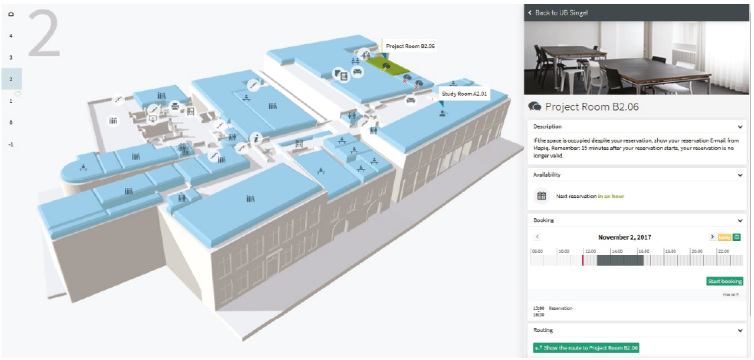
scale
6 buildings
105.184 m2
11 buildings: 200.555 m2

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.
By COVID-19, mapiq added the extension Office Shifts to allow students to reserve projectrooms and study places.

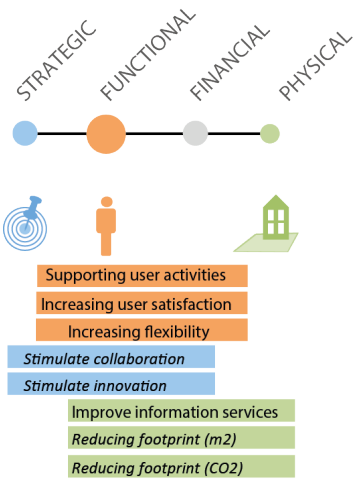


Foreseen developments

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. *The UvA has the ambition to carry out pilots with sensors (Frequency and occupancy) for locating available study places (all), work group rooms and meeting rooms with Mapiq as a tool. Besides, FM aspires to equip bicycle parking spaces with sensors to display free places.*

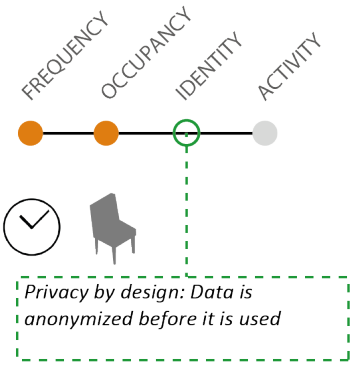
Profile

Why: Objectives



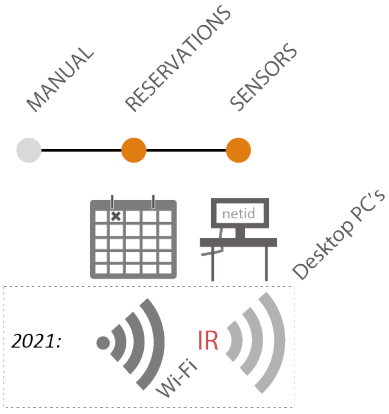
Our objective with Mapiq is to enable users to use the available space better. The next step is to use the information for improved decision-making.

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.
In addition, Infrared sensors are applied at projectrooms (frequency and occupancy) and Wi-Fi data for crowd control (Occupancy)

UvA

Universiteit van Amsterdam - UvA Spacefinder (Mapiq)



functionalities

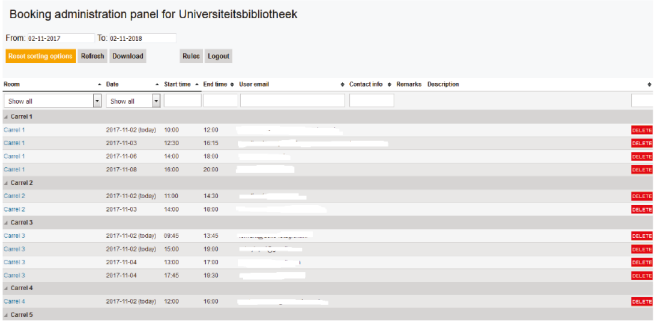
Wayfinding, room booking
monitoring space use,
crowd control, reservation of projectrooms and study places

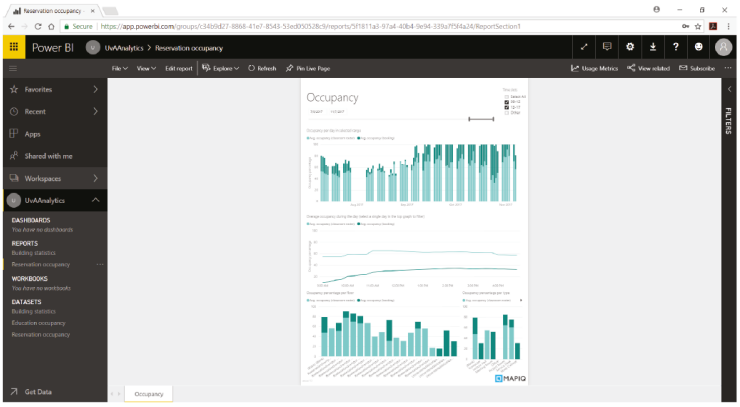
space types

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. *Students can reserve project rooms and study places through Mapiq Office Shifts.* The actual availability based on reservations is displayed. For each space a route to the space can be displayed. *In addition, it is easy for finding available facilities such as teaching desks, printers and coffee machines*



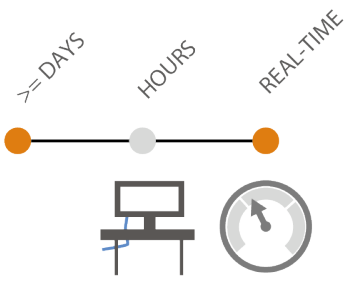


Management information

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.

This is for the purpose of:
- Steering for flexible, efficient, and effective use of space.
- Steering on studyable and workable scheduling.
- Steering on planning of cleaning
- Focus on reducing energy consumption

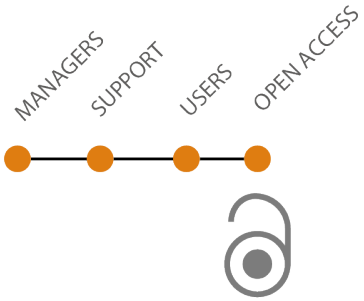
Actuality of the information



The displayed information on the webpage and in the PowerBI dashboard is *near* 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).

A dashboard is available for support staff with the reservation overview.

Reports are available for management.

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

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.

For the possible addition of sensors at all study sites and bicycle parking areas, the existing infrastructure should be used. This consists of the Syllabus Plus, Wi-Fi network, management system and building management system.

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

phase: implementation

scale: 21.000 m2 NFA, 6 buildings

duration: 2015 - present

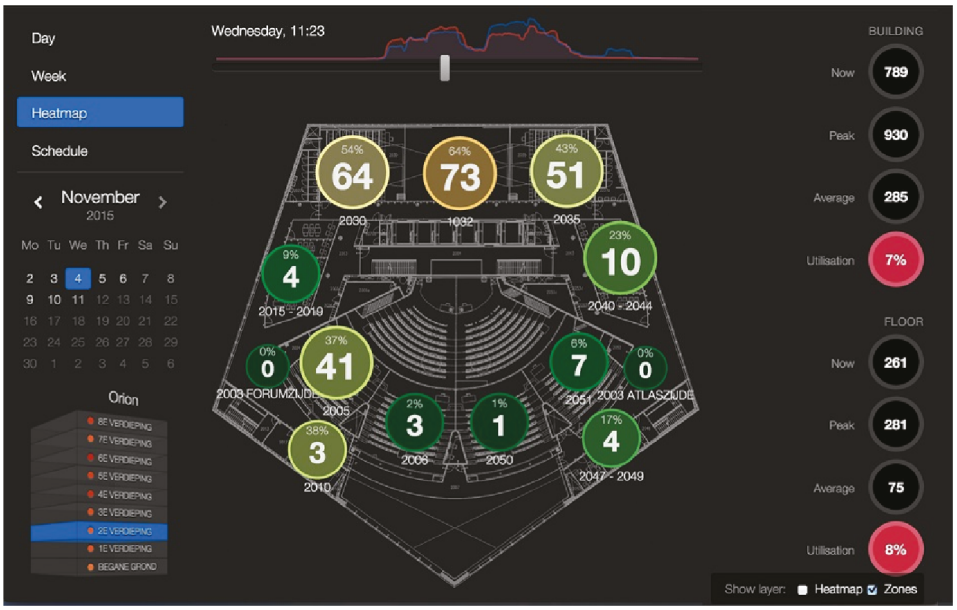


Project description

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

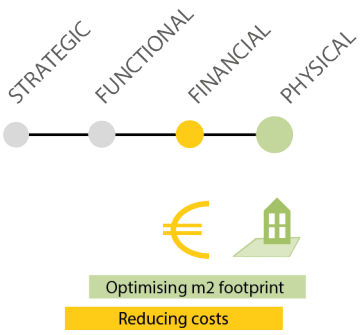
[...]



PIE dashboard

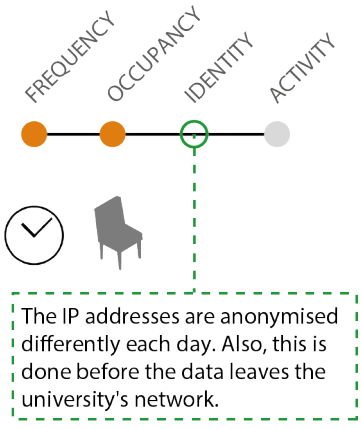
Profile

Why: Objectives



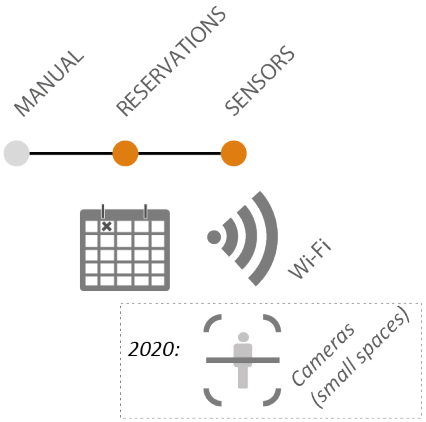
Optimising m2 is done by gaining insight into no-show behaviour. From the facility management perspective the delivery of this information was one of the measures taken to use the existing space more efficiently.

What: Measurement



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

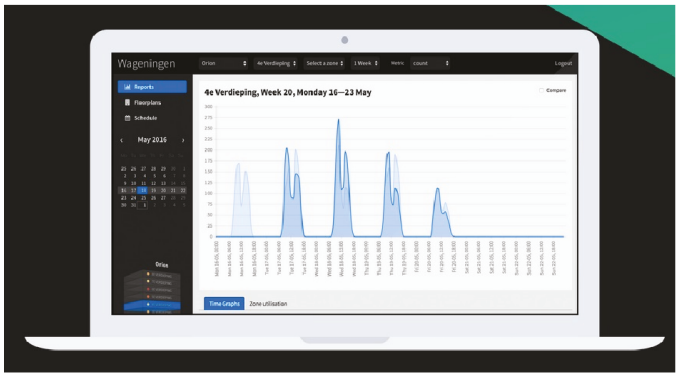
space types
Education spaces,
Common areas,
Whole building

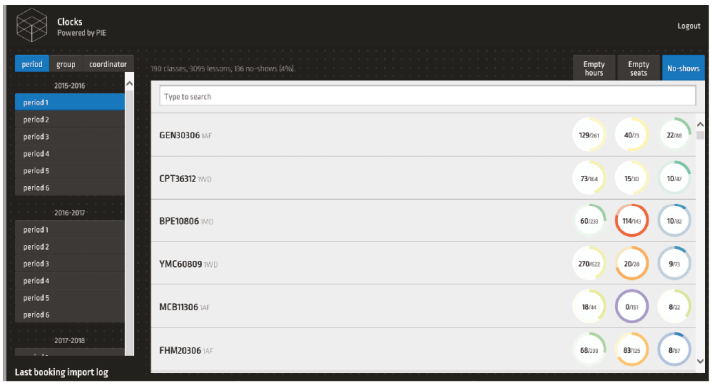


User information (scheduler)

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.





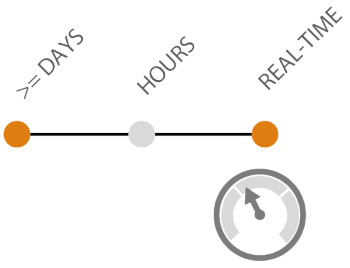
Management information

The building manager can see how many users there are in different zones of the building (see PIE dashboard)

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.

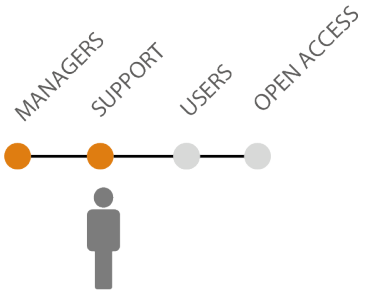
2020: The schedulers now look at empty hours to optimise the schedule, in addition to no-shows.

Actuality of the information



The information displayed in PIE is near-real time.

Access levels



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

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

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

Additional sensors have been added to monitor the use of small spaces - Wi-Fi is not accurate enough for these spaces.

TUE

TU Eindhoven

Book my space - Planon

phase
Implementation

scale
2020:
243.905 m2 (+30.905)

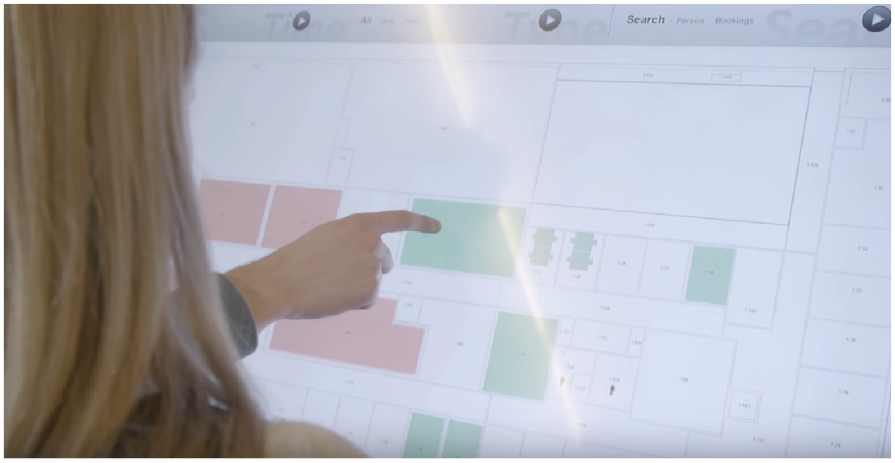
duration
Q1 2016 - present



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.



2020: Planon has organised a webinar with ideas to help in times of COVID-19, e.g. by entrance control. This has not yet been implemented.
There is now a link between Planon and Syllabus, but it is a one-way link (from Syllabus to Planon). We will wait with developing a two-way link until we have a new scheduling system (TimeEdit). Also, we are in the process of procuring our FMIS system (Planon). In the new Planon-app, it is possible to verify a reservation (via QR) - without verification it is cancelled after 15 minutes, in order to reduce the waste of space due to no-shows.

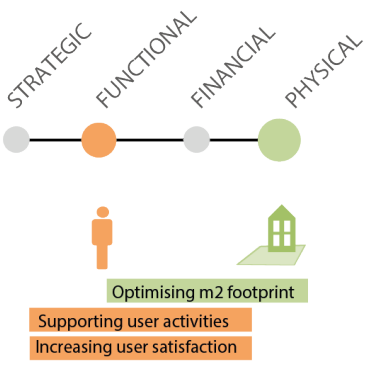
Foreseen developments

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.

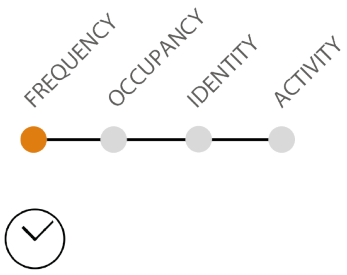
Profile

Why: Objectives



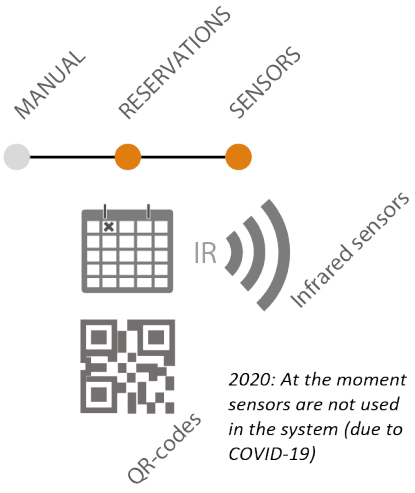
A higher amount of users per m2 has priority, and is achieved by a uniform way of making reservations and findability of available spaces.

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



2020: At the moment sensors are not used in the system (due to COVID-19)

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 work place, room booking, monitoring space use

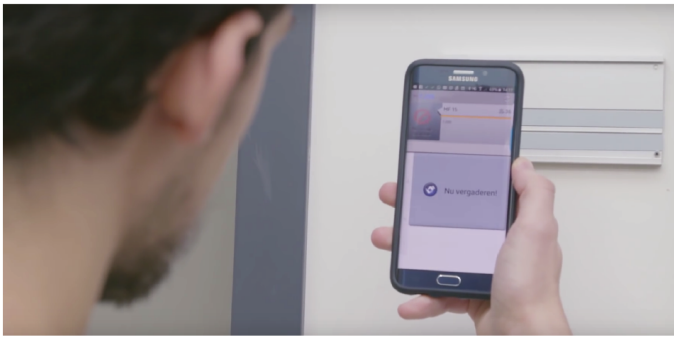
2020: Reserving study places + workplaces

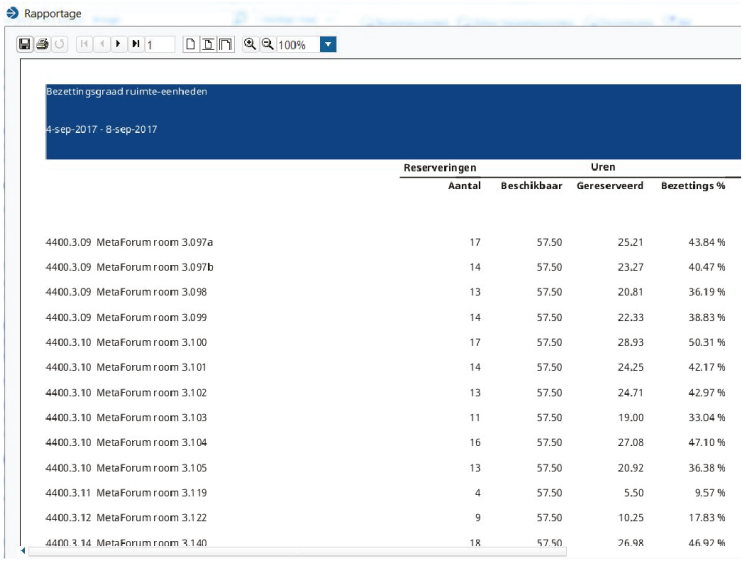
space types

Education space, flexible workplaces, meeting rooms, study places

User information

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





	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

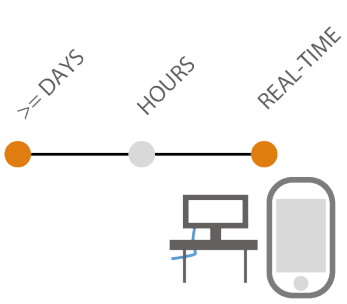
Occupancy percentages of all reservable spaces: education spaces, study places and flexible workplaces.

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%.

2020: With a reservation system for study places it is easier to keep sight of where students are on the campus, and if there may be capacity issues. With regard to the previous benefit: there is no accurate picture at the moment, because not all study places can be reserved.

Actuality of the information

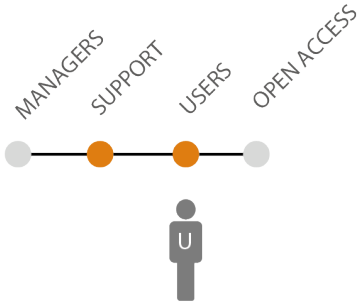


Information on the selfservice, app, and the kiosks is real-time.



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.

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.

2020: In order to check whether rooms are not used with a larger capacity than possible, employees will check on-site if spaces are used correctly. It was a huge operation to realise more bookable spaces: drawings with bookable workplaces, implement al these workplaces and make them bookable or not-bookable, rearrange the furniture in the rooms, communicate with posters, banners and stickers .

5.3.2 Modifications to existing templates

With respect to the templates just shown, the performed modifications are described below, supplemented by a comparison is with the foreseen developments that have been identified in the SCT 2.0 research and ascertain if progress has been made on these developments.

Main modifications

The TU Delft library foresees a development to locate available individual study places for students. This is already possible with 100 places, but the infrared sensors that are applied require frequent battery replacement. Therefore, with sustainability in mind, pilots were conducted with other sensors from Mapiq. Even after improvements, these did not suffice as they were easily disrupted by students. This problem has been reiterated to Mapiq, and the TU Delft is currently searching for a party that can provide sensors that meet their goal. Since COVID-19, they have the additional goal of ensuring safety, and the maximum available study places drive this. Additionally, the last modification concerns management information pointing out that the reports from the PowerBI dashboards are hardly used yet.

The University of Amsterdam expanded Spacefinder from six to eleven buildings during the expansion and is now considered implemented. Thanks to the update of Mapiq with Office Shifts by COVID-19, reservations are also possible on individual study places. Another change is that UvA's support staff has insight into the reservations, and management can obtain reports from Mapiq, which should contribute to the new objectives.

At the WU, little has changed for the current SCT (Pie, Clocks). A pilot project was started with cameras (photo sensors) in meeting rooms and concentration spaces. With the intention to measure frequency and occupancy in order to provide insight into the availability of these spaces for its users. Further, schedulers observe empty hours to optimize scheduling, in addition to the existing focus at no-shows.

The TUE expanded Planon with 30.905m2, but the sensors are unused since the COVID-19 crisis.
In addition, due to the COVID-19 crisis, it is possible to reserve study places for students and flexible work places for employees.

Progression of foreseen developments 2017 - 2021

A component to ascertain university progression is to check for progression around existing foreseen developments inventoried in previous research.

- As for the UvA, two of the three developments have been completed, with a pilot being conducted for the latter.
- The planned development for the case at the TUD has also been achieved, but the sensors are no longer satisfactory. Therefore, research is now being conducted with another sensor.
- For the UU, although Lone Rooftop has been discontinued, the current foreseen development still applies. In this regard, a pilot is now being carried out with a start-up: TwiQel.
- With regard to the progress at the WU, a pilot has been started with cameras for the second development, i.e.more accurate measurement method in small spaces. In addition, the data of building occupancy is now linked to the building management system.

- At the TUE, progress has been made on one of the two foreseen developments. This concerns the link between Planon and Syllabus, however, it is still a one-way link (from Syllabus to Planon).

Newly foreseen developments for the existing templates that emerged during the interviews for this research are described at Chapter 5.4. The next page will present the templates for the new SCTs which is the situation for five of the nine universities. This will be shown in the order of the UvT, UT, VU, RU, and the UU last. After the templates, various results are analyzed and described.

5.3.3 New templates

UvT

Tilburg University - LibCal



phase
Expansion - implementation

scale
7 buildings
There are still study spaces that need to be added.

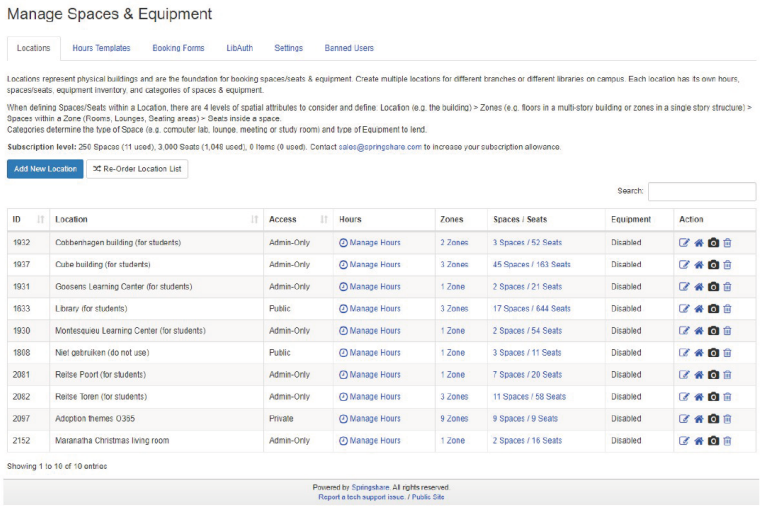
duration
Sept. 2020 - present

Project description

The need to reserve study spaces came from COVID-19 with the need to understand which students are/were on campus and at what location. Due to COVID-19, there were limited places available and this was quickly entered into Planon as this tool was available. The library then purchased LibCAL for the workstations in that building. Facility Services took over that management and incorporated all the study places into LibCAL

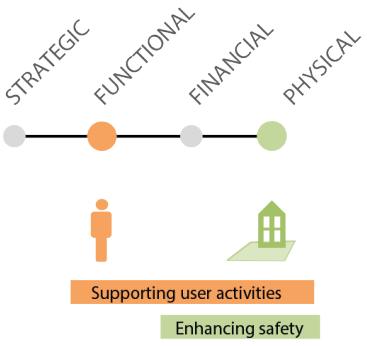
Foreseen developments

The foreseen developments are enabling employees to reserve workplaces. In addition, displaying the crowds per location on narrow casting or webview.



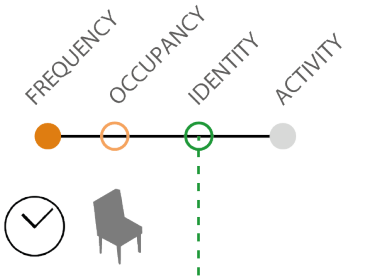
Profile

Why: Objective



In addition to supporting users, in order to meet the "traceable for source and contact research" requirement, security is currently important.

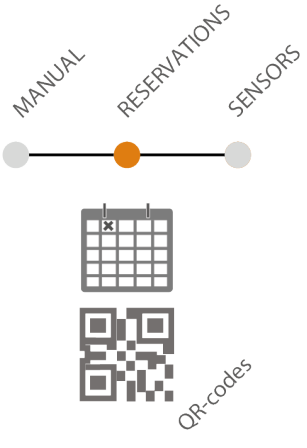
What: Measurement



This information cannot be viewed by other students and is not published anywhere. It can only be seen by the administrators of the tool.

It is original frequency but because it is currently by COVID-19 about individual work places now also occupancy.

How: Measurement method



A booking must be confirmed by scanning the QR code on the table (and at the door in case of meeting room).

UvT

Tilburg University - LibCal



functionalities

Find a study place and project room (incl booking system), monitoring s pace use, signing up for theme sessions, and making appointments with study deans

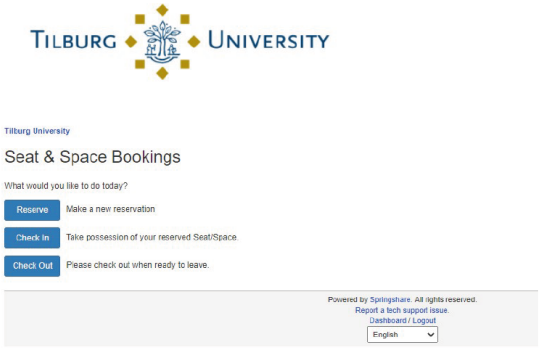
space types

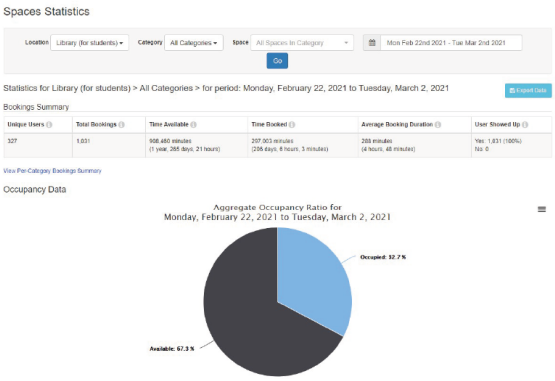
Project rooms and Study places with/without desktop

User information

Currently by COVID-19 a limited group of students can use it by reading in a specific group of "vulnerable students".

A student makes their own reservation and can cancel or confirm it. Upon arrival of this place, a QR code needs to be scanned. If this QR code is not scanned after 30 minutes, the reservation expires and this place can be reserved again.

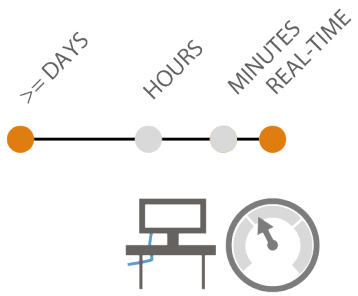




Management information

The management can request an overview of the occupancy per location, per moment, and the popular places. In addition, the percentage of reservations that expire due to cancellation or no-show can be determined.

Actuality of the information

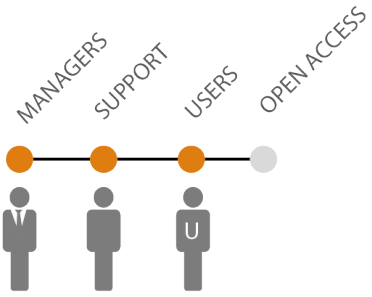


De displayed information on the webpage and in the dashboard is (near) real-time.



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

Access levels



Users (students) who can book project rooms or studyplaces.

Service desk to answer questions and retrieve reservations and surviellants to check reservations.

Managers for configuring the system and they can retrieve overviews of data from LibCal.

Benefits

LibCal provides insight who is in the buildings and it can be used for any source and contact research. This system also allowed a limited number of students to use study places during COVID-19.

Side notes

It was found that the tool can be implemented with little effort and cost. However, it is an existing tool, which can mean that customization is difficult. The tool does what it is supposed to do, but could have a bit more appeal.

UT

Twente University

Crowd control

phase
Implementation

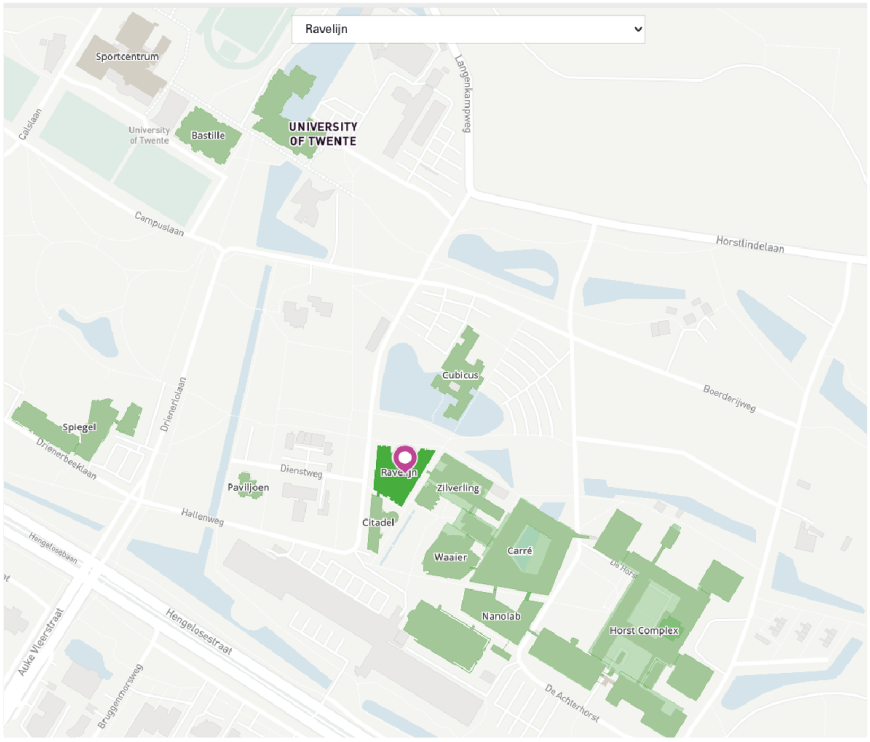
scale
All buildings

duration
Mrt. 2020
- present



Project description

Because of the COVID-19 pandemic in 2020, this pre-conceived dashboard was developed and deployed as an idea. As for monitoring crowds in buildings, we use an application written based on Mazemap.

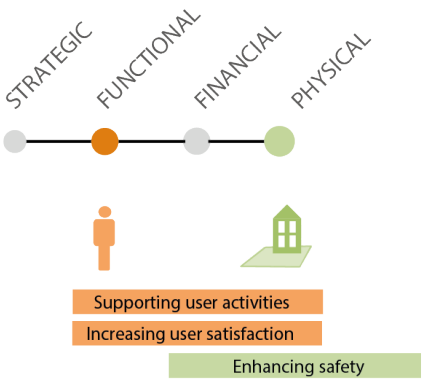


Foreseen developments

There is a wish to analyze the peaks of usage in the past. With this analysis the university can draw conclusions as to what the usage of buildings is during the day and where/when peaks in usage occur.

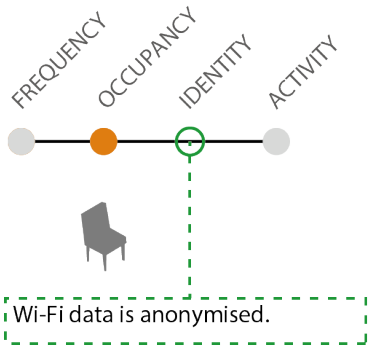
Profile

Why: Objective



The objective of this smart tool is to support users, and indirectly this will also improve safety in the COVID-19 situation.

What: Measurement



Occupancy is measured by monitoring and interpreting anonymized local WIFI connection statistics and projecting this data toward estimates of occupancy by location. This means that it does not measure at the individual level and does not give you a guarantee of the actual rate.

How: Measurement method



WiFi records the number of users connected to the network by monitoring and interpreting anonymized local WiFi connection statistics and projecting these data toward estimates of frequency by location.

UT

Twente University

Crowd control

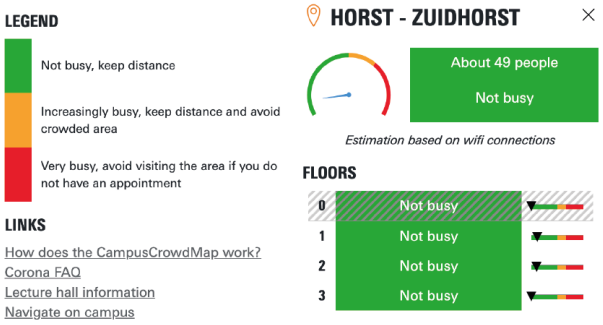
functionalities
Crowd control

space types
Building & floor level



User information

An open access website provides an estimate of the number of users currently in the building and on the floors. The different colors give an indication that can be interpreted as a recommendation, or an advice. This can be viewed by building and floor.

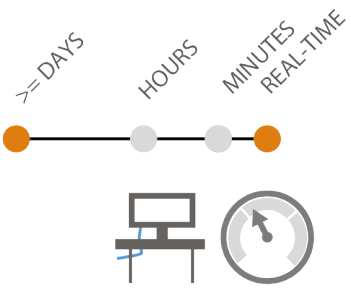




Management information

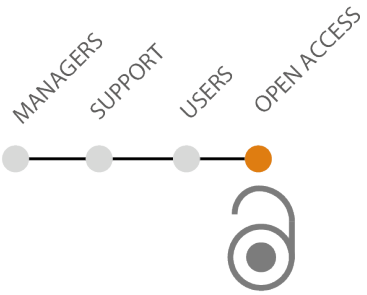
The management information is the same as the user information. It can be used to improve decision making on campus. As an example, one floor looked busy on the dashboard but this was misleading as that floor was actually used as a corridor. This could then be adjusted in terms of walking route.

Actuality of the information



Near real-time, dashboard updates the information every 6 minutes.

Access levels



Everyone can access the webpage.



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

http://apps.utwente. nl/campuscrowdmap

Benefits

to be filled in...

Side notes

to be filled in...

UT

Twente University

Resource Booker

phase
Implementation

scale
All buildings,
150-160 spaces

duration
Jan. 2020
- present



Project description

Two years ago a new teaching method (Twents ondewijsmodel) was implemented at the UT. In this method it turned out that about 500 project rooms were needed for the students. Twente was able to realize 110 reservable spaces. In order to give an indication of the availability, the Resource Booker was used to map out these spaces. In the two years that the system has been in use, resource booker has given an indication that there is a shortage of space during the periods at the end of the block. Currently, there are 150/160 spaces reservable (based on the measurements).

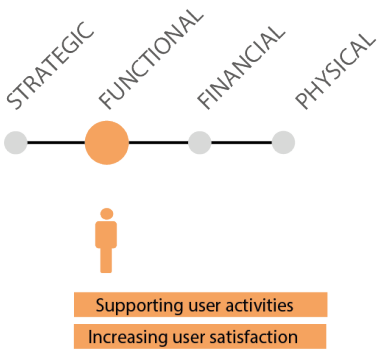


Foreseen developments

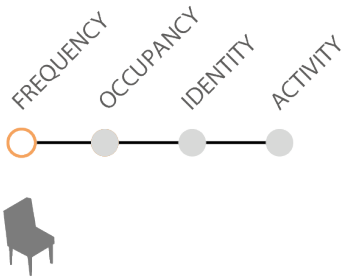
The foreseen developments are the possibility when lecture rooms are empty for 2-3 hours that a student can book this as a study place. Furthermore, updating room bookings based on sensors (Also aimed at reducing no-shows) for finding project rooms.

Profile

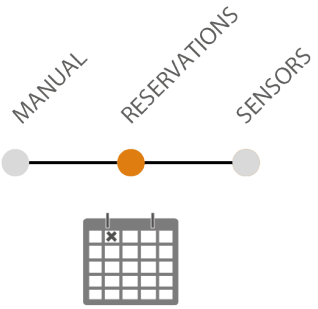
Why: Objective



What: Measurement



How: Measurement method



Equal distribution of places due to the limited space and this system contributes by limiting the number of times you can book that students have equal opportunities. The objective is that as much use as possible is made of it.

Based on reservations, it is possible to determine the frequency whether the space is in use or not. However, it is not possible to determine if this space is actually being used.

There is no measuring method yet.

UT Twente University Resource Booker

functionalities
Find a workplace & roombooking

space types
Project rooms



User information

The users (students) see a dashboard with an overview of the available project rooms that can be reserved.

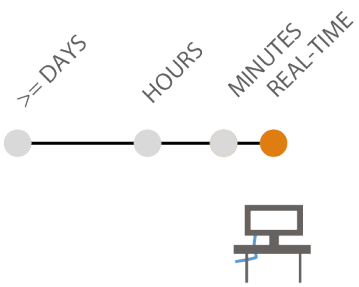




Management information

The management can request an overview of the reserved project spaces from Resource Booker which they can then use to form an impression of the booked numbers of the past period.

Actuality of the information

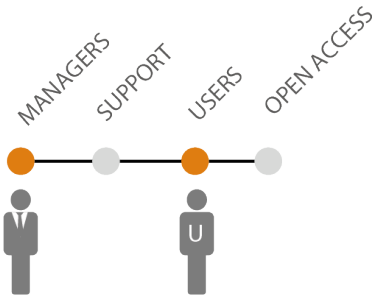


De displayed information on the webpage will be real-time.



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

Access levels



Users (students) who can book project rooms.

Managers can retrieve overviews of data from Resource Booker.

Benefits

This type of information is useful to be able to demonstrate that the project rooms are used very well, as substantiation in discussions with the board.
For example, when analyzing the overviews from resource booker, it became clear that there were few project spaces in certain parts of campus and that, as a result, engineering faculty students used other project spaces more than other studies. Thus, project spaces were added based on demand.

Side notes

Due to short usage not much experience yet to share, resource booker looks better than room booker.
This system works well, but it is not yet clear whether the room is being used or not (no insights of no-shows from the technology side).

VU

Vrije Universiteit - Bezettingstool

phase
Implementation

scale
4880m2

duration
March 2020
- present

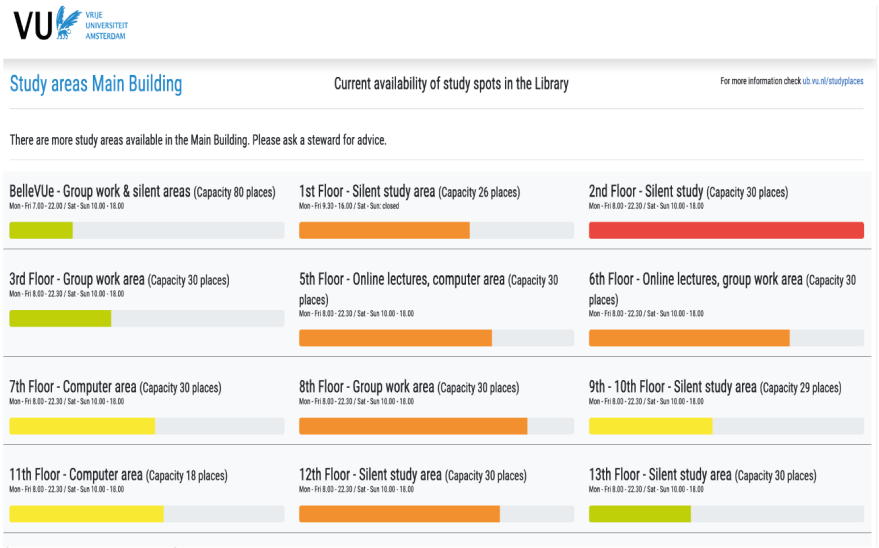


Project description

The reason for the implementation was the desire of students to be able to find (free) study places more easily. Because of the COVID-19 pandemic in 2020, the University Library offers study places on several floors in the Main Building for students who are unable to work at home due to circumstances. In these rooms it is able to study in silence, work on the computer or take an online lecture. As for monitoring crowds in buildings, we use an open source dashboard where the number of seats is limited.

Foreseen developments

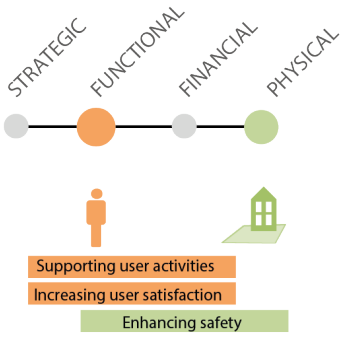
As it seems now, the system will remain in use as it is but we will focus on the Building Intelligence. What is still an improvement is using the data from the tool namely analyzing what are and are not the popular spots.



https://vu-amsterdam.im-motion.net/

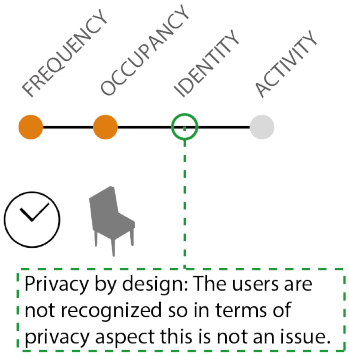
Profile

Why: Objectives



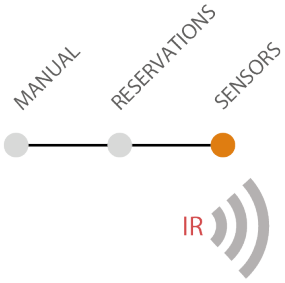
There is primarily a functional objective: to facilitate visits to the studyplace and increase user satisfaction. Management information is not yet used optimally but could be used by anticipating peak and off-peak hours or by better distributing visitors through the building.

What: Measurement



Measurement is done by monitoring and interpreting anonymized infrared data and projecting this data toward estimates of occupancy by location. This means that there is no measurement at the individual level but on space level, and you are not guaranteed actual occupancy rates.

How: Measurement method



A door passage is registered by interruption of an infrared beam. This is transmitted to a router via a radio signal. A server then calculates how many people are in the room.

VU

Vrije Universiteit - Bezettingstool

functionalities

Monitoring space use, crowd monitoring

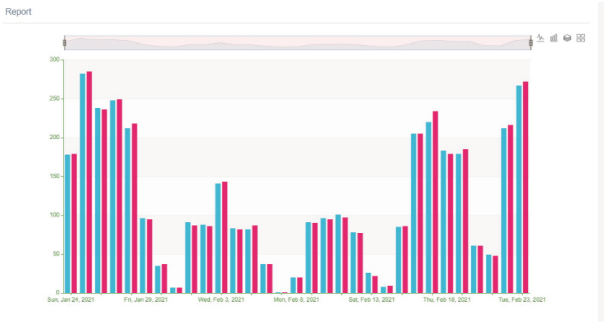
space types

Study places



User information

The different colors in the bar give the user an indication that can be interpreted as a recommendation. For example, if an area is marked with red, this does not mean that it is forbidden to visit the location, but you are advised to leave the location if presence is not really necessary.



Management info passersby per day

Location info			
Name	Vrije Universiteit	Address	De Boelelaan 1105
Code	VU	Zip	1081 HV
Phone		Fax	
Comments	Added by the SensorServer		

Positions | Day report | Week report

Measurement positions

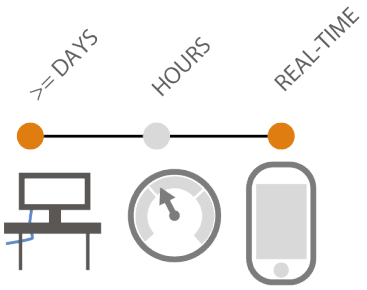
		Hour	Day	Week	Month	Year	Total
Position	9e Main	96	950	3721	17813	23159	783458
Position	1A 01l	0	0	0	0	0	277773
Position	1B gang	0	0	0	0	0	53619
Position	2e Main	55	529	2285	11268	27556	335278
Position	2e Gang	2	12	83	513	1018	23074
Position	13e Main	24	336	1468	5185	12223	101453
Position	3e Main	42	336	1303	5159	13453	139372
Position	5e Main	45	329	1482	7045	17829	135160
Position	5e Trap	0	5	21	105	153	1145
Position	6e Main	58	439	1695	6588	17578	182404
Position	6e Trap	0	1	7	49	109	1210
Position	7e Trap	0	5	28	52	103	3798
Position	7e Main	26	339	1449	4879	12287	116588
Position	8e Trap	0	1	14	37	62	1140
Position	8e Main	68	633	1987	8564	22307	233304
Position	12e Main	52	398	1543	8251	19574	144507
Position	14e Main	47	465	1712	6994	18036	120849
Position	11e Main	26	206	850	3126	7316	20593
Position	BelleVUe	46	246	1082	4385	10775	40427

Management info passersby by period

Management information

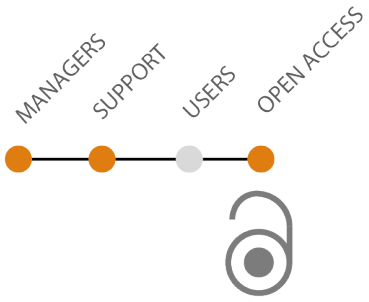
The management information is the same as the user information. In addition, they have the option of requesting a report showing the number of passers-by per room and period. This can be used to improve decision making on campus.

Actuality of the information



The information displayed in the app, dashboard, and webpage is near real-time.

Access levels



Users: It is open-access, insights are given on crowding by space.

Benefits

The advantages gained in a short time is that the tool is easy to apply, it is effective, relatively inexpensive, and it is out of development.



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



Managers and administrators have access to reports that can be requested showing the passers-by in different rooms for a period.

Side notes

The system works well but there is no expansion possibilities in terms of functions, it is sufficient for this purpose.

VU

Vrije Universiteit Building Intelligence

phase
Design brief

scale
3 stories

duration
2017-present



Project description

There is a university-wide focus on a tool that will provide BI. Within the university, the Library, Student Affairs and IT have this need. The aim is to achieve greater efficiency in the use of rooms, a lower no-show for education, and to be able to offer appropriate room sizes to lecturers.

A project plan has been written and last year this project was to be tendered but due to COVID-19, additional investments were needed for education so this tender has been postponed to 2021.
In 2017-2018 a pilot was done with Wally (LoneRooftop) for three floors. This was quite accurate only an expensive application for the library alone. Then we investigated at whether this is possible in a partnership with different services. This was further elaborated in the business case with a team around scheduling and efficiency in the use of spaces.

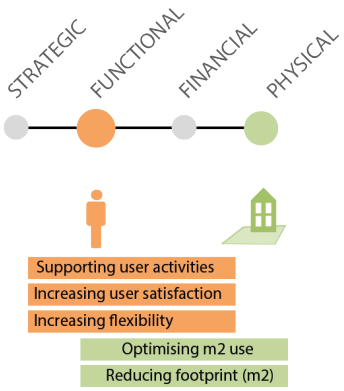


Foreseen developments

One ambition is that when the lecture rooms are not in use that students can use them as study areas and that this becomes transparent to students.
Further goals and use is still under development, for example students have indicated that they would like to know where fellow students are but it is not yet certain that this will be applied.

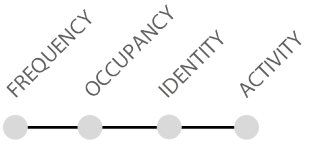
Profile

Why: Objectives



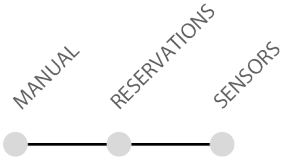
Functional is the first priority, but in the long term physical is also. By using the spaces as efficiently as possible, this means that in the future there may be less need to invest in the number of square meters.

What: Measurement



This is still unclear, probably frequency and occupancy. Privacy is still a barrier in terms of confidence in whether data can be properly safeguarded.

How: Measurement method



This is still unclear. We do want to use as little hardware as possible and rely as much as possible on existing data information points & systems. In addition, mobile networks should be used as much as possible.

RU

Radboud University Nijmegen - MazeMap/ Planon/ Swycs



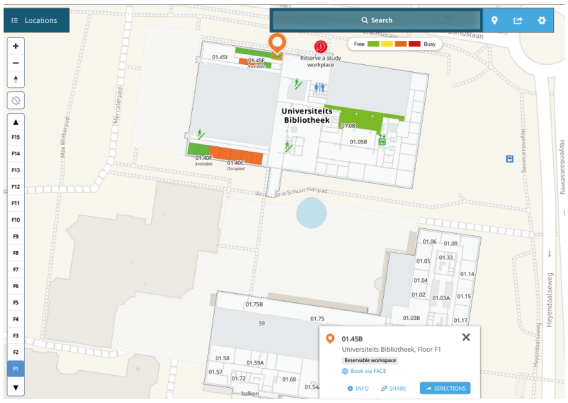
phase
Pilot

scale
1 building -
17.836 m2 GFA

duration
2019-present
Planon 2011 - present

Project description

Students from the student council continuously indicated that there was a shortage of study places. This was also demonstrated by a poor rating from the national student monitor. A survey showed that in particular, students were unable to find available places. After an exchange with several universities (Twente, Tilburg and Amsterdam) to brainstorm about this issue and two input sessions with assessors and students, information and needs were gathered. One of the outcomes was that users were mainly looking for a fixed location or around it, this could be made easily presentable on a floor plan. Then the criteria were devised as to what was important and useful. Students themselves proposed characterizations of study rooms (quiet, peaceful, informal, or bookable). One of the objectives was to use the basic data from Planon that was already in place and to keep this data up to date in this way. The goal of the pilot is to test especially the robustness and scalability.

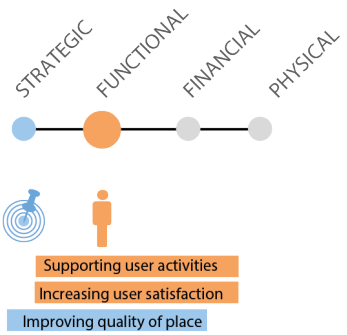


Foreseen developments

The ambition is to process all the buildings on the campus into MazeMaps so that the study places and facilities are mapped across the entire campus. In addition, a pilot is being conducted in the Berchmanianum building to reserve workplaces for the needs of certain employees (Hybrid working). Depending on the result, this will also be implemented in all buildings. Finally, the goal is to offer different information to three different target groups. Three types of MazeMaps for (in addition to some small groups): employees, guests, and students.

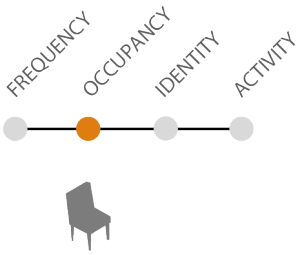
Profile

Why: Objectives



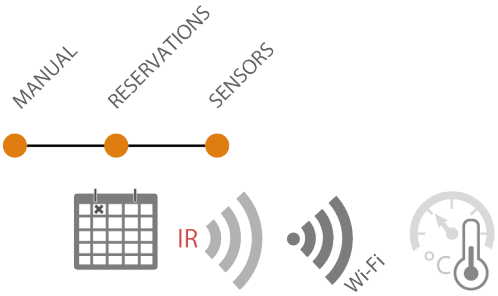
The purpose is primarily functional to address responses from students that they could not find study spaces.

What: Measurement



In the group rooms, occupancy is measured based on movement, and heat (so that movements behind glass walls can be traced). In the larger halls, we use infrared sensors at the doors to measure the occupancy.

How: Measurement method



Now in the COVID-19 period: Coaches (students) check every half hour to see if studyplaces are empty that were reserved in order to find out the no-shows, and to allow these spots to be reserved again.

Reservations go through Planon, Webroom booking, and Face, and this information is linked back to Mazemaps.

In the background, the number of Wi-Fi connections are used for crowd management.

The infrared sensors are used at the doors of large halls.

Sensors in the ceiling measures the heat.

RU

Radboud University Nijmegen - MazeMap/ Planon/ Swycs



functionalities

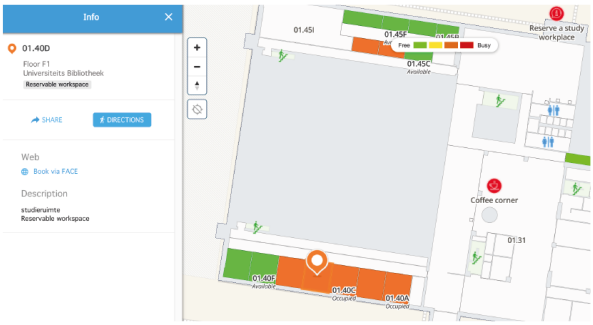
Reservation of work- and study places, find a studyplace, crowd control, and wayfinding

space types

Whole building

User information

Users can discover space and building information in MazeMaps. In addition, an indication is given whether a space is still reservable or has already been reserved. An indication of how busy it is in the spaces is also given using colors based on incoming and outgoing users in those spaces.

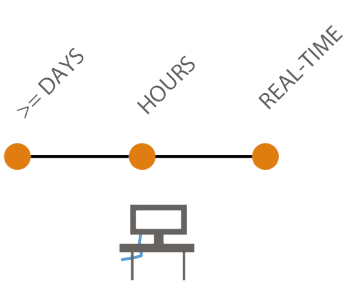




Management information

Management has insights through Planon on how many people visited the library per rooms. They can request reports of this, with which analyses can be carried out. In addition, management can obtain data from Planon on the amount of Wi-Fi connections. This is used for Crowd management such as scaling up and down towards the 'back to campus'. A distinction is made here between employees, students and externals

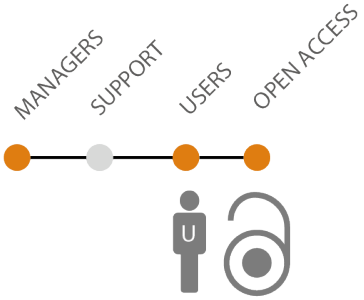
Actuality of the information



The occupancy is displayed near real time.

Space , building, and basic information is updated once a day.

Access levels



Floor plans, space, building information, and availability is visible for everybody; reservations can only be made by students.



The reporting function shows data until as far back as possible.



Reports and crowd management information are available for management.

Benefits

-

Side notes

We deliberately chose sensors at the room level (instead of per workplace) because otherwise you have to provide, and keep track of the location of each sensor/workplace in the floor plan, which is enormously labor-intensive.

VU

Vrije Universiteit Building Intelligence

functionalities

Find a study place

space types

Whole campus



User information

To be filled in.





Management information

To be filled in.

Actuality of the information

>= DAYS | HOURS | REAL-TIME

Access levels

MANAGERS | SUPPORT | USERS | OPEN ACCESS

Benefits

Too early to express an opinion on this.

Side notes

To be filled in.

To be filled in.

There is a preference for open access to share as much as possible but this is not yet certain.

UU

Universiteit Utrecht - LibCal

phase
Implementation

scale
2 libraries
(285 studyplaces)

duration
jan 2021



Project description

Through COVID-19, the need arose from students to reserve study spots. The university has to deal with reduced capacity, and students would (still) like to obtain a spot in the library. Also. through the Storescan sensors in the buildings we want to give students an indication of how busy buildings are through the reservation system.

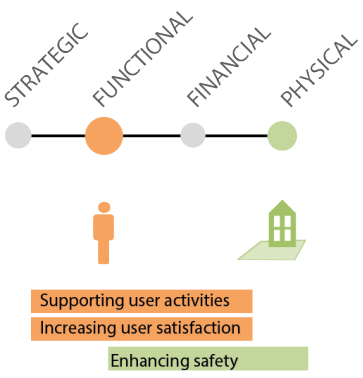


Foreseen developments

This is going to be used for a longer term, even after COVID-19. Ambition is to use this system more broadly, such as by expanding it to study places in other buildings.

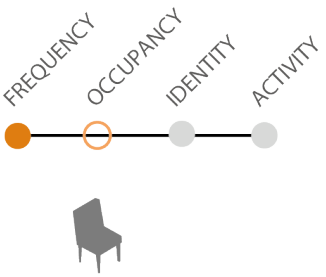
Profile

Why: Objectives



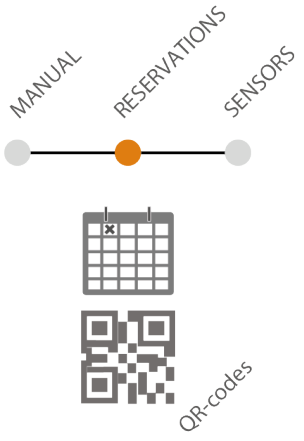
To allow students to study in the library with a reduced number of seats for safety reasons.

What: Measurement



Originally it is occupancy, but because of COVID-19 we look at reservations of individual workplaces, thus it is now temporary frequency.

How: Measurement method



A booking must be confirmed by scanning the QR code on the table (and at the door in case of meeting room).

UU

Universiteit Utrecht - LibCal

functionalities

Reservation of study places

space types

Study places



User information

A student makes their own reservation and can cancel or confirm it. Upon arrival of this place, a QR code needs to be scanned. If the QR code is not scanned then the reservation expires and this place can be reserved again.

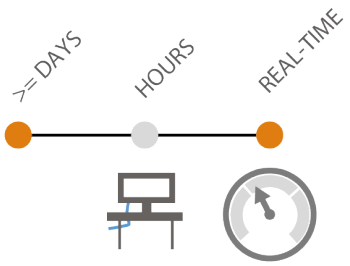




Management information

The management can request an overview of the occupancy per study place, per moment, and the popular places. In addition, the percentage of reservations that expire due to cancellation or no-show can be determined.

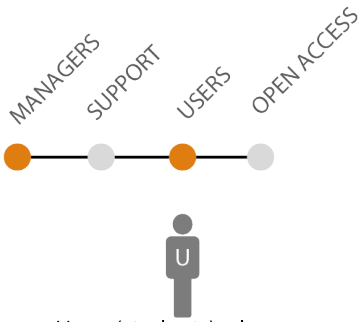
Actuality of the information



The information on the website and dashboard for the available places will be updated in near real time.

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

Access levels



Users (students) who can book studyplaces.

Managers for configuring the system and they can retrieve overviews of data from LibCal.

Benefits

Little experience yet as it has only recently been delivered operationally.

Side notes

-

UU

Universiteit Utrecht - StoreScan



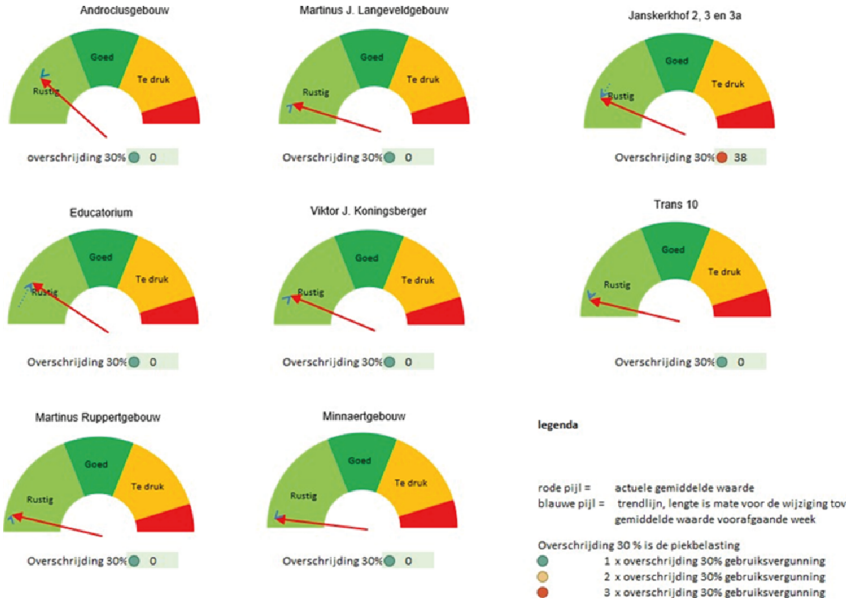
phase
Implementation

scale
7 buildings

duration
april 2020
- present

Project description

Because of COVID-19 the demand arose when we returned (temporarily and for the future) to our buildings to be aware of the pressures in this and to be able to manage this. At one time 100% back to the faculties that is unlikely to happen but possibly with a 40-60-80% occupancy.



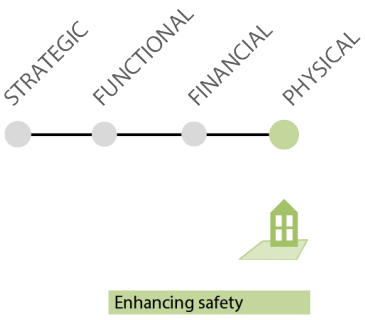
The dashboard that is reported at the College Board level.

Foreseen developments

-

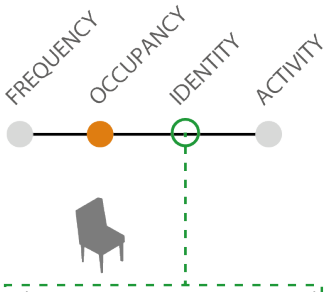
Profile

Why: Objectives



The goal is purely for the concern of the health of our users to allow a safe "back to campus". In addition to all the manual measures in the buildings (1.5 m)

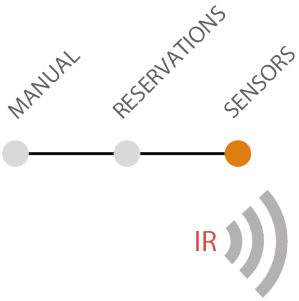
What: Measurement



These users are not recognized so, this is covered in terms of privacy issues.

By measuring how many users are present in the building (incoming and outgoing users) the occupancy can be determined.

How: Measurement method



ScoreScan sensors at the building entrances and exits to monitor how many people are entering and exiting the building.

UU

Universiteit Utrecht - StoreScan



functionalities

Monitoring space use, crowd monitoring

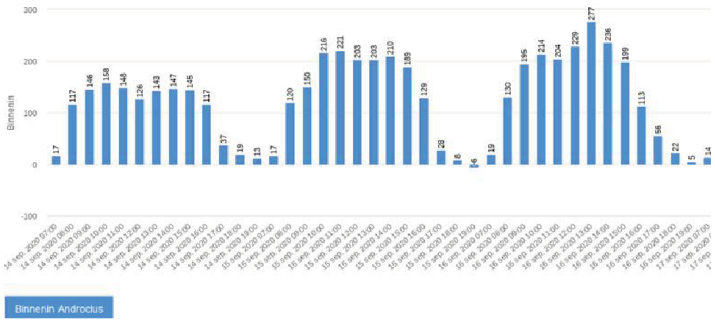
space types

Whole building

User information

Not applicable for users.

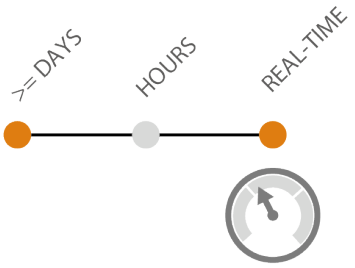




Management information

In the area of management information, results about the crowds in the buildings can be retrieved in a portal (how many people are/were in the building). This way it is also possible to figure out which days are popular. The data is displayed in a dashboard that is reported at the College Board level. From this information, reports can be generated with data per building on hourly occupancy rates.

Actuality of the information

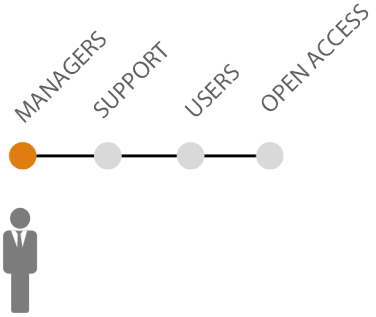


The informationin the dashboard from the StoreScan sensors is near real time.



The data used in the report goes back as far as possible on an hourly basis.

Access levels



Managers have access to the reports and dashboard.

Benefits

Advantage of having a greater control over the amount of people in the building.

Side notes

Very satisfied with this tool and we feel that the quality of the measurements is very satisfactory. It remains to be seen how the accuracy will be when more people walk in and out of the building at the same time.

UU

Universiteit Utrecht - TwiQel

phase
Pilot

scale
1 building,
20 lecture rooms

duration
2019 - present



Project description

The pilot to Twiqel focuses on a concept of teaching logistics that supports interactive, project-based learning. Based on student demand, an instructor can choose an available appropriate space when needed - rather than planning a series of lectures in advance. This allows for more efficient use of lecture rooms and work group spaces. To facilitate this, real-time understanding of space usage is needed.

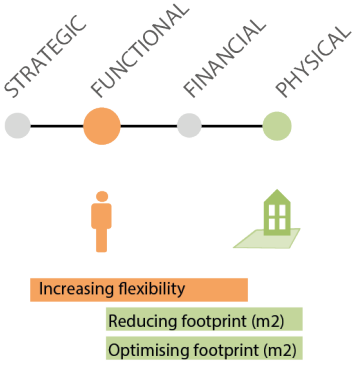


Foreseen developments

This pilot will run for another 9 to 10 months but there are already thoughts of implementing this UU wide. The goal is to use the rooms more efficiently by adaptive scheduling.

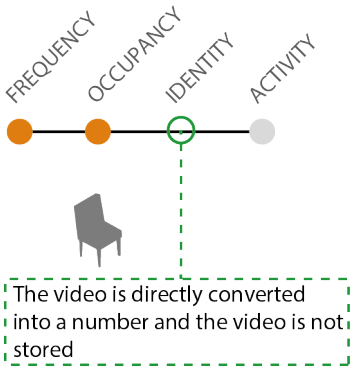
Profile

Why: Objectives



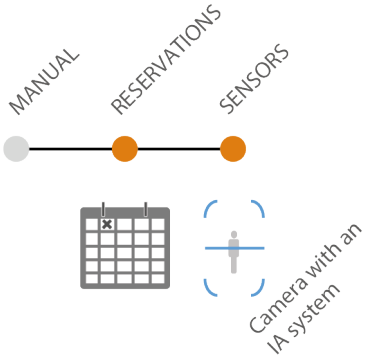
The goal is mainly to be able to efficiently schedule (optimising footprint) and reduce building footprint in the ten-year housing plan.

What: Measurement



Based on the sensors, you determine what the frequency and occupancy and you relate that back to the scheduling system. In this way it is possible to show the difference between what has been planned (expectation) and what the reality is.

How: Measurement method



Tests were conducted with counters at different doors, infrared sensors, passive infrared in the rooms and small cameras with an AI system. The cameras created the most reliable information and thus remain in use. In addition, teachers use the reservation system for lectures.

UU

Universiteit Utrecht - TwiQel



functionalities

Monitoring space use, adaptive scheduling

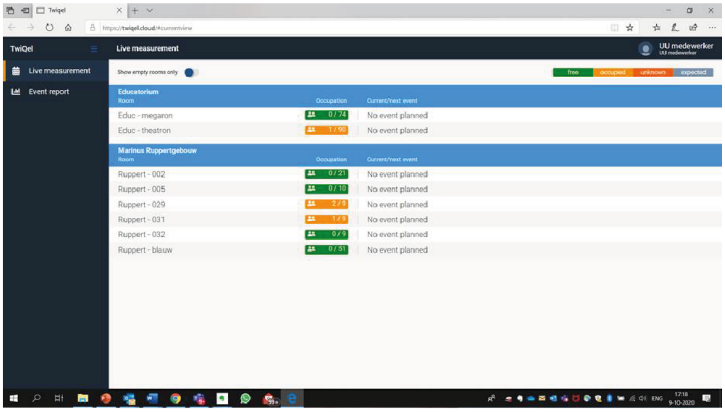
space types

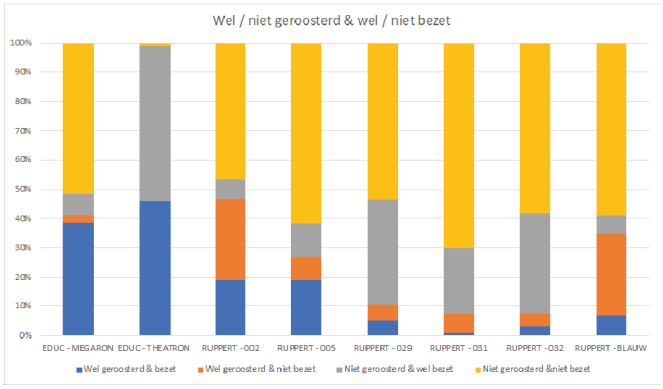
Lecture halls, project rooms

variety of workgroup spaces from 15 users to a lecture room of 400 places.

User information

In this case, the users are the schedulers and teachers, they can book lecture rooms, and workgroup spaces in the dashboard. This dashboard is shown on the right.

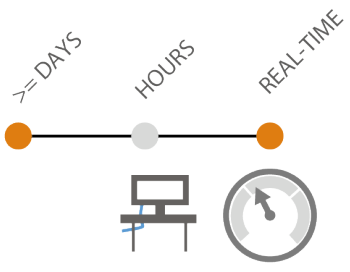




Management information

Timetablers (or schedulers) use the reports and data to start the conversation with teachers. This is focused on efficient timetabling.
Information can be retrieved such as how many rooms were scheduled but empty or not scheduled but users were detected.

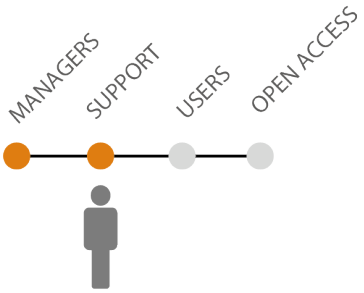
Actuality of the information



The information of occupancy and frequency is updated in near real time (the data is updated every minute).

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

Access levels



Schedulers and teachers who can book lecture rooms and workgroup spaces

Managers can retrieve overviews of data from TwiQel.

Benefits

The choice for a start-up was deliberate because we were looking for a party that could keep up with the growing technology and especially think along with the UU. This meant that a more tailor-made product could be created compared to Lone Rooftop. On the other hand, the looks of the dashboard are less than Lone Rooftop but the quality of the measurements is better.

Side notes

The system still has to learn to distinguish between a bag and a person but in the pilot this system worked well and a high degree of accuracy was achieved. In addition to a test, not much has been able to be measured in practice because of the COVID-19 lockdown.
Furthermore, much attention should be paid to explaining the privacy aspects of the camera system to the users. An external privacy impact assessment has been carried out to identify the risks. From this, a processing agreement has been signed with the supplier to ensure that the measures are properly aligned.

5.4 Analyzing the results

In this chapter, cross-case analysis will be applied to analyze the results of the new and existing cases from the Dutch universities interviewed. These analyses will clarify the following aspects; the timeline, foreseen developments, objectives, space use measurements, measurement methods, actuality of information, and access levels. In this way, insights are created from the obtained data in the cases.

As indicated earlier in Based on the interviews, it is revealed that universities have discontinued or further developed the tools from the previous study, or are active with new SCTs. The table below shows an overview of which tools from previous research were examined as cases included in this research. In addition, other SCTs were not included in the study because there was not enough information available or not enough time in the interview. After the table, the templates that are still in use but have been further developed will be shown first. Most of the information in these templates was inventoried during the SCT 2.0 research. During the interviews, it became apparent that adjustments had been made. Such adjustments are identified in the template in *italic*. In addition, it shows the templates that have been developed since new SCTs were initiated relative to previous research.
Table 5-2, most of these cases are included in the templates, except for future research and the Lone Rooftop case at the RU. In addition, there may be several more design briefs or studies in progress since some cases focused on the library rather than campus-wide.

Timeline

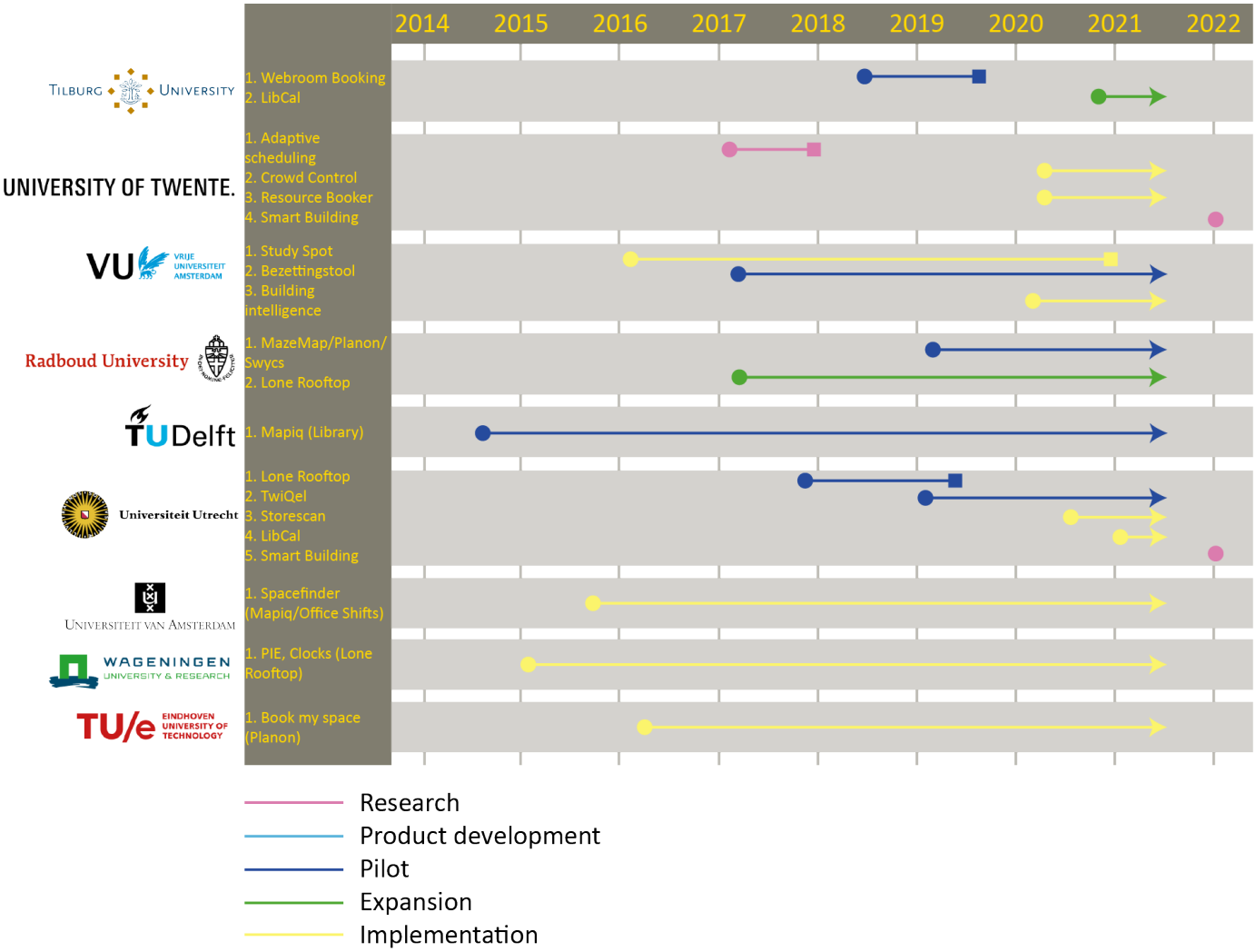


Figure 5-11: Timeline of the SCTs at Dutch universities (updated from Valks et al., 2018)

The timeline shows twenty cases collected from nine Dutch universities. Of these cases, four have discontinued, nine new cases arose, four SCTs are still in use, and two cases of which information can be given at a later stage. Taking the figure into consideration, it is notable that a large proportion of new SCTs (six out of nine) -which are still functioning- were initiated around 2020-2021. But it can also be noted that these cases reached the implementation phase in a short time. From the initial brainstorming session, it appeared that through COVID-19 there was an increased support for SCTs. This seems to be confirmed by the timeline. Besides, it is noteworthy that of the four discontinued cases, three are in different phases.

Foreseen developments

For the nine Dutch universities, a description will be provided of the foreseen developments of the expansion of existing and new cases. First, the explanation will be given for specific cases, and then the foreseen developments will be divided among space types.

To start, several universities intend to expand their (intended) solution further across campus: the RU, TUD, and UU mention this. Besides, the FM of the UvA aspires to equip bicycle parking spaces with

sensors in order to indicate free parking places. Furthermore, Since COVID-19, more universities have started measuring the number of users in the buildings. The VU and UT are interested in analyzing such data to identify popular locations and times. Also, the RU has the ambition to provide different information in MazeMap to three different target groups (employees, guests, and students). Besides, the RU intends to create a campus-wide structure (in collaboration with campus development) that should further develop a smart campus. According to the TUE, since the progression on the one-way link between Planon, the further goal is to enable a two-way link. This will be further developed after TimeEdit is implemented as a scheduling system. At the WU, pilots are carried out with cameras, which may be replaced with infrared sensors since cameras are expensive and there is solely a need to measure frequency in small spaces.

Study places
The UvA, TuD, and UT desire to increase the utilization of sensors (measuring frequency and occupancy) in order to locate available study places, or rooms, and reduce no-shows. Also, the VU and UT are still planning to allow lecture halls that are not scheduled to be applied as study areas, and this should be transparent to students.

Lecture rooms
The UvT aspires to measure frequency and occupancy at the lecture halls to enable adaptive scheduling overtime. The UT still recognizes the potential of the adaptive scheduling if a developer is able to facilitate this with the scheduling system in mind.

Office places
Also, the RU and UvA both have ambitions to provide the possibility to reserve workstations for employees, with RU already running a pilot in this regard.

Meeting rooms
The UvA has the ambition to carry out pilots with sensors (measuring frequency and occupancy) for locating available meeting rooms.

For the following cross-case analysis, figures have been created to analyze different aspects from the templates. In order to make comparisons possible as an indication based on numbers, numbers and percentages are shown in the light blue rows of the results from the SCT 2.0 and this research. According to the left column, the colors below indicate whether this is a new SCT or an existing SCT that is still in use.

New SCT cases
Existing SCT cases and still in use

In the figures, icons are displayed in the rows in which for existing cases a distinction is made in the opacity of these icons. This is shown in full opacity for modified parts and reduced opacity for existing parts. With regard to the textual parts in the figures, modifications are indicated in *italic* as it does in the existing templates. First, the objectives are outlined.

Objectives

During the interviews, the objectives for which the SCT should contribute were requested again for new and existing cases. For this purpose, the objectives from the framework of Den Heijer et al. are applied (Chapter 3). In addition, enhancing safety is added as an additional objective.

First, a description will be presented to reflect the type and associated objectives inventoried during the SCT 2.0 study. Then, following Figure 5-12, it can be analyzed whether there are similarities or differences with corresponding new and existing SCTs. The objectives ‘reduce footprint’ and ‘enhancing safety; are marked with a star to indicate that these objectives did not occur in the SCT 2.0 study and hence there is a larger difference between the results from the SCT 2.0 and this research.

The SCT 2.0 research shows that there are four types of SCTs (which are still in use) inventoried at Dutch universities. First, the real-time monitoring of teaching space (1) where the objectives focus on physical and financial goals. Then three types of SCTs for finding a study place (2), for studying in unscheduled teaching spaces (3), and to find a group room (room booking + sensors) (4), where for all three types the emphasis is on supporting users (functional) and strategic objectives.

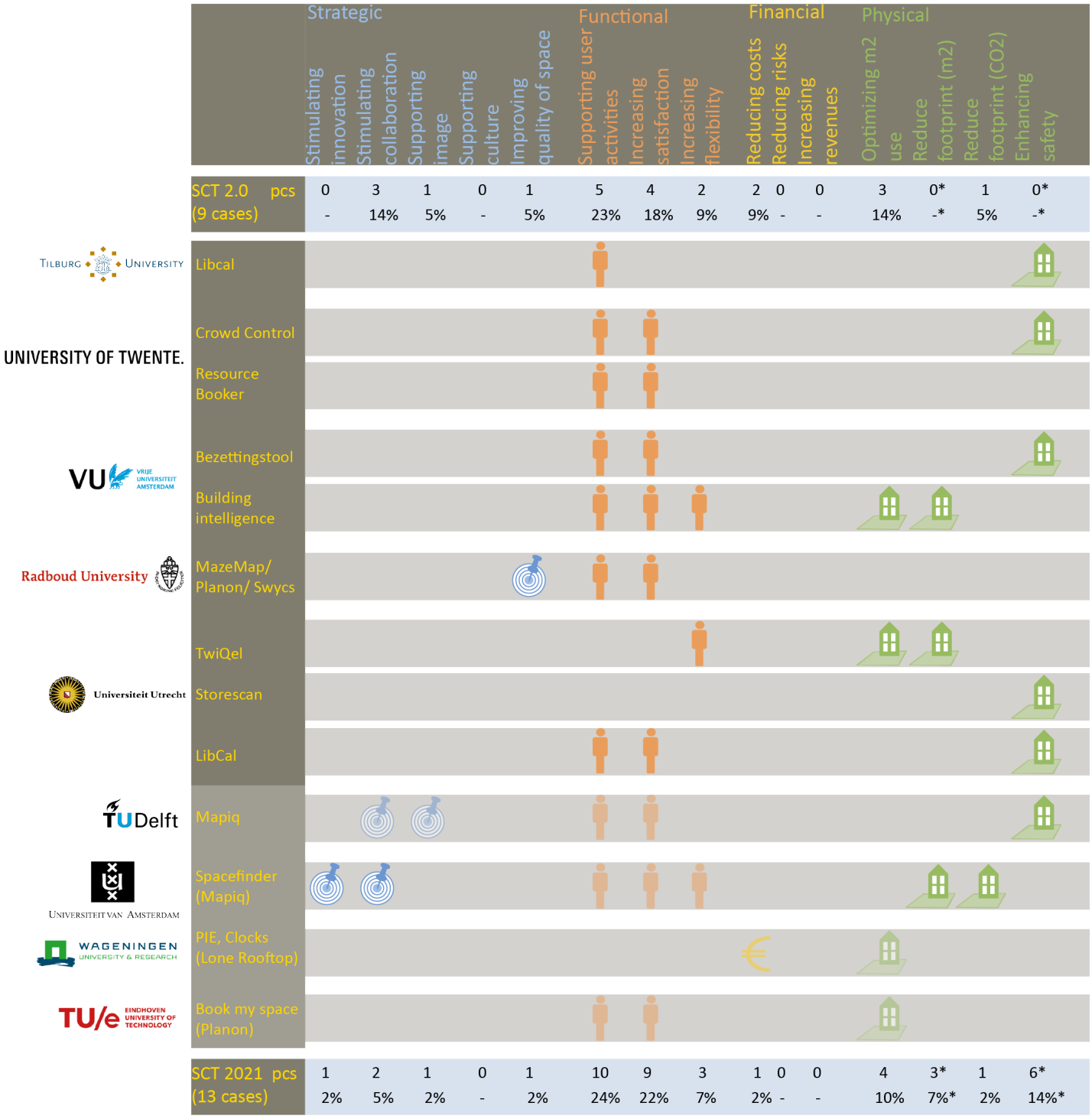


Figure 5-12: New and existing cases at the nine Dutch Universities with the different objectives per case (adapted from Valks et al., 2018)

From the figure, it can be concluded that it is remarkable that few strategic objectives, and none of the financial objectives, have been defined and that enhancing safety is considered an objective by COVID-19 in six out of thirteen cases.

The interviews reveal that there are three types of SCTs inventoried at the nine Dutch universities. First, a corresponding SCT compared to the SCT 2.0 research is the real-time monitoring of teaching space. The UU and WU aim for similar goals, namely the physical goals of optimizing or reducing the footprint (m2). Besides, the financial goal of the WU which is not mentioned at the WU, which is striking. The reduction of space often goes hand in hand with the reduction of costs.

The next type is a SCT for reservations that seven universities utilize. This tool is designed to support the user and has similar objectives as the type of SCTs 2 to 4 from the SCT 2.0 study (as described earlier). It is noteworthy that some of these types of SCT in the SCT 2.0 study also have strategic objectives attached to them. This is not the case with the comparable cases in this study. This may be explained by the fact that those SCTs were implemented in a short period to facilitate the back-to-campus due to the COVID-19 virus. Possibly strategic objectives may become more important later. In addition, there is a difference compared to the SCT 2.0 research that enhancing safety was not mentioned before. It can be concluded that during the COVID-19 crisis, to protect the users, the number of users on campus can be regulated with this type of SCT.

The same applies to the last type of SCT used for crowd monitoring which focuses on the user, such as enhancing safety and functional objectives.

Figure 5-12 indicates that 14% of the total objectives serve to enhance safety and that several inventoried SCTs serve this purpose. In addition, despite the different types of SCTs, the emphasis is still on functional objectives, taking into account the percentages of the SCT 2.0 and this study.

Space use measurements

For space use measurements, comparable levels were applied as in the SCT 2.0 research again. The figure below shows that relative to the SCT 2.0 study, there is still an emphasis on frequency and occupancy, despite the different SCT types.

	Case	Privacy	Frequency	Occupancy	Identity	Activity
	SCT 2.0 pcs (9 cases)		9 53%	8 47%	0 -	0 -
Tilburg University	Libcal	This information cannot be viewed by other students and is not published anywhere. It can only be seen by the administrators of the tool.	✓	✓		
University of Twente.	Crowd Control	Wi-Fi data is anonymised.		✓		
	Resource Booker	Not applicable	✓			
VU Vrije Universiteit Amsterdam	Bezettingstool	Privacy by design: The users are not recognized so in terms of privacy aspect this is not an issue.	✓	✓		
	Building intelligence	Privacy is still a barrier in terms of confidence in whether data can be properly safeguarded.				
Radboud University	MazeMap/ Planon/ Swycs	-		✓		
Universiteit Utrecht	TwiQel	To be filled in	✓	✓		
	Storescan	These users are not recognized so, this is covered in terms of privacy issues.		✓		
	LibCal	To be filled in	✓	✓		
TU Delft	Mapiq	Not applicable	✓	✓		
Universiteit van Amsterdam	Spacefinder (Mapiq)	*Privacy by design: Data is anonymized before it is used*	✓	✓		
Wageningen University & Research	PIE, Clocks (Lone Rooftop)	The IP addresses are anonymised differently each day. Also, this is done before the data leaves the university's network.	✓	✓		
TU/e Eindhoven University of Technology	Book my space (Planon)	Not applicable	✓			
	SCT 2021 pcs (13 cases)		9 47%	10 53%	0 -	0 -

Figure 5-13: New and existing cases at the nine Dutch Universities showing the various uses of the measurement space. Privacy issues are presented when applicable (adapted from Valks et al., 2018)

For the crowd monitoring type of SCT, it appears that there is a stronger focus on occupancy since this involves monitoring the number of users present in the buildings. Despite the different types of SCTs, the five universities that apply this type of SCT may have shifted the emphasis in terms of percentages to occupancy instead of frequency. In addition, since COVID-19 project spaces are temporarily used as individual study places. This results in two of the five cases; the frequency is measured (this is now automatically the occupancy).

Regarding the measurement level for the type of SCT for real-time monitoring of teaching space, there is a new case from the UU and an existing case of the WU which measures frequency and occupancy, which is similar to the SCT 2.0 research.

According to the privacy aspects, the SCT 2.0 research examined the ways in which data was anonymized across cases. An interview revealed one case that utilized Wi-Fi switched to a different measurement method due to privacy reasons. In contrast, the UT indicates that the Wi-Fi data is anonymized, and that they do not experience issues with privacy.

Measurement methods

Compared to SCT 2.0, it appears that different measurement methods are still applied in the new cases. In the figure on the next page, each university and case are described by name, explanation of measurement method, measurement method, and lastly -where possible- what the specific application is.

Case	Measurement method	Manual	Reservations	Sensors	Sensor application
Libcal	A booking must be confirmed by scanning the QR code on the table (and at the door in case of meeting room).		Self-booking tool; Check in and out with QR-codes		
Crowd Control	WiFi records the number of users connected to the network by monitoring and interpreting anonymized local WiFi connection statistics. Projecting this data is done toward estimates of occupancy by location.			Wi-Fi	active connections
Resource Booker	There is no measuring method yet.		Self-booking tool		
Bezettingstool	A door passage is registered by interruption of an infrared beam. This is transmitted to a router via a radio signal. A server then calculates how many people are in the room.			Infrared	At the doors
Building intelligence	This is still unclear. We do want to use as little hardware as possible and rely as much as possible on existing data information points & systems. In addition, mobile networks should be used as much as possible.				
MazeMap/ Planon/ Swycs	Now in the COVID-19 period: Coaches (students) check every half hour to see if studyplaces are empty that were reserved in order to find out the no-shows, and to allow these spots to be reserved again. Reservations go through Planon, Webroom Booking, and Face, and this information is linked back to Mazemaps. In the background, the number of Wi-Fi connections are used for crowd management. The infrared sensors are used at the doors of large halls. Sensors in the ceiling measures the heat.		Self-booking tool	Infrared; Wi-Fi	At the doors; active connections
TwiQel	Tests were conducted with counters at different doors, infrared sensors, passive infrared in the rooms and small cameras with an AI system. The cameras created the most reliable information and thus remain in use. In addition, teachers use the reservation system for lectures.		Self-booking tool	Camera with an IA system	
Storescan	ScoreScan sensors at the building entrances and exits to monitor how many people are entering and exiting the building.			Infrared	At the doors
LibCal	A booking must be confirmed by scanning the QR code on the table (and at the door in case of meeting room).		Self-booking tool; Check in and out with QR-codes		
Mapiq	The data source used is reservations, from the reservation system of Mapiq. Infrared sensors have been added on 100 individual study places; they measure activity on that study place. 10 infrared sensors have been added to meeting rooms; they measure activity in the room.		Self-booking tool	Infrared	Desk (PIR); At the doors
Spacefinder (Mapiq)	Booking data is used from Mapiq and from Syllabus to show availability. Desktop PC usage is logged in order to show occupancy per workplace. *In addition, Infrared sensors are applied at projectrooms (frequency and occupancy) and Wi-Fi data for crowd control* (occupancy)		Self-booking tool; Desktop PCs	Infrared; Wi-Fi	
PIE, Clocks (Lone Rooftop)	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.		Self-booking tool	Wi-Fi; Camera	
Book my space (Planon)	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; Check in and out with QR-codes	Infrared	*At the moment sensors are not used in the system (due to COVID-19)*

Figure 5-14: New and existing cases at the nine Dutch Universities with the different measurement methods applied and description (adapted from Valks et al., 2018)

Table 5-3: Comparison of numbers and percentages for the measurement methods of existing and new SCTs between the SCT 2.0 and this research.

Reservations				
Self-booking tool	1	11%	6	55%
Schedule data	5	56%	0	0%
Self booking tool + schedule data	2	22%	2	18%
Self booking tool + QR-code	1	11%	3	27%
Total:	9	100%	11	100%
Sensors				
Wi-Fi	4	50%	4	31%
Infrared	2	25%	5	38%
PC login	2	25%	1	8%
CO2	0	0%	1	8%
Camera	0	0%	2	15%
Total:	8	100%	13	100%

From the figure, it can be concluded that compared to the SCT 2.0 research, there is a low use of schedule data. This is also evident in Table 5-3. In the SCT 2.0 research this was often the case with the type of SCT for real-time monitoring of teaching space (1). In this research, there are two cases at the UU and WU where it is inventoried that they utilize a self-booking tool for the teaching spaces instead of schedule data.

For certain types of SCTs from the SCT 2.0 research such as finding study places (available PCs) (2), project rooms (4) modifications have taken place. More specific, in the SCT 2.0 study the availability of project rooms was based on reservations in two of the four cases. On the other hand, the TUD and TUE utilized infrared sensors to monitor the use of the project rooms. In this research it appears that the UvA and RU also apply this sensor method for project rooms.
It is also noticeable that the method for reservation measurement has increased through the different reservation tools for individual study places. The focus on individual study spaces arose from the COVID-19 situation to enable the back-to-campus. Only the TUD applies an infrared sensor for a number of individual places. The other cases do not yet measure the use of individual study places or partly measure this by the utilization of QR-codes. This results in a less reliable no-show and occupancy data. In chapter 5.5, the approach to reservations will be discussed further.

With respect to the last type of SCT revealed in this study, which is different from the SCT 2.0 research, it appeared that some cases do not only rely on data from reservation systems. These are the cases that keep track of how many users are present in the buildings to analyze if it is not too crowded. For this, three out of five times Wi-Fi is applied, and the other two apply infrared as measurement method.

Wi-Fi and Infrared are still the most common sensors. New sensors that were not yet used in the SCT 2.0 research is the use of a camera and temperature sensor. The same applies relating to obtaining data, where three cases at the RU, UvA, and WU utilizes two or three sensors instead of one.

Actuality of information

In terms of actuality of information, comparable actuality of information is applied for different cases. Figure 5-15 shows an overview of the different cases at universities with a description and the actuality of information. In Table 5-4, the numbers are shown with percentages of the different information supply to provide an indication of the results from the SCT 2.0 research compared to this research.

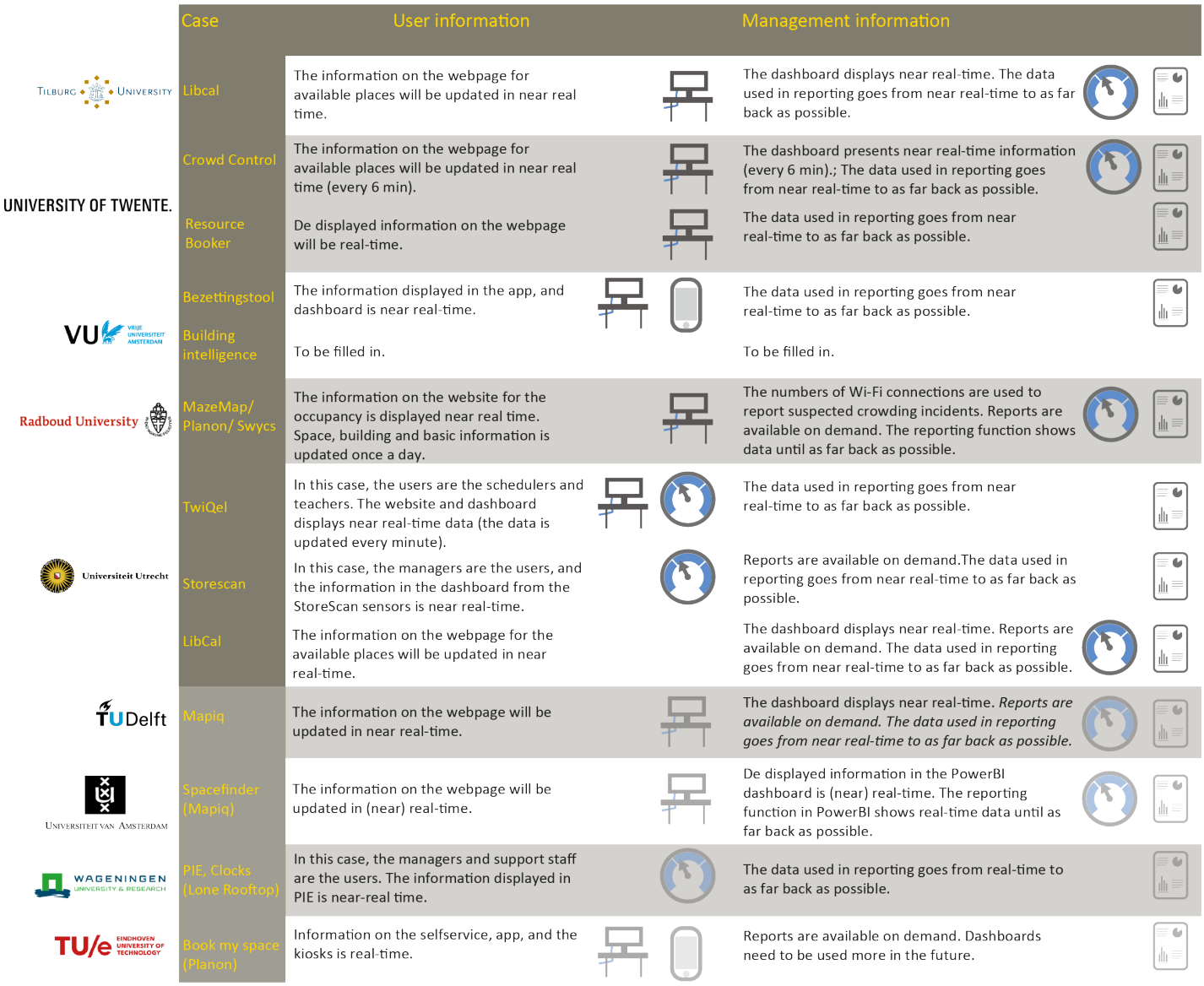


Figure 5-15: Per case information about the actuality of information reported at the nine Dutch Universities (adapted from Valks et al., 2018)

Table 5-4: Comparison of numbers and percentages for presenting the actuality of information of existing and new SCTs between the SCT 2.0 and this research.

Type	SCT 2.0				SCT 2021			
	user		Manager		user		Manager	
Webpage	4	67%	0	0%	9	82%	0	0%
App	2	33%	0	0%	2	18%	0	0%
Dashboard	0	0%	6	50%	0	0%	9	43%
Report	0	0%	6	50%	0	0%	12	57%
Total	6	100%	12	100%	11	100%	21	100%

From the figure above, it can be concluded that the actuality of the information is similarly to the SCT 2.0 research, management information (twelve out of thirteen cases) is presented in a dashboard or report. In the cases where the SCT provides information to students (six out of thirteen), this is made available through a webpage, and in two case at the VU and TUE, also via an app.
These similarities of presenting information between the SCT 2.0 and this study are apparent from the Table 5-4, despite the different types of SCTs.

With regard to the actuality of the information and despite the different type of SCTs, it still concerns about near real-time data. With regard to the new type of SCT for which individual study places can be reserved, in most cases space usage is not yet measured by sensors for real-time information.

As for the existing cases, the actuality of information remained the same.

Access levels

In terms of access level, different access levels are applied for similar cases. Figure 5-16 presents an overview of the different cases at the universities with a description and the level of access.

	Case	Specification	Managers	Support	Users	Open access
	SCT 2.0 pcs (9 cases)		4 25%	6 38%	4 25%	2 12 %
Tilburg University	Libcal	Users (students) who can book project rooms or studyplaces. Service desk to answer questions and retrieve reservations and surviellants to check reservations. Managers for configuring the system and they can retrieve overviews of data from LibCal.	●	●	● U	
University of Twente.	Crowd Control	Everyone can access the webpage.				●
	Resource Booker	Users (students) who can book project rooms. Managers can retrieve overviews of data from Resource Booker	●		● U	
VU Vrije Universiteit Amsterdam	Bezettingstool	Users: It is open-access, insights are given on crowding by space. Managers and administrators have access to reports that can be requested showing the passers-by in different rooms for a period.	●	●		●
	Building intelligence	There is a preference for open access to share as much as possible but this is not yet certain.				
Radboud University	MazeMap/ Planon/ Swycs	Floor plans, space and building information, and availability is visible for everybody; reservations can only be made by students. Reports and crowd managment information are available for management.	●		● U	●
Universiteit Utrecht	TwiQel	Schedulers and teachers who can book lecture rooms and workgroup spaces. Managers are able to retrieve overviews of data from TwiQel.	●	●		
	Storescan	Managers have access to the reports and dashboard.	●			
	LibCal	Users (students) who can book studyplaces and managers for configuring the system, and they can retrieve overviews of data from LibCal.	●		● U	
TU Delft	Mapiq	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.	●	●	● U	●
Universiteit van Amsterdam	Spacefinder (Mapiq)	The floor plan and location of spaces is visible to everyone. Room bookings can only be made by students and employees (via UvA netID). *A dashboard is available for support staff with the reservation overview. Reports are available for management.*	●	●	● U	●
Wageningen University & Research	PIE, Clocks (Lone Rooftop)	PIE is available to location managers and Clocks is available to schedulers. Also, PIE and Clocks are available to specific people from Facility Services.	●	●		
TU/e Eindhoven University of Technology	Book my space (Planon)	Students and employees have access via Selfservice, an App, Outlook and the Kiosks in the buildings. Secretaries have access to reservations via Planon Procenter.		●	● U	
	SCT 2021 pcs (13 cases)		10 34%	7 24%	7 24%	5 17%

Figure 5-16: New and existing cases at the nine Dutch Universities with a description and method of access level (adapted from Valks et al., 2018).

From the figure, it can be concluded that different access levels are present for different type of SCTs. With respect to comparable cases related to the SCT 2.0 research (the two cases for real-time monitoring of teaching space), the results appear to be consistent as managers and support staff have access to this information.
The access level for the type of SCTs that appeared in the SCT 2.0 research for finding an available study place (PC) and booking a project room are similar as regard to which users of the university can make reservations. However, compared to the results from the SCT 2.0 study, it is striking that in five of the nine cases where users can book a project room, there was no access level for managers to retrieve reports. The results in Figure 5-16 reveal that for the type of SCT for reserving individual study places, managers at six of the nine universities have insight into the use of reservations on the basis of reports. This is also an explanation why the percentage of managerial access in this research is higher compared to the SCT 2.0 research. Possibly this also concerns an important reason, that emerged from the chapter of the impact of COVID-19, that managers are increasingly demanding more data-driven decision making due to the COVID-19 crisis.

For the new type of SCT applied for crowd monitoring, a distinction is made in the new cases between whether the information is available to managers in the background or whether it is publicly accessible. The VU and UT even offer this information publicly.

With regard to the existing cases, the access level remained the same except for the case at the UvA. By adding individual spots reservations support staff and managers have insights into the history of reservations.

Furthermore, the figure reveals that the access level for education spaces is similar to the SCT 2.0 research; more specific for managers and support staff.

Regarding study spaces and users in the case of the UvT, the support staff is also able to view bookings and to answer questions. At the RU, room occupancy and building information is visible to everyone, but booking information is restricted to university students only. In the other cases, with respect to reserving study places or rooms, this is also possible for users of the own university only.

Finally, the cases (two out of four) in which crowding in buildings is presented concern open access. In the other two cases, such information is only visible to management.

5.5 Additional information

In this chapter, results from the case study that not have been examined in the SCT 2.0 research are displayed and analyzed. These are results regarding causes for delay or termination of SCT projects and how universities utilize reservation systems. In addition, the interviews investigated the extent to which the SCTs applied to meet the needs and usage during COVID-19 and potentially after the COVID-19 period.

Reason for delay or termination of SCT projects

Since this is a repeated research, experience has been gained, therefore it is interesting to identify what have been the reasons for little or no success with SCTs at the Dutch Universities. For this purpose, the reasons appearing in the research of Cisco (2017) were applied. These reasons are related to a symbol in this study and are described in Table 5-5.

Table 5-5: Explanation symbols with reasons for delay or termination of SCT projects (Own table)

Symbol	Explanation reason
	Stakeholder support has changed
	The demand for information or tool has changed
	Smart tool expertise, whether internally or through external partnerships
	Time to completion, because it took too long to implement, an alternative was chosen
	The investment proved too high in retrospect
	IT and the organization are not on the same page
	Different interests between teams
	Technology focused culture – that result from top-down leadership and sponsorship
	Quality of data, Other expectation with data to be obtained or how to deal with it?

Figure 5-17 indicates the reason for delay or termination of SCT projects. This includes four cases, of which the cases from the VU and UU were investigated in the SCT 2.0 research, and the other two are new. For this purpose, no modifications were made to the existing templates and no new templates were created since they are no longer in use. After the figure, a brief explanation of the most salient reasons will be given.

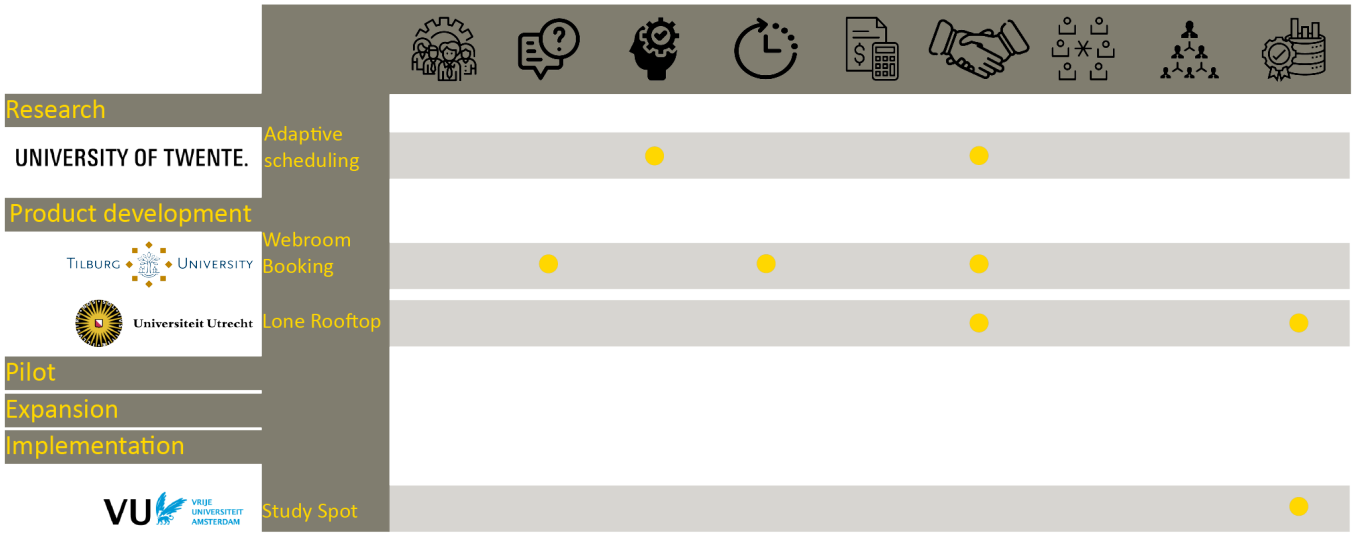


Figure 5-17: Results at Dutch universities with the reasons for no or little success for process of the SCTs (own figure).

The figure reveals that collaboration between IT and the organization is the most common reason, followed by the quality or expectation of data. At the UvT, it has been experienced that it is difficult to add specific functions because the software is designed for offices and not specifically for schools/universities.

At the UT, the case failed mainly because of a lack of knowledge. During a study into adaptive scheduling, it turned out that there was not yet a developer who could develop a tool for adaptive scheduling in combination with timetabling software.

The quality or expectation of the data is disappointing two out of four times. For the UU case, measuring based on Wi-Fi was not accurate enough. The privacy aspect was also a problem. In the case of the VU, there were higher expectations in advance than in the end, and it is not as expected. Different types of people could book in a separate system, but these systems was not able to communicate.

Cisco's research shows the outcomes to be similar to the above results. In this study, a survey of 1845 IT and business decision-makers was conducted. The key findings show that collaboration between IT and the business side emerged as the nr. 1 reason (Cisco, 2017). Also, sixty percent of respondents highlighted that initiatives often look good on paper but become much more difficult than expected.

Reservation system

Since COVID-19 has implemented many different reservation systems in a short time, the figure below shows the different approaches.

	Use of a reservation tool	Use of slots	How many slots/hours per user can be reserved?	how far in advance can a reservation be made (days)	Space types	Measurement method	No-show (%)	Incentives or penalites
Tilburg University	Yes LibCal	No	15 h	3	Project rooms and study places with/without pc	QR-code	50	Yes and not yet
University of Twente.	Yes Resource Booker	Yes	4 h	14	Project rooms	-	Unknown	No
Radboud University	Yes Webroom Booking & Face	Yes	No restrictions	5 workdays	Workplaces: study places:	IR Manual	Unknown	No
TU Delft	Yes Mapiq & Office Shifts	Yes, 3 day parts	2 slots 5 slots*	7 14*	Project rooms and study places	Manual	First 30, now 10 - 20	Not any more
Universiteit Utrecht	Yes LibCal	Yes, flexible	Min. 1h and max. closing time	7	Groupwork- and study places	QR-code	Unknown	No
Universiteit van Amsterdam	Yes Office Shifts	Yes, 3 day parts	First 4 but now 2 times a week	3	Project rooms, study- and workplaces	Access control vs reservations	First 30, now 10	No
VU Vrije Universiteit Amsterdam	No							
Wageningen University & Research	Unknown							
TU/e Eindhoven University of Technology	Yes Planon				Study places, meeting spaces, flexible workplaces	QR-code and Infrared		

Figure 5-18: Overview of the use of reservation systems at the seven Dutch universities (own figure)

According to Valks et al., the definition of a SCT is: "a product or service that collects real-time data to improve space use on the current campus and decision-making about the future campus" (2018). Since COVID-19, reservation systems have been used in six out of seven cases, a few applying real-time information. Thus, there are differences of opinions on whether a stand-alone reservation system can be considered a SCT even though it can improve the space use. This research will neither deny nor confirm this but instead, focus on the current use of reservation systems since this is an important tool during the COVID-19 period.

Study places

- The first thing to notice from the figure is that the VU is the only one of the seven cases that do not utilize reservations. They favor an accessible system whereby the student - based on an open-source website with an indication of crowding for each room - can decide for himself whether there will be a place. Depending on the regulations surrounding COVID-19, a steward is assigned to personally guide students to an available study place.
- It was noted that the UU and RU use different reservation systems and aspire a uniform reservation method.

- Also, it was experienced that there is a distinction at universities with the measurement of no-shows where cases have no insights or none yet, the other based on manual checks or based on real-time information, or by the use of QR-codes.
- At the RU and TUD, work students manually check for no-shows. If this is the case, the places are made available for reservation again.
- Three of the seven cases do not yet have information on the percentage of no-shows. Since the RU recently applied Swycs sensors to track no-shows and early leaves for room reservations, no percentage of no-shows is known (also not from the manual method). The same applies to the UU with the use of QR codes. At the UT, there is no monitoring at all = whether a user fulfills the reservation.
- Two cases at the UvT and UU apply a reservation system in combination with QR codes. These are scanned upon entry and exit. If the reserved place has not been checked in 30 minutes after the start time, this place is given away, and a new reservation can be made. With this method, it is impossible to determine whether the user performs this operation on entering or leaving earlier.

Incentives or penalties

Results and approaches for 'Study-desk hogging' or the analogy, according to Valks et al. (2018), to the "towel problem," the sunbeds on vacation that are claimed with towels but not used.

- At the TuD, they approached this in a different way than using SCTs. By modifying student behavior with a Hospitality team consisting of FM, security guards, service point staff, and hosts. Through shopping baskets and parking tickets, an investment was made for 1.5 years to modify the behavior, and this was experienced as a success. In addition, in times of COVID-19, by addressing users who conspicuously did not show up but had reservations, the no-show rate dropped from 30 to 10-20%.
- At the UvT, there is a preference that a student's "reservable hours per week" are reduced by the number of hours booked in the event of a no-show. As a reward when canceling a reservation, the hours returned. Currently, the system still works in such a way that the student always receives his hours back.

Offices and meeting rooms

- The TUE is the only university that applied reservable flexible workplaces (even before COVID-19) and have made changes in capacity and instructions related to COVID-19. Further, at the RU, a pilot is now being carried out with the reservation of workplaces for employees. In addition, only at the UvA it has emerged that they intend to utilize reservation systems for workplaces. But because of COVID-19, this is on hold.

To what extent do these SCTs meet universities' needs and use after COVID-19

During the interview, the universities addressed this question to ascertain whether a SCT was applied during the COVID-19 period, how it was appreciated, and what could be improved.

The responses from the interviews reveal that six of the seven universities -because of the reservation system- allowed the number of study spots to be scalable and therefore met the university's demand. The SCT made it possible to fairly provide students the option to study on campus. At the VU, this was also possible but was handled using the busyness indicator based on real-time data where students could estimate for themselves if there was space available. They are very satisfied with this combination of low-tech data and human support (stewards), fulfilling their needs.

Certain tools have also met the demand for identifying the users in the buildings for source contact, indicated by the UvA and UvT. A similar tool at the RU involved using real-time information for crowd management where possible incidents occur. The students informed the UvT that they preferred the reservation tool because there is no longer the need to secure a seat.
In conclusion, there have been no negative reactions. The SCTs handled this period have been positively liked, but there are areas for improvement.

The UvA indicated that a working product was realized in a short period of time, but there is room for fine-tuning since the demand is more concrete by utilizing the tool. In addition, the UvA and UvT indicated that the data obtained could be better applied. Also, the TUD is satisfied with the functioning of the SCT but is still looking for a supplier of sensors for individual study places that fit their vision. Last, the UT indicated that the use of reserved project spaces could not be traced, so that is another action point to apply sensors.

The WU specified that when the COVID-19 outbreak occurred, they desired to better utilize the meeting and concentration spaces in the offices. Thus, a Pilot was started with Lone Rooftop to find these available spaces. Because the offices have been almost non-existent since March 2020, they could not yet indicate whether they are satisfied with this during the interview conducted earlier.

The following section describes the results of the case study at international universities. The answer to the fourth and fifth sub-questions is given as the conclusion of this chapter at chapter 7.6.

6 Smart tools at international universities

As the second part of the case studies, this chapter will begin by exploring the use and progression of SCTs at universities abroad. The purpose of this chapter is to answer the sub-questions
What progress have Dutch universities, universities abroad, and other organizations realized on Smart (campus) tools addressing space utilization compared to previous research? (4) Accordingly, this will contribute to the emphasized part of the main question: "**What has changed in terms of type, demand, and use of Smart campus tools** at **universities** and other organizations **due to COVID-19 compared to the 'Smart campus tools 2.0' research?".** A case study is conducted to answer these questions.
This chapter will first describe the selection process of the cases, and for each case, it will give a brief description. Then, the templates provided with the collected data of the cases will be displayed. These templates serve as a basis to analyze the properties of the cases. Also to be able to conclude what the progression and modifications are concerning the SCT 2.0 research.

6.1 Cases

For this study, five foreign universities were selected for the case study. The cases were selected on the fact that these cases were also examined during previous research. Due to time constraints, it was impossible to interview the thirteen international universities from the SCT 2.0 research. The map on the right shows the five locations of the universities that were interviewed.

In the table below, an overview has been created with the interviewed universities, along with the function of the interviewee(s).

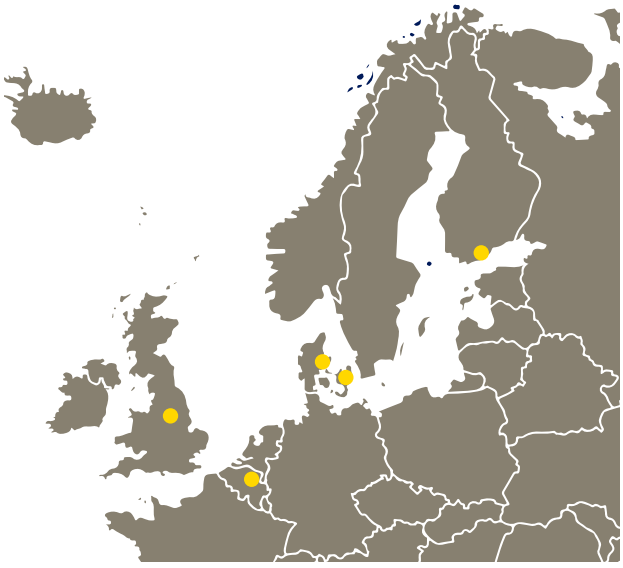


Figure 6-1: Map of the interviewed cases of the foreign universities

Table 6-1: Overview of the foreign universities interviewed, the abbreviation, and the position of the interviewee.

Country	Universities abroad	Abbreviation	Function of interviewee(s)
Denmark	Aarhus University	AU	Campus management
Denmark	Technical University of Denmark	DTU	Library
United Kingdom	Sheffield Hallam University	SHU	Campus management
Finland	Aalto University	Aalto	Campus real estate
Belgium	KU Leuven	KL	Library

6.2 Case description

This section briefly explains the context for each university. This information derives from the interviews with the universities. In addition, general information for each university is presented in an image as an indication. These numbers were obtained from annual reports or websites of the universities.

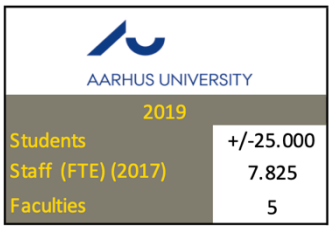


Figure 6-2: General information about the AU (own figure, info from annual reports)

At Aarhus University, a digitalization strategy has been applied to the entire campus. This strategy focuses on a period between 2020-2025 in which +/- 38 different projects have been prioritized. Of these, the university board has decided that 2/3 will be implemented. Furthermore, there is an ambition to create a campus city in University Park, the university's core, with city life and park life opposite. The development of this is going where many SCTs projects are included in this part of the campus.

At the Technical University of Denmark, the smart library -which is still functioning as a living lab- has experienced delays due to an external factor. As of December 2020, the current cameras/software of ModCams were acquired from Meraki (a subsidiary of Cisco). This has led to some changes in usage. With the current software of the Meraki cameras, it is not possible to measure movement between different small zones, as was possible with the Modcams. Around August, an update of the Meraki cameras with the old algorithm of the ModCams will be released, which may enable more features again.

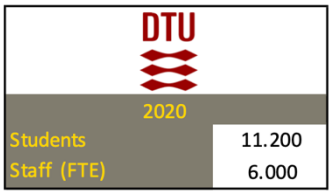


Figure 6-3: General information about the DTU (own figure, info from annual reports)

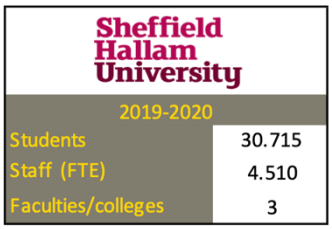


Figure 6-4: General information about the SHU (own figure, info from annual reports)

The Sheffield Hallam University has carried out some modifications to enable the 'Back-to-campus' phase. A dashboard in Tableau has been created with data from Clocks. In this way, it can monitor the number of users on a larger scale than at local or module level. In addition, a standalone reservation system was implemented with the use of QR codes on desks.

In the past 3-4 years, the Aalto University has reduced its footprint from 320,000 to 220,000m2. With the 100,000m2 of vacant real estate, a high school has been provided with a building. Furthermore, with the other vacant real estate, the Aalto spaces as a concept for the university has emerged for leasing space for start-ups, scale-ups or corporations. Furthermore, the SCT has expanded in almost doubling the amount of m2, now to 200,000m2.

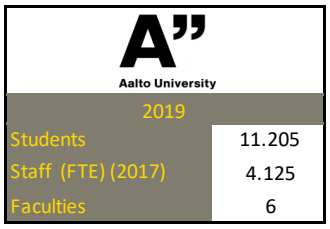


Figure 6-5: General information about the Aalto University (own figure, info from annual reports)

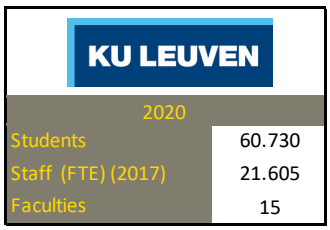


Figure 6-6: General information about the KL (own figure, info from annual reports)

The KU Leuven University has carried out modifications to enable the 'Back-to-campus' phase as reaction of the COVID-19 virus and the need to facilitate use of the campus given the restrictions to using indoor space. The SCT has accommodated this with reduced capacity by enabling study places to be reserved.

The last two universities abroad were interviewed by Ir. Valks around August 2020 as input for the first brainstorming session. From these interviews, the progression and aspects around COVID-19 at the universities can be outlined but the approach for reservations will be explained to a limited extent. The following section will display the templates of the existing and new SCTs at the universities abroad.

6.3 Templates

Based on the interviews, it was revealed that universities have discontinued or further developed the tools from the previous study or are active with new SCTs. The table below shows an overview of which tools from previous research were examined as cases included in this research. In addition, other SCTs were not included in the study because there was not enough information available or not enough time in the interview. After the table, the templates that are still in use but have been further developed will be shown first. Therefore, most of the information in these templates was inventoried during the SCT 2.0 study. During the interviews, it became apparent that adjustments had been made which are indicated in the template in italics. Next, it shows the templates that have been developed since new SCTs were initiated relative to previous research.

Table 6-2: SCTs at universities abroad from SCT 2.0, and SCTs attached as case in this research (adapted from Valks et al., 2018)

University	Previously surveyed SCTs (2018) Past research	Included as case Present research	Other Known cases of SCTs Future research
Aarhus University	Design brief	Design brief (on hold)	Smart campus city
Technical University of Denmark	Smart Library	Smart Library	
Sheffield Hallam University	Clocks (Lone Rooftop)	Clocks (Lone Rooftop)	Building intelligence dashboard
KU Leuven	Blokken in Leuven	Blokken in Leuven	
Aalto University	New case	Aalto Spaces	

6.3.1 Existing templates

After the next page, the templates created during the SCT 2.0 research are displayed with the modifications that arose during the period between the SCT 2.0 study and this study. Of the five universities abroad interviewed in this research, three existing cases are still in use, and one case experience delay or termination of a SCT Project. The modifications to the existing templates of the SCT 2.0 research are shown in italics. This involves the cases still in use at the DTU, SHU, and KL. First the situation prior to this research at those universities will be described. The case with a delay or termination of a SCT project is at the AU and the reason for this is described on page 130.
The case with a new SCT will be explained in Chapter 6.3.3.

Existing situation

Due to an outdated library building at the DTU with many visitors per day there were problems with the indoor climate and lighting. In addition, the goal was to improve the service for students. As of 2013 the library is equipped with a SCT (Smart Library) which is supported by CO2 sensors and video cameras. Students are able to identify available study and project space, adjust the lighting and reserve project spaces.

A SCT is in use at SHU as of 2017 for two reasons. The academics at the university tend to overbook space but with a scarcity of space this creates pressure on the available spaces. In addition, to

contribute to the Estates master plan by providing information. Thus, Lone Rooftop is applied to measure education spaces by means of Wi-Fi and scheduled data.

Due to an increasing demand for social learning on campus, KL has been using a SCT (Blokken in Leuven) in the library since 2013. This tool provides insight into the distribution of students across campus. It uses existing infrastructure such as access control and reservation data to determine the number of study places and project rooms.

The other cases not included in this study but inventoried during SCT 2.0 were similar types of SCTs tools such as for real-time monitoring of space use (1), and wayfinding apps (2) (Valks et al., 2018). A other type of SCT that is not similar to the inventoried cases in this research is to find available people in your field of interest.

DTU

Technical University of Denmark - Smart Library

phase
Living Lab

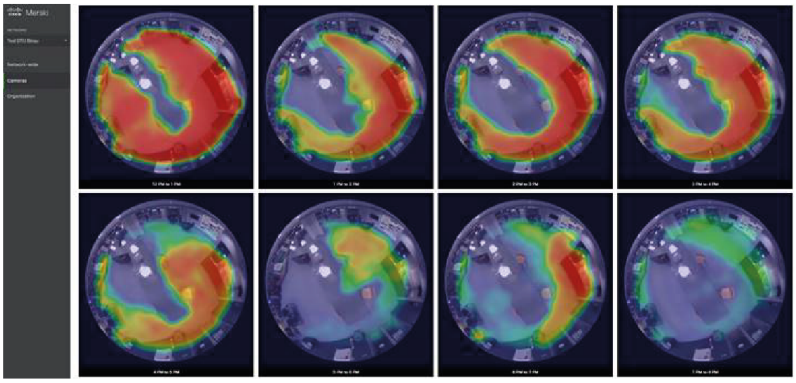
scale
35.000 m2
1 building

duration
2013 - present



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.



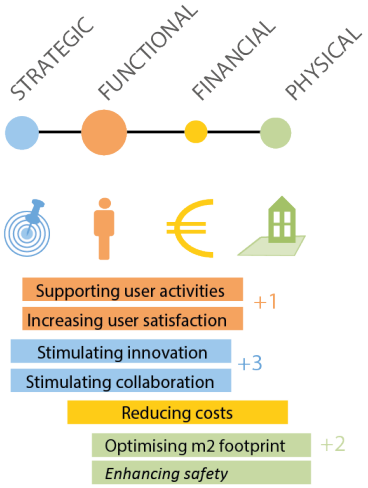
Display of the Meraki cameras with a heatmap for each camera.

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. *We want to experiment with Radar as sensors, since it is very cheap to produce and has almost the same capabilities as a camera. Also, testing Syntax sensors (French infrastructure) at the entrance. These are known as sensors for the outdoors, but can measure CO2, humidity, and temperature. Eventually, a whole platform that communicates between the CO2, the light, and the reservation system.*

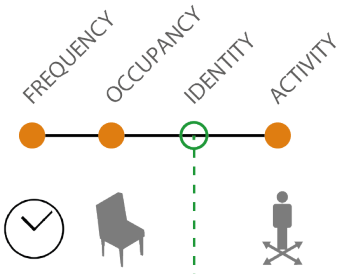
Profile

Why: Objectives



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.

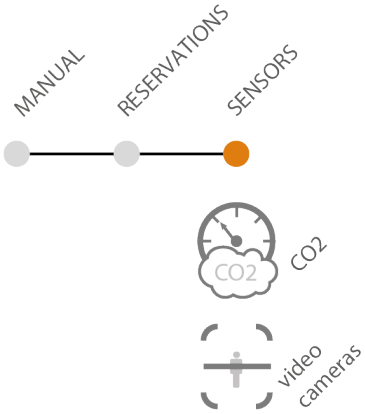
What: Measurement



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. *For the Meraki cameras: The camera processes the data in the camera and not in the cloud so, it is anonymous data. The data that can be obtained are statistics.*

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.
Since Cisco acquired ModCams, the size of the zone has increased.

How: Measurement method



The cameras in place create a panorama as they each measure the amount of users in *three floor zones* and communicate with each other to see movements *between floors. The Wi-Fi and sensortags as sensors are not in use any more since the data from cameras is more accurate.*

DTU Technical University of Denmark Smart Library



functionalities

Find a study place,
Optimising study place comfort,
Monitoring space use

space types

Study places,
project rooms

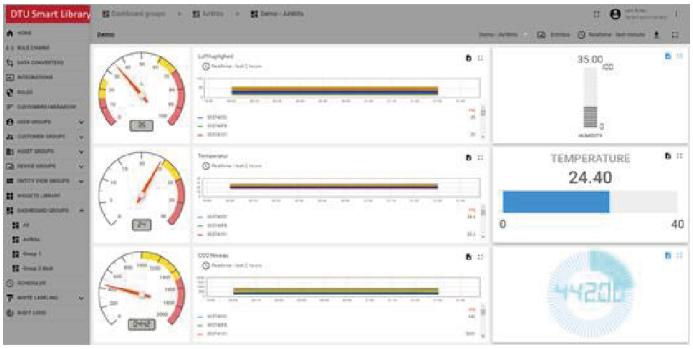
User information (employees)

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.

On the right image the indication of the available places is shown which is accessible to everyone.



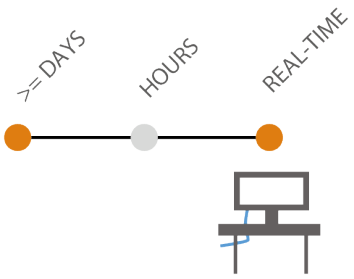


Management information

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. *Because iBeacons are experienced as not accurate enough this is still on hold.*

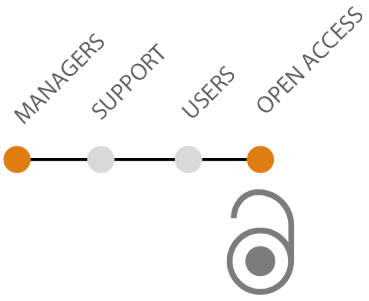
The left image shows the dashboard where managers can monitor the temperature, CO2, and humidty.

Actuality of the information



The information displayed on the webpage is real-time.

Access levels



Everyone can access the webpage and the open data. *This is the goal but that is not yet possible but with Microsoft Azure this should work. The insights of the amount of available spots is open access.*



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



The reporting will be internal in the initial stages.

Benefits

When we had to go into lockdown due to COVID-19, we were able to react quickly and count the occupancy to monitor capacity.

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.

During tests it was proven that the cameras provide a considerably higher accuracy of information. So, we no longer operate with Wi-Fi or infrared and currently only use cameras and CO2-sensors.

SHU-1 Sheffield Hallam University Clocks (Lone Rooftop)



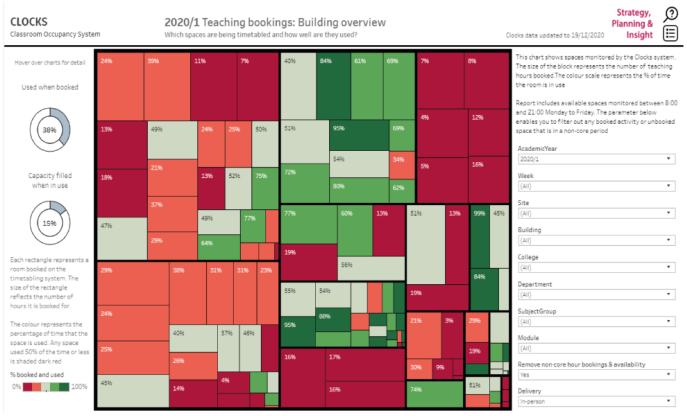
phase
pilot
Implementation

scale
5 buildings
All teaching 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.



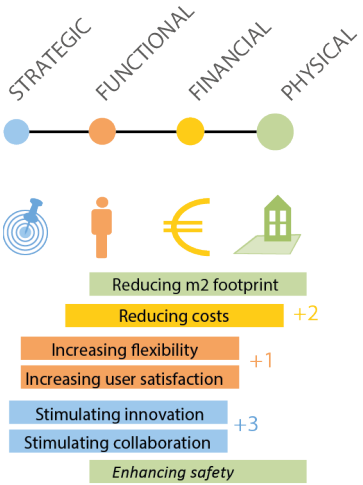
Exported data from Clocks imported into Tableau

Foreseen developments

A foreseen development is to look at other modules such as PIE. *Besides, BID (Lone Rooftop) is being considered for new buildings, with data from CO2 systems and different types of lights. In this way, they will begin to collect different types of data on how space is being used. In these buildings, there should be a flexible floor plan with mostly collaboration spaces.*

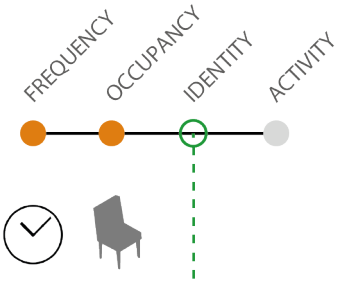
Profile

Why: Objectives



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.

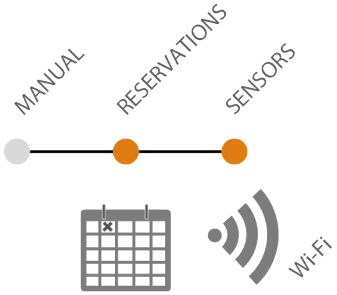
What: Measurement



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. *Because of the mixed and spread campus frequency is considered more than occupancy*

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.



Exported data from Clocks imported into Tableau



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.

The capacity in Clocks is not automatically updated, so we created our dashboard in Tableau. Now it is possible to view the data broadly in line with the COVID-19 capacity rather than at module level in the Clocks Dashboard.

Actuality of the information

>= DAYS — HOURS — REAL-TIME

The information displayed in Clocks is near-real time.

Access levels

MANAGERS — SUPPORT — USERS — OPEN ACCESS

Benefits

It supports curriculum planning, cost planning, and estate planning when we have the data that there are users on campus. This has not been the case since last March (2020) because of COVID-19.

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

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

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.

KL

University of Leuven

Blokken in Leuven



phase
Implementation

scale
2020:
30.151 m2 (+2.276 m2)
12 buildings (+2)

duration
2013 - present

Project description

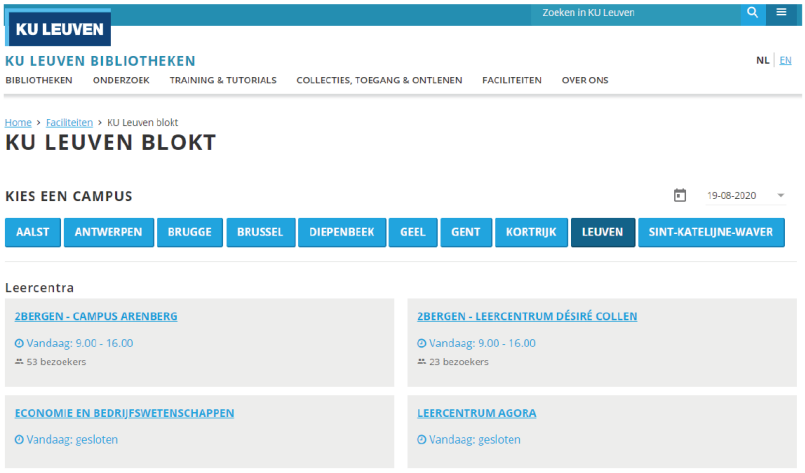
The initiative of this smart tool was taken as one of the measures to enable the increasing demand for social learning on campus. Blokken in Leuven was introduced to give students insight into the distribution of students across campus. The data and infrastructure was already in place; access control 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.

2020: The initiative to make adjustments was taken in reaction to the Coronacrisis and the need to facilitate use of the campus given the restrictions to using indoor spaces.

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 (anonimised) research on the relation between the time that a student studies in the library and his/her study results - Learning Analytics.

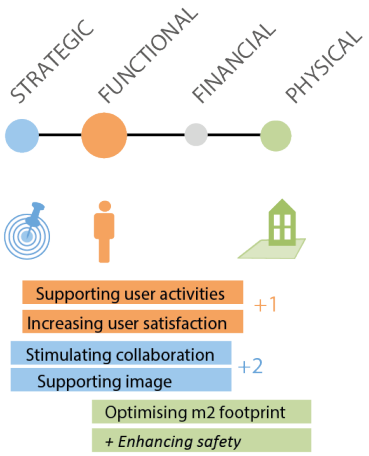
2020: Reducing synchronisation time to enable action on no-shows and early check-outs. Learning Analytics is still an idea, perhaps for a student research project.



2020: User interface on webpage

Profile

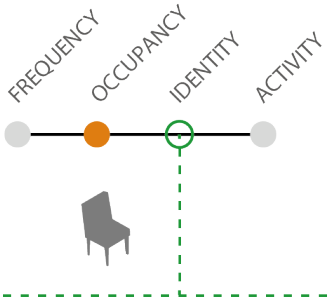
Why: Objectives



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

2020: Enhancing safety is added as the tool supports a safe return to campus

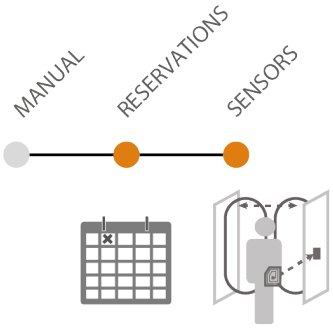
What: Measurement



The data is anonymised in reporting.
2020: The system uses sensitive information as it can identify if a student has a reservation. The student agrees to the use of his/her personal data for the purposes of access control when he/she uses the system.

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

How: Measurement method



Reservations (booking system)

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.

2020:During the COVID-19 crisis students can reserve a study place and gain access to buildings via their reservations.

KL

University of Leuven

Blokken in Leuven



functionalities

Find a study place, Monitor space use, Room booking

space types

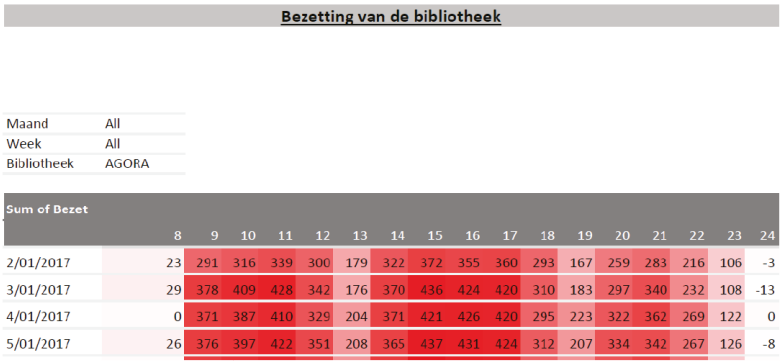
Study places, project rooms

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.

2020: The user sees an overview of the Library locations on campus and opening hours. The occupancy of the locations is now hidden. The user can click on each location to show further information, among which a link to the reservation portal (KURT) to make a reservation for a study place.





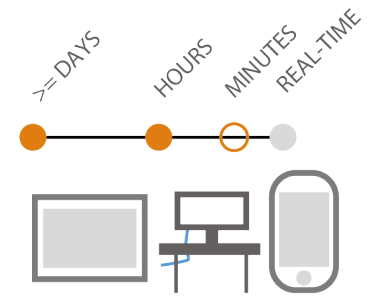
Management information

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

In the picture, the library occupancy per hour is shown. The shades of red show intensity; light red shows low occupancy, dark red high occupancy.

2020: There are now also reports available regarding the reservations. Reporting is done in Excel, but there are plans to do reporting via PowerBI.

Actuality of the information

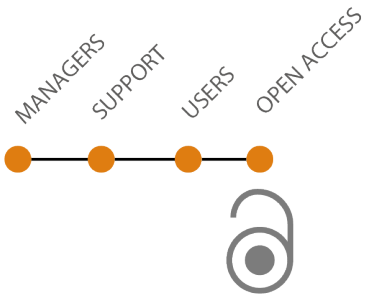


2020: The information that is displayed has a delay of +/- an hour due to synchronisation issues between applications. (Previously the delay was a few minutes)



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

Access levels



Everyone can access the webpage.



2020: Reservations are restricted to users.



Reports are accessible to the persons responsible for each Library desk and to the coordinator. 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.

2020: We were worried that the demand for study places would be too big in returning to campus. The Smart campus tool has resulted in the acceptance of the reduced capacity.

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.

2020: The balance between types of places in the libraries and learning centres is something that we will have to figure out in this new situation. What kind of study places do students want when they come to study on campus?

6.3.2 Modifications to existing templates

For the templates just shown, the performed modifications will be described. In doing so, a comparison is also included with the foreseen developments that have been identified in the SCT 2.0 research and ascertain if progress has been made on these developments.

Main modifications

At the Technical University of Denmark, changes have taken place that were particularly related to Cisco's acquisition of the ModCams. Due to the different software, this has affected the camera's functions, such as the ability to measure in smaller zones is now changed to floor level. In addition, tests have been conducted that have shown that the cameras provide considerably higher accuracy of information. For that reason, Wi-Fi, iBeacons, and infrared are no longer utilized, and only cameras and CO2 sensors are utilized. To conclude, since COVID-19, students have insights through an open-source website to the number of study spaces available.

The Sheffield Hallam University focuses on level measurements less on occupancy but rather on frequency since creating a mixed and spread-out campus. Also, experienced benefits mentioned that contribute to the goals support the curriculum, cost, and estate planning. The last modification concerns the management information -what was already a note and implemented since COVID-19- a dashboard was created in Tableau. This allows to monitor -in line with COVID-19- capacity broadly rather than at module level in the Clocks dashboard.

At the KU Leuven, the SCT has been extended to two extra buildings and modifications have mainly been made to facilitate back-to-campus in connection with COVID-19. As a result, there is the possibility for students to reserve study places and they have access to the buildings based on a reservation. By means of the reservation, the management has insight into reports on reservations. In addition, a greater delay is experienced due to the synchronization between applications, this is about an hour instead of previously with a few minutes.

At all the three universities, as a result of COVID-19 is enhancing safety as an additional objective.

Progression of foreseen developments 2017 – 2021

One component to ascertain progression at universities abroad is to check for progression around existing foreseen developments inventoried in the SCT 2.0 research.

- The DTU still has the existing goal with the living lab that users can find a place with their comfort level or go to a room and adjust this (like the light, heat, etc.) For this purpose, the DTU is still aiming for a data management system where a web or application solution is launched. So far, data is collected in Microsoft Azure.
- The SHU expanded Clocks from five to all buildings and is now considered as the implemented phase. The other development, looking at other modules like PIE, still applies.
- The KL has not yet made progress on the developments foreseen but these are still valid.

The new foreseen developments for the existing templates that emerged during these interviews are described at Chapter 6.4. The next page will present the template for one new SCT. This is the situation for the Aalto university. After the template, various results are analyzed and described.

6.3.3 New template

Aalto University

Aalto Spaces

phase	scale	duration
Implemented	104 000 m2 4 buildings *2020:* *200 000 m2* *18 buildings*	2016-present

Project description

Aalto University wanted to develop a user-friendly space information system, which enables to utilize space reservation information with mobile devices. The mobile app enables to spot vacant spaces, reserve them, and find a route by using self-phone's location data.

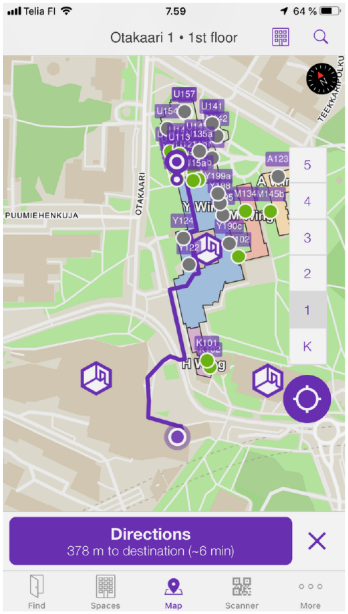
Foreseen developments

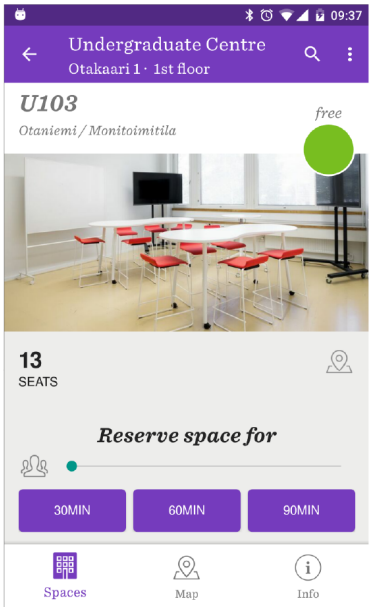
The objective is to extend Aalto Spaces to eventually cover all buildings on campus.

Including identification to the service is also being considered.

2020: We are currently looking at using sensors to measure no-shows and occupancy. This would be helpful to further improve the efficient use of spaces on campus.

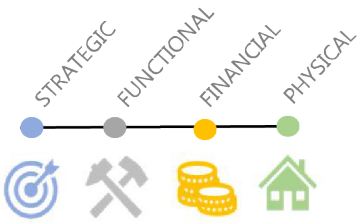
Investment costs (per m2 GFA): € 1,15. *2020: € 0,75*
Operating costs (per m2 GFA): € 0,12. *2020: € 0,75*





Profile

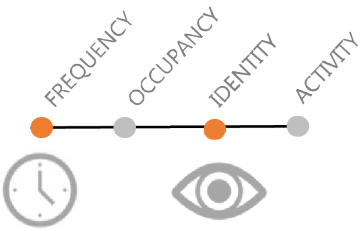
Why: Objectives



Information sharing
Space efficiency
Finding places
Enabling innovations

Main objective is to provide easy access to information regarding what kind of spaces are available, and in that way increase space usage rates.

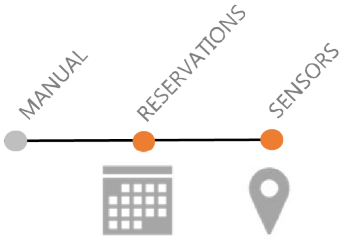
What: Measurement



Application has rights to identify users by phone number. Identification is used to minimize misuse cases.

Reservation data is used to determine the frequency (usage) rate of the spaces that can be reserved in Aalto Spaces.

How: Measurement method



Aalto Spaces offers a functionality to reserve spaces via the app. Spaces can also be reserved via MS Exchange and via a webpage. In the reservation system, all bookings are put together and one can see from which interface the booking is made.

Location data of the users is provided via Bluetooth (by Steerpath). This enables the user to navigate through the building from their current position.

Aalto University

Aalto Spaces

functionality

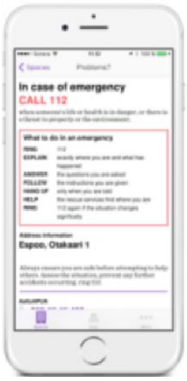
Finding space, guiding route

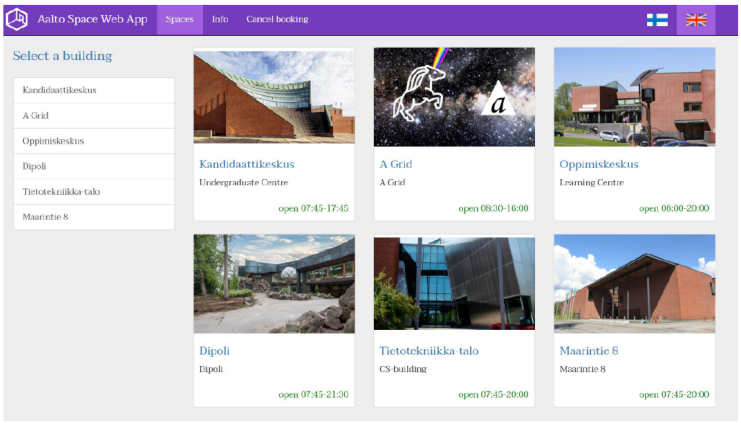
Space types

Class rooms, learning spaces, meeting rooms

User information

Easy to view which spaces are vacant in real time in any location with your own self-phone. Some of the spaces can be booked via the app. The app also guides user to the selected destination (room). The service is also available in web browser version.



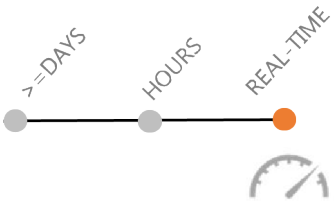


Management information

Management can use the system to deliver emergency messages. Management may monitor the number of bookings made by individual user. The system collects anonymous raw data which can be used in statistics, analyses, and research carried out by Aalto university and its partners.

2020: The analyses mostly are done with booking system data, which serves Aalto Space app. Feedback of the app itself & the spaces may be also given in the app. App usage provides data for the usage of various reservation channels.

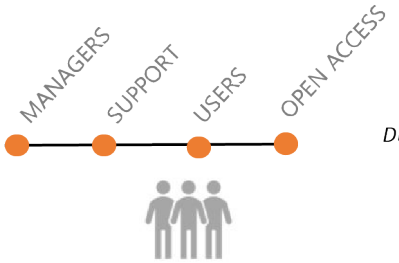
Actuality of the information



Real-time information about space reservations is available in mobile app.

2020: Management information is available from real-time until a year back in the reservation system.

Access Levels



Data collection is enabled for management, space bookings are available for students and staff, and guidance to selected places is provided as open access.

Benefits

2020: The navigation functionality reduces the time needed to find a suitable space to 3-5 minutes. The space reservation functionality has dramatically increased the space usage (frequency); exact number not available. During COVID-19, the reservations and space tracking enable safe use of the campus.

Side notes

Aalto Space has been designed together with the users of the spaces and with the entire Aalto community.

The aim of the Aalto Space campus app is to support the University's digital strategy. We want to offer a seamless mobile user experience and platform that serves the whole Aalto community. Aalto Space is user-oriented, and its agile development process brings together the different actors at the campus.

6.4 Analyzing the results

In this chapter, cross-case analysis will be applied to analyze the results of the new and existing case(s) from the universities abroad interviewed. These analyses will clarify the following aspects; the timeline, foreseen developments, objectives, space use measurements, measurement methods, actuality of information, and access levels. In this way, insights are created from the obtained data in the cases. These include four of the five universities interviewed since the SCT at the AU has been on hold.

Timeline

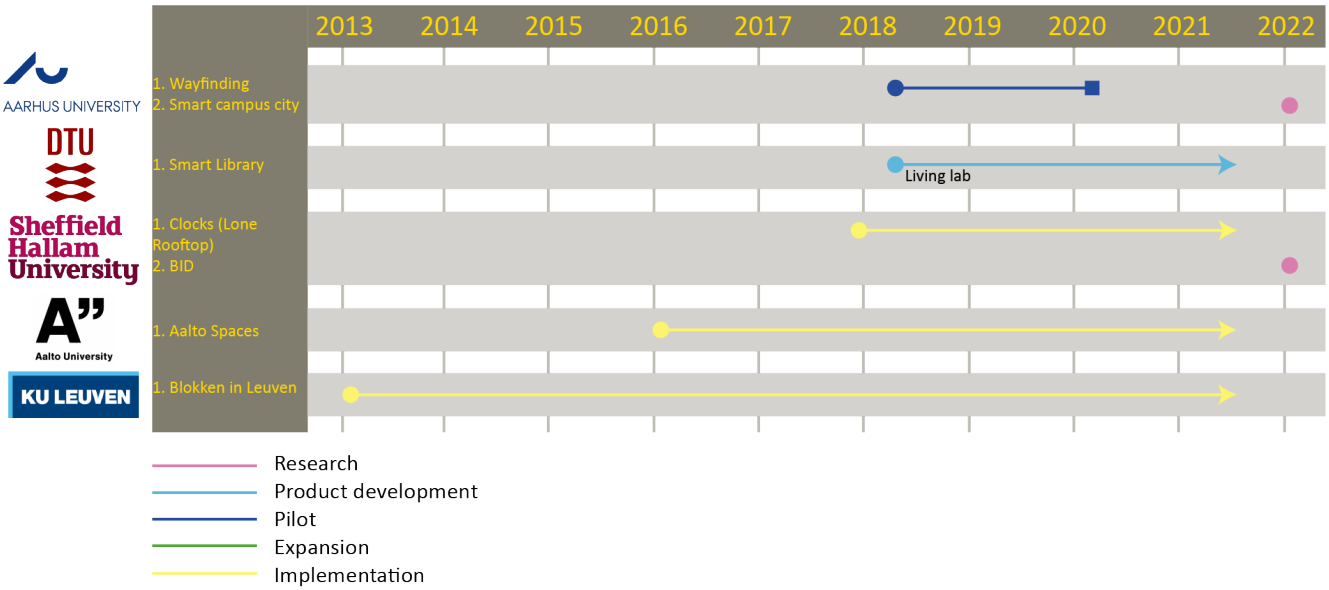


Figure 6-7: Timeline of the SCTs at universities abroad (updated from Valks et al., 2018)

The timeline presents five cases collected from three universities abroad. One has discontinued, no new cases, and two cases of which information can be given later. Considering the figure, the timeline changes compared to SCT 2.0 are the Wayfinding of the AU, which is on hold, and the that Clocks of the SHU has been implemented.

Foreseen developments

For the four universities abroad, a description will be provided for the foreseen developments of the expansion of existing cases.

Since the case at AU is on hold, this certainly still has the ambition to fulfill the current SCT when the development is resumed. Indoor wayfinding remains the goal since the physical campus will be more complicated. In addition, the application of a reservation system for study places, workspaces, and group workspaces. By using these systems, the use of these spaces becomes more efficient and increases the utilization rate. At this moment, the buildings are still being used traditionally, exclusive and territorial as Den Heijer (2019) describes it. For the foreseen developments of the new campus city as described in the context, the ambition is to apply many smart buildings aspects

At the DTU, there is a foreseen development to perform tests with radar and CO2 sensors at the entrance to figure out which one is more accurate. The final development is a whole platform that communicates between the CO2, the light, and the reservation system.

At the SHU, there are plans to dispose of old buildings and add other buildings to their portfolio. Flexible floor plans with mostly collaboration spaces and BID (Lone Rooftop) are considered for these new buildings. With the utilization of sensors that generate different types of data about CO2 and lights. In this way, various data will be collected on how space is used. Lastly, the SHU reconsiders the workplace policy. With the vision, staff will also need to reserve a desk when they want to go to campus as there will no longer be a personalized desk

At the Aalto, the new anticipated development is to apply sensors to measure no-shows and occupancy. In this way, the use of space on campus could be improved.

At the KL, partly because of the increased problem of synchronization time, the goal is to reduce this time to anticipate the no-shows and early leaves.

For the following cross-case analysis, figures have been created to analyze the previously mentioned aspects. In order to make comparisons possible as an indication based on numbers, numbers and percentages are shown in the light blue rows of the results from the SCT2.0 and from this research. According to the left column, the colors below indicate whether this is a new SCT or an existing SCT that is still in use.

New SCT cases
Existing SCT cases

In the figures, icons are displayed in the rows where for existing cases a distinction is made in the opacity of these icons. This is shown in full opacity for modified parts and reduced opacity for existing parts. With regard to the textual parts in the figures, modifications are indicated in italics as in the existing templates. First, the objectives are outlined.

Objectives

During the interviews, for new and existing cases, the objectives for which the SCT should contribute were requested again. For this purpose, the objectives from the framework of Den Heijer et al. were applied (Chapter 3). In addition, enhancing safety was added as an additional objective.

First, a description will be presented to reflect the type and associated objectives inventoried during the SCT 2.0 research. Then, following Figure 6-8, it can be analyzed whether there are similarities or differences with corresponding new and existing SCTs.

The SCT 2.0 research reveals that there are three types of SCTs (which are still in use) inventoried at universities abroad. First, the real-time monitoring of space use (1) where the objectives focus on all four categories but the emphasis is on reducing the footprint (m2). Then a type of SCT for finding a study place with iBeacons and access gates (2), where the focus is on strategic, physical and functional objectives but the emphasis is on the last category. The third SCT is for finding a study place and

optimize comfort (3), where the objectives focus on all four categories but the emphasis is on the comfort of their user (functional).

Figure 6-8 will present the objectives of the new and existing (still in use) SCTs in an organized manner. The objectives; reduce footprint and enhancing safety is marked with a star to indicate that these objectives did not occur in the SCT 2.0 research and hence there is a larger difference.

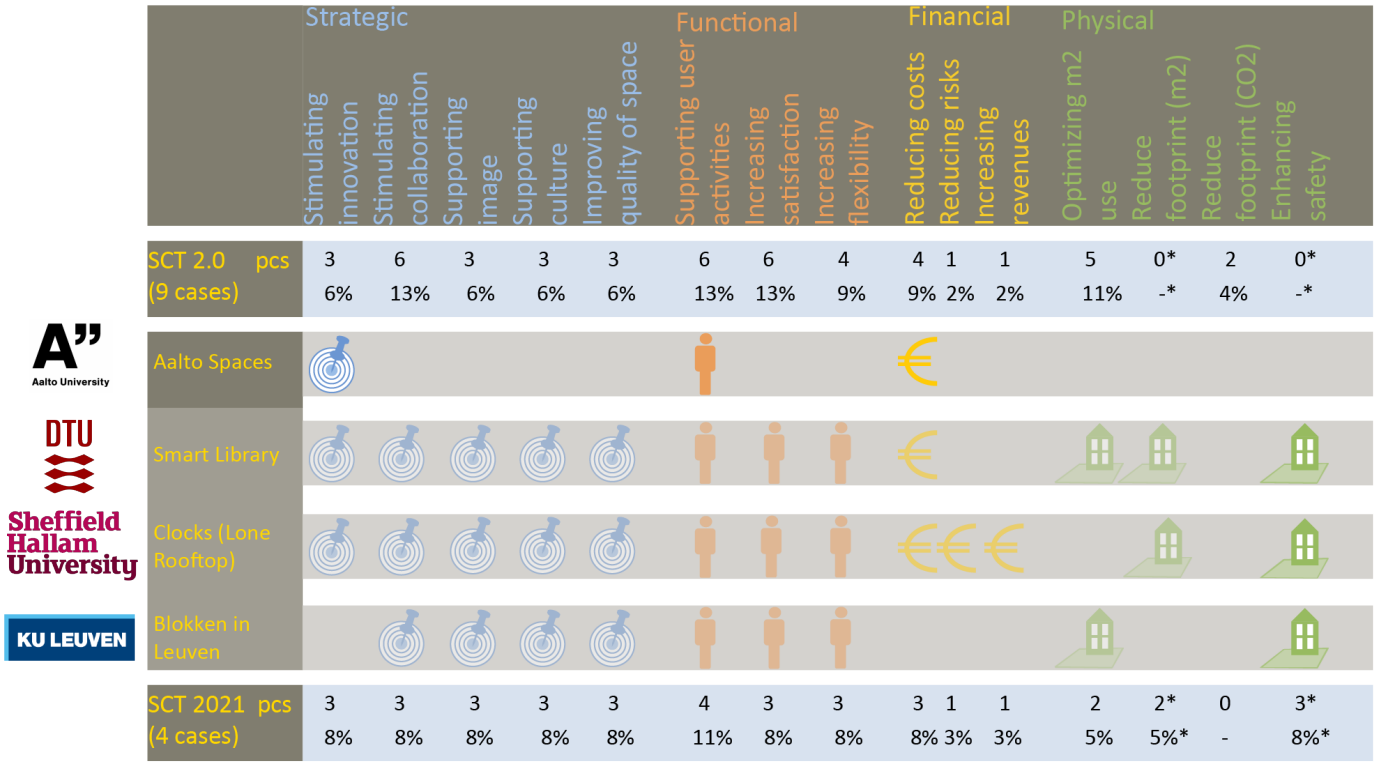


Figure 6-8: New and existing cases at the four universities abroad with the different objectives per case (adapted from Valks et al., 2018)

From the figure, it can be concluded that it is remarkable that compared to the existing cases, there is a focus on fewer objectives in the Aalto's case, despite the different types of SCTs.

The interviews and the figure reveal that there is one new type of SCT at the four universities abroad. This type serves to find education and meeting spaces and provide guiding routes (with Bluetooth) at the Aalto. Where the main objective is to easily provide the user with information of available spaces. Besides the possibility of the guiding routes, this case Is similar to the type of case of the KL, yet the cases differ in terms of objectives.

In addition, there is a difference compared to the SCT 2.0 research that enhancing safety was not mentioned before. This can be concluded that by the COVID-19 crisis the SCT cases are applied to protect the users. In terms of modifications to objectives, all three of the existing cases include enhancing safety as an additional goal with the aim to regulate the number of users on campus.

In terms of comparing percentages, these are comparable to the SCT 2.0 research because not many changes have taken place.

Space use measurements

For space use measurement, the existing cases apply the same level of space use measurement as in the SCT 2.0 research. This does not apply to the new case at Aalto where a level (identity) is applied which is not utilized by the universities interviewed. Relative to the SCT 2.0 study, this was applied at two universities.

Case	Privacy	Frequency	Occupancy	Identity	Activity
SCT 2.0 pcs (9 cases)		3 25%	6 50%	2 17%	1 8%
Aalto Spaces	Application has rights to identify users by phone number. Identification is used to minimize misuse cases.				
Smart Library	First we want to make sure 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. *For the Meraki cameras: The camera processes the data in the camera and not in the cloud so, it is anonymous data. The data that can be obtained are statistics.*				
Clocks (Lone Rooftop)	Privacy is addressed by working together with a compliance officer - at the moment looking at the GDPR.				
Blokken in Leuven	The data is anonymised in reporting. *The system uses sensitive information as it can identify if a student has a reservation. The student agrees to the use of his/her personal data for the purposes of access control when he/she uses the system.*				
SCT 2021 pcs (4 cases)		3 38%	3 38%	1 12%	1 12%

Figure 6-9: New and existing cases at the four universities abroad showing the various uses of the measurement space. Privacy issues are presented when applicable (adapted from Valks et al., 2018)

Figure 6-9 shows that relative to the SCT 2.0 study, there is still an emphasis on frequency and occupancy. For the case at the Aalto spaces, measurement is done on frequency to determine how many spaces can be booked. Measuring identity is applied by using the Bluetooth of the smartphone, where the user has the choice to agree. Considering the case of the KL which have similarities in terms of type of SCT, both SCTs apply reservations but at the KL monitoring is applied on the amount of people in the library and at the Aalto on space level and thus frequency.

Measurement methods

Compared to SCT 2.0, it appears that a different measurement method is applied in the new case. In the figure below, each university and case are described by name, explanation of measurement method, measurement method, and lastly -where possible- what the specific application is.

Case	Measurement method	Manual	Reservations	Sensors	Sensor application
Aalto Spaces	AaltoSpaces offers a functionality to reserve spaces via the app, MS Exchange, and a webpage. In the reservation system, all bookings are put together and one can see from which interface the booking is made. Location data of the users is provided via Bluetooth (by Steerpath). This enables the user to navigate through the building from their current position.		Self-booking tool	Bluetooth	
Smart Library	The cameras in place create a panorama as they each measure the amount of users in *three floor zones* and communicate with each other to see movements *between floors. The Wi-Fi and sensortags as sensors are not in use any more since the data from cameras is more accurate.*			Camera	
Clocks (Lone Rooftop)	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	
Blokken in 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. *During the COVID-19 crisis students can reserve a study place and gain access to buildings via their reservations.*		Self-booking tool	RFID	Access control (Campus card)

Figure 6-10: New and existing cases at the four universities abroad with the different measurement methods applied and description (adapted from Valks et al., 2018)

Type	SCT 2.0		SCT 2021	
Reservations				
Self-booking tool	0	0%	3	100%
Schedule data	1	100%	0	0%
Total:	1	100%	3	100%
Sensors				
Wi-Fi	2	18%	1	25%
Infrared	3	27%	0	0%
CO2	1	9%	1	25%
Camera	1	9%	0	0%
Temperature	1	9%	0	0%
Bluetooth	1	9%	1	25%
RFID	2	18%	1	25%
Total:	11	100%	4	100%

Table 6-3: Comparison of numbers and percentages for the measurement methods of existing and new SCTs between the SCT 2.0 and this research.

From the figure above, it can be concluded that compared to the SCT 2.0 research, there is a lower use of schedule data. This is also evident in Table 6-3.

In the SCT 2.0 research this was similar to the current situation at the SHU only there for a different type of SCT type. This is for real-time monitoring of teaching space. In this research, there are two cases at the Aalto and KL where it is inventoried that they utilize a self-booking tool for booking of different types of spaces. This is a modification at the KL compared to the SCT 2.0 research and was caused by the COVID-19 virus. Now it is possible for users to reserve individual study spaces to enable the back-to-campus.

Actuality of information

In terms of actuality of information, comparable actuality of information is applied for different cases. Figure 6-11 shows an overview of the different cases at universities with a description and the actuality of information. In Table 6-4 the numbers are shown with percentages of the different information supply to provide an indication of the results from the SCT 2.0 research compared to this research.

	User information	Management information
Aalto Spaces	Real-time information about space reservations is available in a mobile app.	Management information is available from real-time until a year back in the reservation system.
Smart Library	The information displayed on the webpage is real-time.	The data used in reporting goes from real-time to as far back as possible.
Clocks (Lone Rooftop)	In this case, the users are the managers and supportive staff. The information displayed in Clocks is near-real time.	The data used in reporting goes from real-time to as far back as possible.
Blokken in Leuven	*The information that is displayed has a delay of +/- an hour due to synchronisation issues between applications. (Previously the delay was a few minutes)*	The data used in reporting is aggregated data over a monthly or yearly period

Figure 6-11: Per case information about the actuality of information reported at the four universities abroad (adapted from Valks et al., 2018)

Type	SCT 2.0				SCT 2.0			
	user		Manager		user		Manager	
Webpage	2	29%	0	0%	2	40%	0	0%
App	2	29%	0	0%	2	40%	0	0%
Dashboard	1	14%	1	14%	0	0%	1	20%
Report	0	0%	6	86%	0	0%	4	80%
Display	2	29%	0	0%	1	20%	0	0%
Total	7	100%	7	100%	5	100%	5	100%

Table 6-4: Comparison of numbers and percentages for presenting the actuality of information of existing and new SCTs between the SCT 2.0 and this research.

According to Figure 6-11, the presenting of information for the universities abroad is offered in a mostly similar way. Similar to the SCT 2.0 research, management information (all the four cases) is presented in a report. In the cases where the SCT provides information to students (three out of four), it is available through a webpage, and at two cases at the Aalto and KL, also by an app. These similarities of presenting the information between the SCT 2.0 and this study are apparent from the Table 5-4, despite the different types of SCTs.

With regard to the actuality of the information, there are differences. While Aalto allows for the provision of real-time information, the comparative type of SCT from the KL has a change compared to the SCT 2.0 study where there is now a delay of one hour.

The actuality of the information at the cases of the DTU and SHU is unchanged.

Access levels

In terms of access level, comparable access levels are used for different cases. Figure 6-12 shows an overview of the different cases at universities with a description and the level of access.

Case	Specification	Managers	Support	Users	Open access
SCT 2.0 pcs (9 cases)		7 47%	2 13%	2 13%	4 27%
Aalto Spaces	Data collection is enabled for management, space bookings are available for students and staff, and guidance to selected places is provided as open access.			U	
Smart Library	Everyone can access the webpage and the open data. *This is the goal but that is not yet possible but with Microsoft Azure this should work. The insights of the amount of available spots is open access.* The reporting will be internal in the initial stages.				
Clocks (Lone Rooftop)	The dashboard and reporting functions are available to the space resource manager and the management information officer.				
Blokken in Leuven	Everyone can access the webpage *but reservations are restricted to users.* Reports are accessible to the persons responsible for each Library desk and to the coordinator . Libraries can specify the reports to their own locations.			U	
SCT 2021 pcs (4 cases)		4 33%	3 25%	2 17%	3 25%

Figure 6-12: New and existing cases at the four universities abroad with a description and method of access level (adapted from Valks et al., 2018).

From the figure, it can be concluded that different level of access is present for different type of SCTs.

With respect to comparable cases with the SCT 2.0 research, the type of SCT at the Aalto to find education and meeting spaces and guiding route (with Bluetooth) and at the KL to find a study place (iBeacons and access gates), the result appears to be consistent in which all different users have access to this information.

With respect to the existing cases that are still in use, since the possibility at the KL to reserve individual study places and project rooms, only students from the KL university are able to reserve these places. Regarding to the other two cases, no changes have been made with respect to the access level.

6.5 Additional information

From this chapter, results from the case study are displayed and analyzed that were not examined in the SCT 2.0 research, concerning the causes for delay or termination of SCT projects and how universities utilize reservation systems. In addition, the interviews investigated the extent to which the SCTs applied to meet the needs and usage during COVID-19 and potentially after the COVID-19 period.

Reason for delay or termination of SCT projects

Since this is a repeating research experience has been gained so, it is interesting to identify what has been the reasons for delay or termination of SCT projects at the universities abroad. For this purpose, the reasons and logos described on page 104 are applied again and are presented in the figure below.



Figure 6-13: Result at universities abroad with the reason for delay or termination of SCT projects (own figure).

As indicated earlier, there is one case at universities abroad where there was no success during developing a SCT. This concerns the AU, where the reason was that stakeholder support changed. The wayfinding case was one of the gross catalog projects but not prioritized, as described under context. When the board was distributing the funds, there were plans to locate the faculty (of the pilot) in another part of the campus. Since the timeframe for this was unknown, it was not a priority to handle a technological investment. The faculty has started a pilot outside of the founded digitalization strategy itself, but due to COVID-19 combined with no financial support, this is not a priority right now.

Reservation systems

	Use of a reservation tool	Use of slots	How many slots/hours per user can be reserved?	how far in advance can a reservation be made (days)	Space types	Measurement method	No-show (%)	Incentives or penalites
AARHUS UNIVERSITY	No							
DTU	Yes, Super saas (temporary)	Yes 4h	1 slot per day	14	Project rooms and study places	-	Unknown	No
Sheffield Hallam University	Yes	Yes flexible	-	14	Study places with/without pc	-	Unknown	No
Aalto University	Yes				Class rooms, learning spaces, meeting rooms			
KU LEUVEN	Yes				Project rooms and study places	Access control		Yes

Figure 6-14: Overview of the use of reservation systems at the three universities abroad (own figure)

The figure reveals that two of the three universities employ a reservation system. Since COVID-19, DTU has been applying a reservation system and an open-source website that indicates how many users are still accessible in the library. The simple and therefore, temporary reservation system (web-based) is held until a smarter reservation system is implemented to send information back (information about no-show). Currently, a user has the ability (manually) to use a reserved spot is used if it remains unused 15 minutes after the reservation start time. Using sensors to measure (no-show) is an intention for the future.

At SHU, two different reservation systems are in place to reserve study places. For employees, there is no reservation system in place yet; this is a foreseen development.

For all the universities, there are no insights to no-show in reservations.

At the KU, the problem of no-shows and early check-outs is being worked on. If a student is more than half an hour late, they want the system to delete the reservation. Now the delay in synchronizing between the access control system and the reservation system is about an hour, which is too long. They want this to be reduced to at least less than half an hour.

To what extent do these SCTs meet universities' needs and use after COVID-19

At the AU, there is no SCT in use yet, and this process is on hold. The DTU and Sheffield are satisfied, and the SCTs have met the needs and use during the COVID-19 crisis period. In both cases, by using the current sensors, real-time information could be obtained about the occupancy within the buildings. This could be monitored to keep track of the reduced capacity (according to COVID-19 regulations). In addition, both universities indicated that the data obtained could be better used. For DTU, after the update of the cameras, more functionalities are available, which contribute to the monitoring of space use. Next, the SHU would like to generate more insights into using spaces outside the timetabling system and use heatmaps to support the Back-to-campus phase.

The Aalto indicates that changes can easily be made to the properties of spaces in the database to inform users of the current situation. This is done through an app that also includes instructions on how to use spaces.

The KU indicates that they are satisfied about the short-term solution but that there are aspects to improve for the middle and long term. Such as the aspect described at the reservation chapter for the no-show and early check-out. In addition, for the early check-outs it is thought to apply a similar removal of bookings, but then by sending the student in question a trigger (e.g. via SMS) to verify whether the booking can be changed.

The following section describes the results of the case study at the other organizations. The answer to the fourth and fifth sub-questions is given as the conclusion of this chapter at chapter 7.6.

7 Smart tools at other organizations

As the third part of the case studies, this chapter will begin by exploring the use and progression of SCTs at other organizations in the Netherlands. The purpose of this chapter is to answer the sub-questions what progress have Dutch universities, universities abroad, and other organizations realized on Smart (campus) tools addressing space utilization compared to previous research? (4), and to what extent do these Smart (campus) tools meet the needs and use of the Dutch universities, universities abroad, and the other organizations after COVID-19? (5) Accordingly, this will contribute to the emphasized part of the main question: "**What has changed in terms of type, demand, and use of Smart campus tools** at universities and **other organizations due to COVID-19 compared to the 'Smart campus tools 2.0' research?".** A case study is conducted to answer these questions.

This chapter will first describe the selection process of the cases, and for each case, it will give a brief description. Then, the templates provided with the collected data of the cases will be displayed. These templates serve as a basis to analyze the properties of the cases. But also to be able to conclude what the progression and modifications are concerning the SCT2.0 research.

7.1 Cases

For this study, three other organizations in the Netherlands were selected for the case study. The cases were selected on the fact that these cases were also examined during previous research. Due to time constraints, it was impossible to interview the eight other organizations from the SCT 2.0 research. The map on the right shows the three locations of the organizations that were interviewed. Concerning the offices of the EDGE and ABN, this is not the only location in the Netherlands and abroad.



Figure 7-1: Map of the interviewed cases of the other organizations.

In the table below, an overview has been created with the interviewed organizations and the function of the interviewee(s).

Table 7-1: Overview of the other organizations interviewed, the abbreviation, and the position of the interviewee (adapted from Valks et al., 2018)

Other organizations	Abbreviation	The function of the interviewee(s)
Dutch Government	NLG	Innovation management
ABN AMRO	ABN	Facility management; facility management
EDGE Technologies (former OVG)	EDGE	Innovation management

7.2 Case description

This section briefly explains the context for each organization. This information derives from the interviews with the organizations.



Figure 7-2: Logo ABN AMRO (logo from website)

A large-scale renovation program was started at ABN AMRO between the period of the SCT 2.0 research and now. A pilot floor construction with new sensors is ongoing at the head office. Even though the renovation program has been temporarily interrupted, the new Homebase has been formed. This is the new name of the (already existing) building on the Foppingadreef (Amsterdam), completely renovated and expanded from 2022-2025. This will be ABN AMRO's most important building that must optimally meet the employee experience, a new way of working, sustainability, and smart buildings requirements/expectations.

In March 2020, the use case of Place Checker changed due to COVID-19. This changed to analyzing whether there are too many people in the building. Further, a development that has been going on for three years is creating a private LoRa network. This allows connecting sensors to a private network (a benefit for the privacy aspect). A proof of concept has just been completed with major suppliers and will be followed by implementing the additional network layer.



Figure 7-3: Logo Dutch Government (logo from website)



Figure 7-4: Logo EDGE Technologies (logo from website)

Mainly since COVID-19, EDGE has noticed an increase in interest in the use case among its customers. Before that, the use case was seen as interesting instead of necessary. This is about interest in the use of smart tools for the short and long term. In the short term for facilitating 'back-to-office' with reduced space due to COVID-19 regulations. In addition, for the long-term vision, a tool that contributes to the development whether offices still need their entire portfolio and for the consequence if offices start to reduce in surface area. As a final note, it should be explained that another participant was interviewed for the interview of the case compared to the SCT2.0 research. From this, information was obtained at an outline rather than a detailed level. Thus, no modifications were made to the template, but this will be described textually.

The following section will display the templates of the existing Smart tools at the other organizations.

7.3 Templates

According to the interviews, it was discovered that the organizations further developed the Smart tools from the SCT 2.0 research or are active with new Smart tools. Table 7-2 presents an overview of which tools from the SCT 2.0 research were observed as cases included in this research. In addition, other Smart tools were not included in the research since there was not yet enough information available. After the table, the templates that are still in use but have been further developed will be shown first. Therefore, most of the information in these templates was inventoried during the SCT 2.0 research. During the interviews, it became apparent that adjustments had been made which are indicated in the template in italics. Next, it shows the templates that have been developed since new Smart tools were initiated relative to previous research.

Table 7-2: SCTs at other organizations from the SCT2.0 research and SCTs attached as case in this research (adapted from Valks et al., 2018)

Organization	Previously surveyed tools (2018)	Included as case	Other Known cases of Smart tools
Dutch government	Plekchecker	Plekchecker	LoRa Network
ABN AMRO	Intelligent building, Lone Rooftop	Intelligent building (Lone rooftop), Pilot Floors, Werkplekbezetting	
EDGE Technologies	Mapiq, Philips (the Edge)	Mapiq, Philips (the Edge)	

7.3.1 Existing templates

From the next page, the templates created during the SCT 2.0 research are displayed with the modifications that arose during the period between the SCT 2.0 study and this study. Of the three other organizations interviewed in this research, the three existing cases are still in use. There are no cases experience delay or termination of a Smart tool project. The modifications to the existing templates of the SCT 2.0 are shown in italics. This involves the cases still in use at the ABN and NLG. First the situation prior to this research at those universities will be described. The cases with new Smart tools are explained at the Paragraph 7.3.3.

Existing situation

At the ABN, a Smart tool was initiated in 2016 to better manage scarce resources. Thanks to the monitoring of space use, insights can be created into the use of the building. In addition, insights towards available workplaces for the employees. Since then, Lone Rooftop has been applied and based on Wi-Fi as sensor to measure the occupancy in the office.

At the NLG, a similar case was started in 2017 for insight into available workplaces for employees. This originated from a strategy from the government which affected the office at the Rijnstraat where the norm changed to 0.7 workplaces per employee. By means of Wi-Fi, the occupancy is measured at the office and the frequency by the desktop pc's and docking stations.

The other cases not included in this study but inventoried during SCT 2.0 were similar types of Smart tools such as for real-time monitoring of space use, find a workplace or meeting room, and align energy use with the building use (Valks et al., 2018).

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.

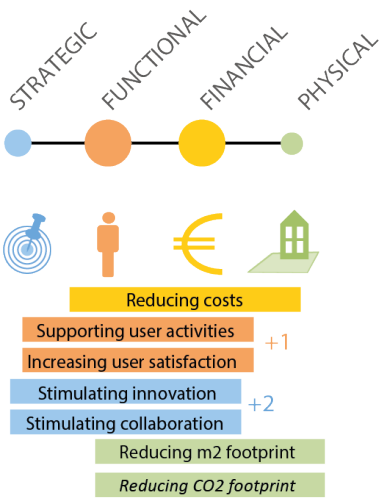


Foreseen developments

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

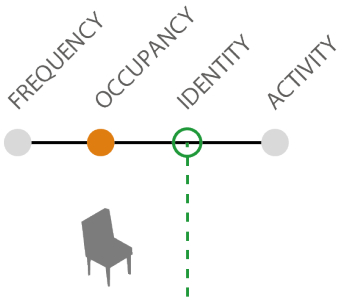
Profile

Why: Objectives



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. *Actually, the functional objectives are as important as the financial objectives.*

What: Measurement



With Wi-Fi personal data is collected. Lone Rooftop deals with this issue by anonimizing its data differently every day and by anonimizing 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

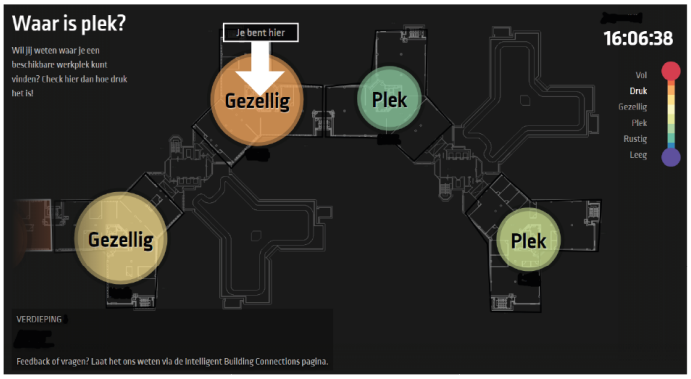
Monitoring space use, find a workplace

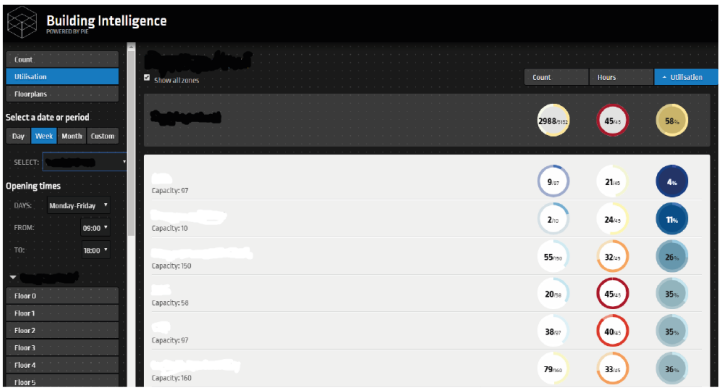
space types

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.

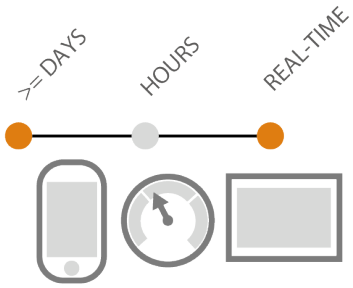




Management information

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

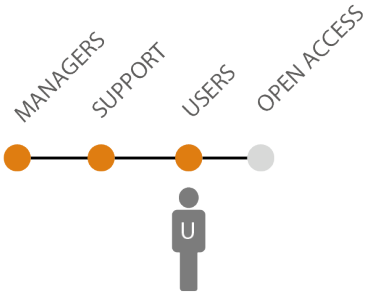


The information displayed in the dashboard for employees, in floorplans and reports is real-time.



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 organisation.

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.

To create -as we call it- a Wi-Fi 2.0, the access points are replaced to improve the Wi-Fi structure. Due to the large offices this has taken longer than expected, only when this structure improvement is completed then the system can be recalibrated. This resulted in hardly any use of the tool in the last two years.

NLG-1 — Dutch government — Plekchecker

phase: Implementation

scale: 80.000 m2, 1 building

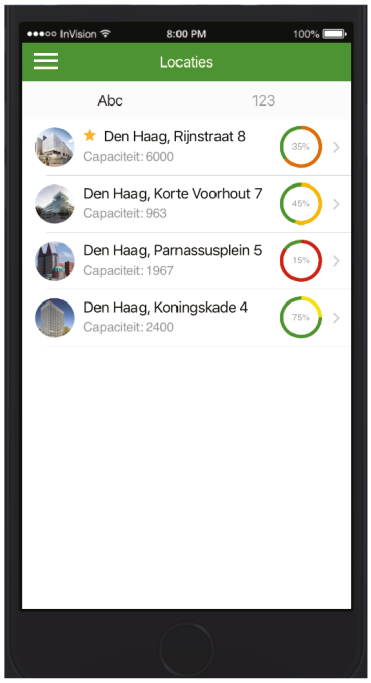
duration: July 2017-present



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.





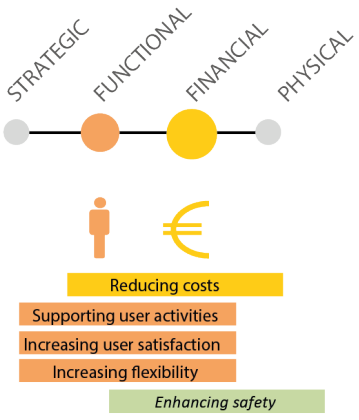
Foreseen developments

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.

One development is the creation of our own LoRa. This is a faster network to which sensors can be connected. This has advantages in terms of own management of data without intermediaries (The location for this implementation has yet to be determined). In addition, a new kind of PlekChecker with reservation possibilities (First, the possibilities on the market are examined and otherwise the current PlekChecker will be expanded).

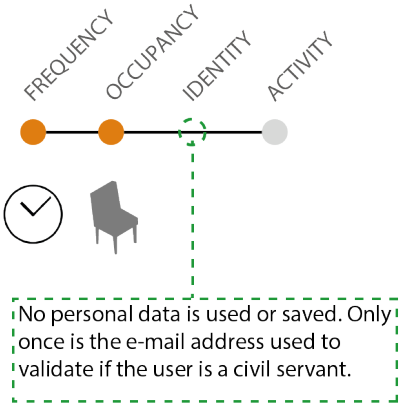
Profile

Why: Objectives



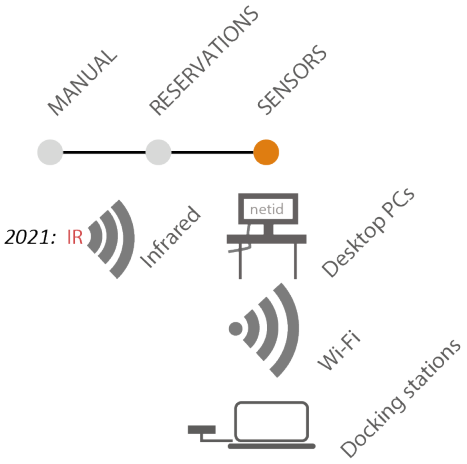
Financial objectives have priority, they are achieved by reducing the amount of offices and using the existing space more effectively.

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.

Infrared sensors are positioned beneath the desks. Due to the height of the buildings, we are not positive about the accuracy via Wi-Fi.

NLG-1 Dutch government Plekchecker

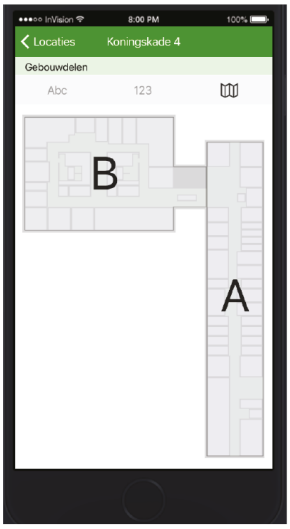
functionalities
Find a workplace, monitoring space use

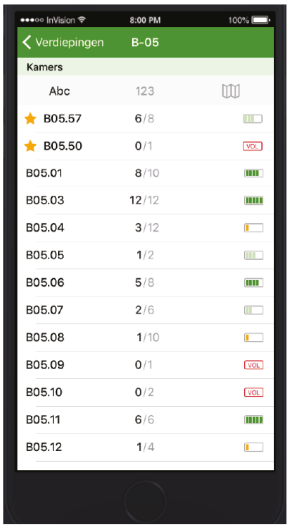
space types
Whole building



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.



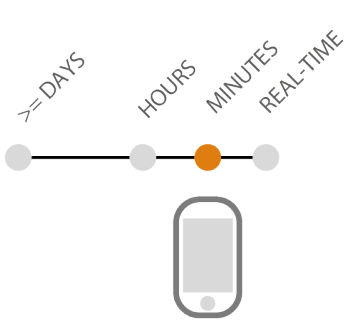




Management information

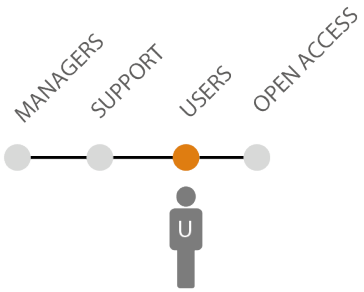
The occupancy reports based on the collected Plekchecker data has not been developed yet. At the moment there are talks with facility services providers about the form of these reports. This functionality will then be developed in a separate development process.

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.

Wi-Fi signals do not function well enough in our buildings because of the height. In addition, the algorithms to measure aspects over Wi-Fi are not government owned, so this has to be purchased commercially from a party which is not actually preferred

7.3.2 Modifications to existing templates

For the templates just shown, the performed modifications will be described. In doing so, a comparison is also included with the foreseen developments that have been identified in the SCT 2.0 research and ascertain if progress has been made on these developments.

Main modifications

First of all, building intelligence is the existing case at ABN. ABN has created an additional goal, reducing the CO2 footprint. In addition, the functional objectives have been given equal importance to the financial objectives, whereas the latter used to be the focus.
A striking statement is that this case has hardly been used in the last two years. Apart from COVID-19, this has had to do with the improvement of the Wi-Fi network. The access points are being replaced to create the Wi-Fi 2.0 (as they call it) network. Only when all these units are replaced can the network be recalibrated for use. Since the large offices, this has taken longer than expected.

The second case, the Plekchecker at the NLG. In addition to improving safety as a secondary goal, Wi-Fi has been perceived as an inaccurate measurement method due to the tall buildings. An action adapted to this is to apply infrared sensors underneath the desks.

The third case, of Edge Technologies at the Edge building where Deloitte had many initiatives as an ambition. There have been several small pilots with point solution providers but no structural changes in the building yet. Outside of the innovation track of Deloitte, the 'Smart' part did move more towards the core business of their portfolio. This is a new angle of the company.

The new foreseen developments for the existing templates that emerged during these interviews are described at chapter 6.4.

Progression of foreseen developments 2017 - 2021

One component to determine progress among the other organizations is to check for progress around existing anticipated developments identified in previous research.

- As for the ABN, the existing foreseen development for creating insights into the frequency and occupancy of meeting rooms with other sensors is still valid. A pilot is now being conducted for this ambition.
- The same applies to the three foreseen developments at the NLG. To comply with all own requirements, an own Lora network is now implemented to link sensors and so that data is in own control.
- Because it cannot be explained with certainty which developments have been achieved at the Edge, this is unknown.

The next page will present the templates for the new Smart tools. This is the situation for the ABN, who initiated two new Smart tools. After the templates, various results are analyzed and described.

7.3.3 New templates

ABN — ABN AMRO — Werkplekbezetting



phase	scale	duration
Research	220.000 m2 4 buildings	2020 - present

Project description

We are now in the phase of naming requirements for a Smart Building solution as we would like it to be in the future. This is not just about presence, but more about the principle of 'searching' and 'finding' all the facilities, colleagues or other information you need before you go to the office, are in the office and leave the office again. Whether or not in combination with being able to reserve these facilities or not. The number of individual workstations will become scarce and so the plan is for employees to make reservations. But what needs to be reserved? Is this about a chair, stool, space, or a part of the day? It is yet to be determined what the solution will be, and what tooling will be used to do so.

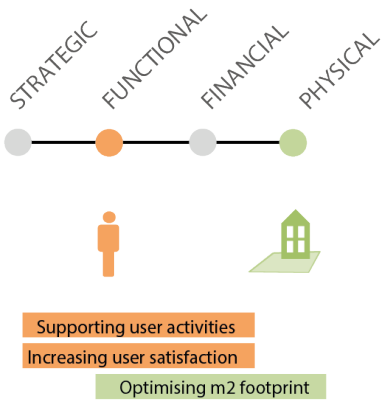


Foreseen developments

Once it is clear what the future of work will look like, and what needs to be reserved, this workplace system should be offered to employees in an application, or browser.

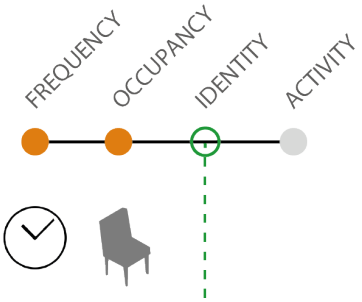
Profile

Why: Objectives



The aim is to use workplaces as efficiently as possible and to reduce the number of places occupied by a bag or coat.

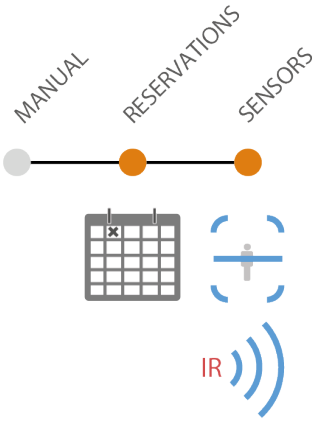
What: Measurement



The video analysis technology in the ceiling is a sensor that translates the video directly into a number which indicates the number of users.

Depending on which type of sensor will be implemented after a pilot but both sensors can measure frequency and occupancy.

How: Measurement method



The user will soon have to make reservations to attend the office. In addition, there are two sensor techniques to be tested in a pilot. One is a PIR solution namely a desk sensor (infrared) and the other a video analysis technique from the ceiling.

ABN

ABN AMRO

Werkplekbezetting

functionalities

Find a workplace, monitoring space use, booking system

space types

Whole office building



User information (employees)

The user - in this case employees - will soon get an indication on a display or application with a floor plan whether a workplace is completely available or almost available or occupied. In addition, the user will need to make reservations from home to attend the office. What needs to be reserved has yet to be researched.

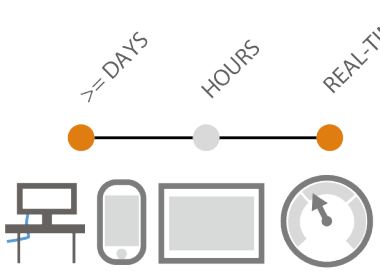




Management information

In addition to dashboard access, managers need to get insights from reports to information such as no-shows. The number of bookings and the busy spots in the office.

Actuality of the information

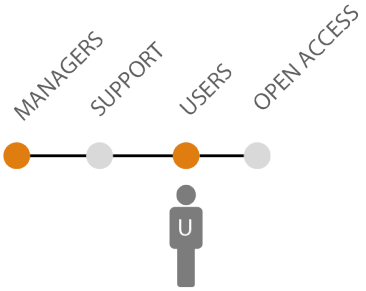


For user information, it is not yet certain whether it will be an app, display, or a site. The information will be near real-time.



The data used in reporting will be from near real-time to as far back as possible.

Access levels



Information from the tool will be available for the employees, and they are able to reserve.



The dashboard and reporting functions will be available to managers.

Benefits

-

Side notes

-

ABN

ABN AMRO

Pilot Floors (TRP)

phase
Pilot

scale
2 floors, 2000m2

duration
jan. 2020 - jan. 2022

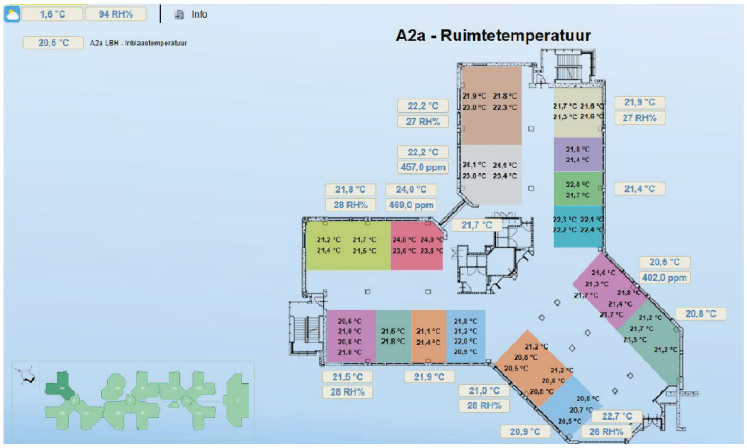


Project description

In addition to using a current smart tool - Building Intelligence with Lone Rooftop - an additional goal has been added that was less focused on three years ago, and this is sustainability. Besides measuring occupancy we want to measure different aspects to reduce energy consumption. The pilot is primarily about verifying the operation of the installations and the measurements. Technical factors such as decibel, lumen/lux, ventilation rate, °C, and possibly measuring oxygen or CO2. It is not yet clear how we will implement this, or how it will be represented in a tool.

Foreseen developments

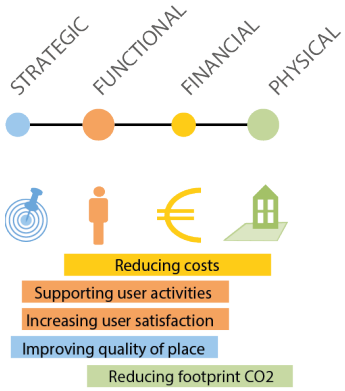
We are still exploring the possibilities of presenting data obtained from the sensors to our employees. It would be great if this could be incorporated into the dashboards in collaboration with Lone Rooftop.
We are just starting the development of a new office in Amsterdam Zuid-Oost (realized in four years). This office will be state-of-the-art that must optimally meet employee-experience, new way of working, sustainability and smart buildings requirements/expectations. If the pilot is a success this smart campus tool will be implemented in this building.



Management information about the relative humidity, temperature, and CO2.

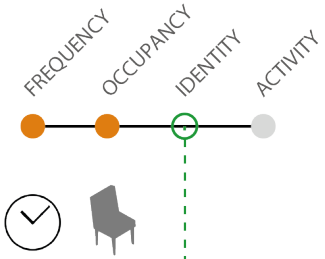
Profile

Why: Objectives



A goal from ABN AMRO is to comply with the paris proof agreement and to make this happen, the goal is to demand-controlled ventilation and lighting. In this way, the aim is to reduce energy and also costs. In addition, the goal is to provide a healthy working environment for the employees.

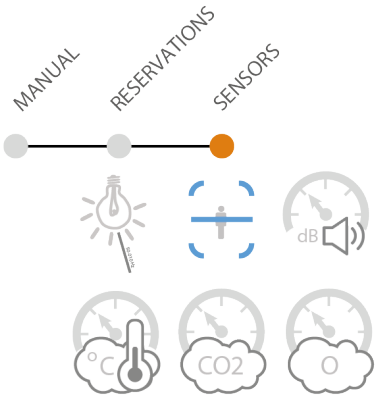
What: Measurement



The video analysis technology in the ceiling is a sensor that translates the video directly into a number which indicates the number of users.

Frequency and occupancy are measured on the office floor and in the rooms.

How: Measurement method



Sensors from the building control system supplier are used to measure the temperature in the room (these can also be used to set the room temperature)
In addition, another test is being conducted in this pilot with a ceiling sensor (video analysis technique) that measures frecuency and occupancy. Other sensors measures information about the lighting system, frequency, occupancy, temperature, sound, and humidity.
Also, depending on the occupancy, a quantity of air is supplied for ventilation. That quantity of air is attuned to the CO2 concentration.

ABN

ABN AMRO

Pilot Floors (TRP)

functionalities

Monitoring space use, demand-controlled ventilation and light

space types

Offices (2 floors)



User information (employees)

The user - in this case employees - has no access to the information during the pilot. Eventually, users should be informed, for example, by a monitor per work floor with a rating of the indoor climate.

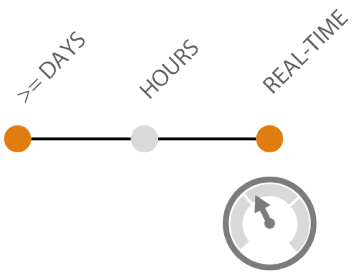




Management information

For managers, there is acces to the technical data per space. The pilot is testing sensors that can retrieve data on cooling, sound, light, heating, ventilation, oxygen, and CO2.

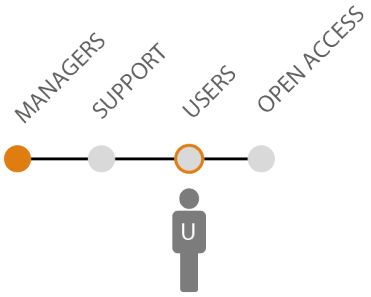
Actuality of the information



The information displayed in the dashboard is near real-time (an average of every 10 minutes is registered)

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

Access levels



In the pilot, users do not yet have access to the data. This still needs to be facilitated.

The dashboard and reporting functions are available to the managers

Benefits

The pilot has just started and it will last for a year to monitor and analyze the seasons and figure out how the installations are performing with it. So, it is still too early to mention benefits.

Side notes

This pilot also includes a test to measure room temperature and climate at the ceiling. This should actually be measured at observation height rather than the ceiling. The difference between the observation height and the ceiling height is now being investigated to create data with the difference.
In addition, we are curious to be able to control the ventilation in advance instead of ventilating away excessively high CO2 concentrations afterwards.

7.4 Analyzing the results

In this chapter, cross-case analysis will be applied to analyze the results of the new and existing cases from the other organizations interviewed. These analyses will clarify the following aspects; the timeline, foreseen developments, objectives, space use measurements, measurement methods, actuality of information, and access levels. In this way, insights are created from the obtained data in the cases.

Timeline

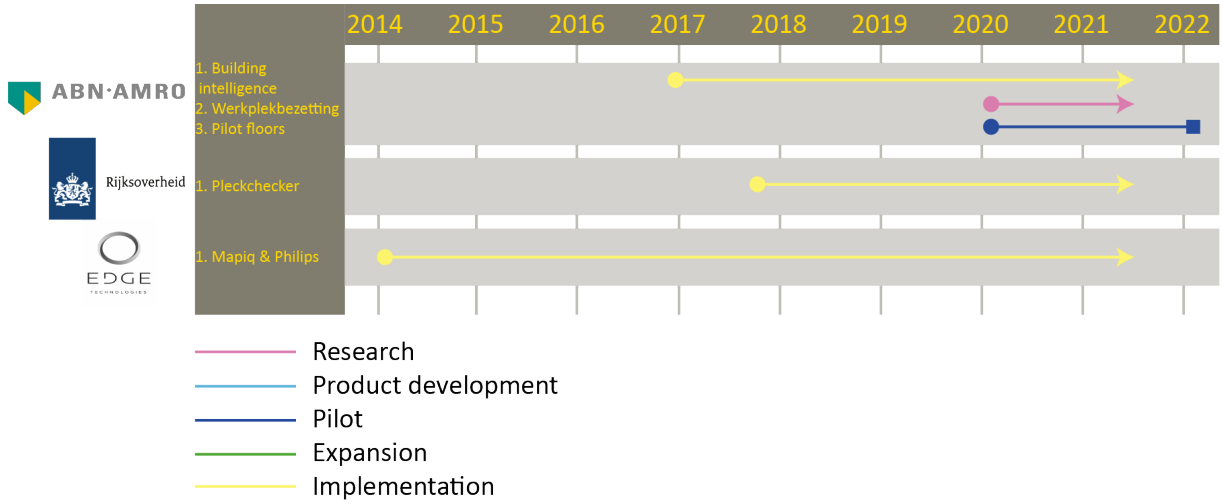


Figure 7-5: Timeline of the Smart tools at the other organizations (updated from Valks et al., 2018)

The timeline describes five cases collected from three other organizations in the Netherlands. From the timeline, it appears that there are no cases that are on hold. Also, it is notable that two new cases at the ABN have been initiated around 2020-2021.

Foreseen developments

An explanation will be provided for the new foreseen developments of existing cases and the new cases for the three organizations.

At the ABN, regarding the werkplek case, once it is clear what the future of work will look like and what needs to be reserved, a system should be offered to employees in an application or browser. ABN still needs to experience how the systems and technologies function and how this will be presented to the users for the pilot floors. Depending on the pilot, the infrared or video analysis technique will be selected as the measurement method.

At the NLG, the location for implementing the LoRa network has yet to be determined. A proof of concept has just ended with major vendors with their hardware. Then the implementation of the additional network layer begins. In addition, NLG is looking for an employee reservation system. Depending on what the market can provide, Plekchecker will be considered to offer this. Last, offer users the possibility to use spaces depending on their preferences, such as ambient noise or indoor climate. Hence the variety of sensors being tested in the pilot.

From the interview with EDGE, it appears that Deloitte, due to COVID-19, is identifying what their needs are for the new way of working, including in terms of portfolio strategy

For the following cross-case analysis, figures have been created to analyze the previously mentioned aspects. In order to make comparisons possible as an indication based on numbers, numbers and percentages are shown in the light blue rows of the results from the SCT2.0 and from this research. According to the left column, the colors below indicate whether this is a new SCT or an existing SCT that is still in use.

New SCT cases

Existing SCT cases still in use

In the figures, icons are displayed in the rows where for existing cases a distinction is made in the opacity of these icons. This is shown in full opacity for modified parts and reduced opacity for existing parts. With regard to the textual parts in the figures, modifications are indicated in italics as in the existing templates. First, the objectives are outlined.

Objectives

During the interviews, for new and existing cases, the objectives for which the Smart tool should contribute were requested again. For this purpose, the objectives from the framework of Den Heijer et al. were applied (Chapter 3).

First, a description will be presented to reflect the type and associated objectives inventoried during the SCT 2.0 research. Then, following Figure 7-6, it can be analyzed whether there are similarities or differences with corresponding new and existing SCTs.

The SCT 2.0 research indicates that there are three types of Smart tools (which are still in use) inventoried at the other organizations. These are the real-time monitoring of space use (1), to find a workplace (2) or meeting room (3). Many of these organizations from the SCT 2.0 research employ a Smart tool that allows them to provide these three capabilities. In all organizations, the objectives focus on the four different aspects with the functional objectives being the most common.

On the next page, Figure 7-6 will show the objectives of the new and existing (still in use) Smart tools in an organized manner. The objectives reduce footprint and enhancing safety is marked with a star to indicate that these objectives did not occur in the SCT 2.0 research and hence there is a larger difference.

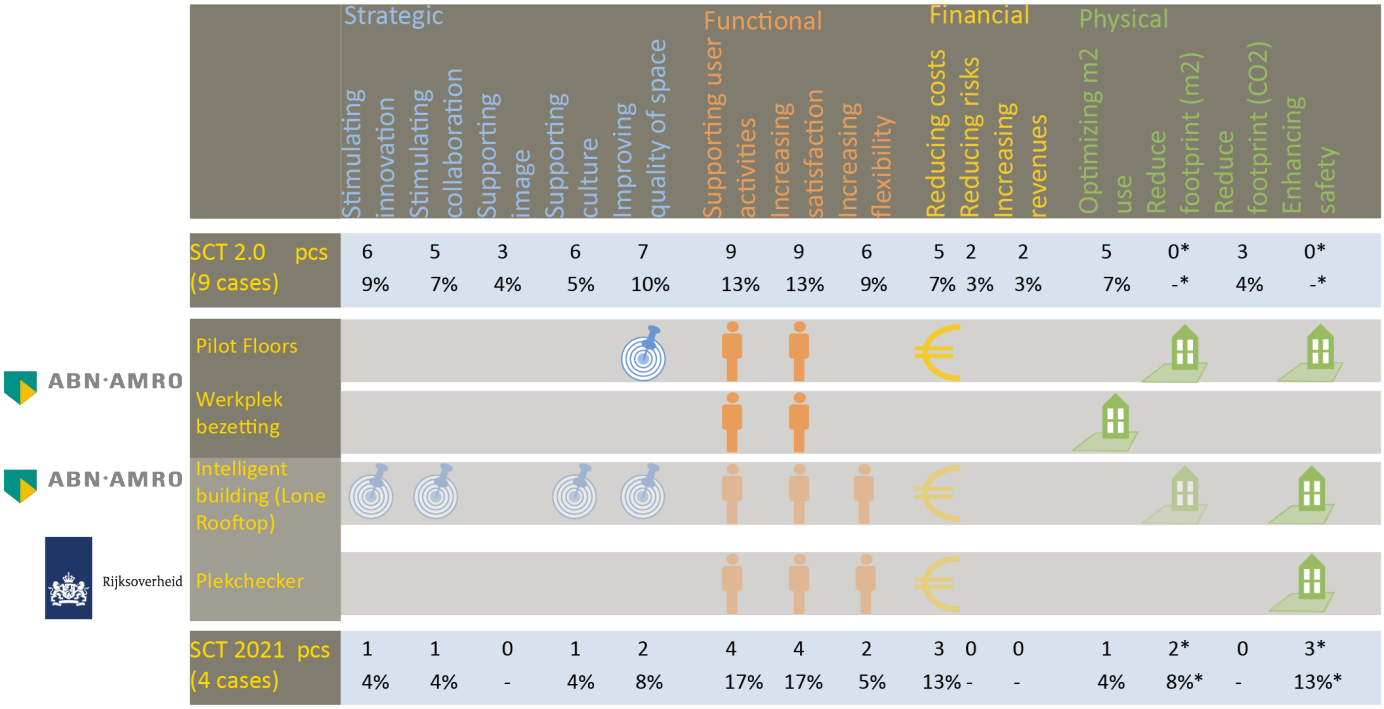


Figure 7-6: New and existing cases at two organizations with the different objectives per case (adapted from Valks et al., 2018)

From the figure, it can be concluded that the focus is on different objectives but mainly on functional objectives, despite the different types of Smart tools, which is comparable with the cases in the SCT 2.0 research.

The interviews reveal that there are three types of Smart tools inventoried at the two organizations. These are all corresponding Smart tools compared to the SCT 2.0 research and are the real-time monitoring of space use (1), to find a workplace (2) align energy use to the building use (3). Where in each type of Smart tool, supporting the user is still central.

The figure shows that 13% of the total objectives serve to enhance safety and that three out of four inventoried Smart tools serve this purpose. This partly indicates the modification at the NLG where the Smart tool serves to monitor how many people are in the office since the reduced capacity by COVID-19. At the ABN, this is subject to an attendance record for the same reason, to enable back-to-office.

Space use measurements

For space use measurements, the same types were again applied as in SCT 2.0. The figure below shows that relative to the SCT 2.0 study, there is still an emphasis on frequency and occupancy, despite the different Smart tool types.

Case	Privacy	Frequency	Occupancy	Identity	Activity
SCT 2.0 pcs (9 cases)		6 50%	5 42%	0 -	1 8%
Pilot Floors	The video analysis technology in the ceiling is a sensor that translates the video directly into a number which indicates the number of users.				
Werkplek bezetting	The video analysis technology in the ceiling is a sensor that translates the video directly into a number which indicates the number of users. With the IR-sensor, the users are not recognized so in terms of privacy aspect this is not an issue.				
Intelligent building (Lone Rooftop)	With Wi-Fi personal data is collected. Lone Rooftop deals with this issue by anonimizing its data differently every day and by anonimizing it directly after data collection.				
Plekchecker	No personal data is used or saved. Only once is the e-mail address used to validate if the user is a civil servant..				
SCT 2021 pcs (4 cases)		3 43%	4 57%	0 -	0 -

Figure 7-7: New and existing cases at two organization showing the various uses of the measurement space. Privacy issues are presented when applicable (adapted from Valks et al., 2018)

In terms of the level of space measurements, the three cases focused on the use of office and meeting rooms, which is consistent with the results of SCT2.0. It appears that for monitoring the number of employees present in the office building, at the ABN and NLG, there is a stronger focus on occupancy. With respect to the two existing cases at the ABN and NLG, there are no changes in terms of space use measurement.

According to the privacy aspects, the SCT 2.0 research examined the ways in which data was anonymized across cases. From the interviews, it became clear that there are no issues with the privacy aspect for these cases. A deliberate choice at the ABN was made for a video analysis technique in the ceiling that does not look like a camera and where the video directly converts users into numbers.

Measurement methods

Compared to SCT 2.0, it appears that different measurement methods are still used in the new and existing cases. In the figure below, the organization and case are described by name, explanation of measurement method, measurement method, and lastly -where possible- what the specific application is. In Table 7-3, the numbers are shown with percentages of the different measurement methods to provide an indication of the results from the SCT 2.0 research compared to this research.

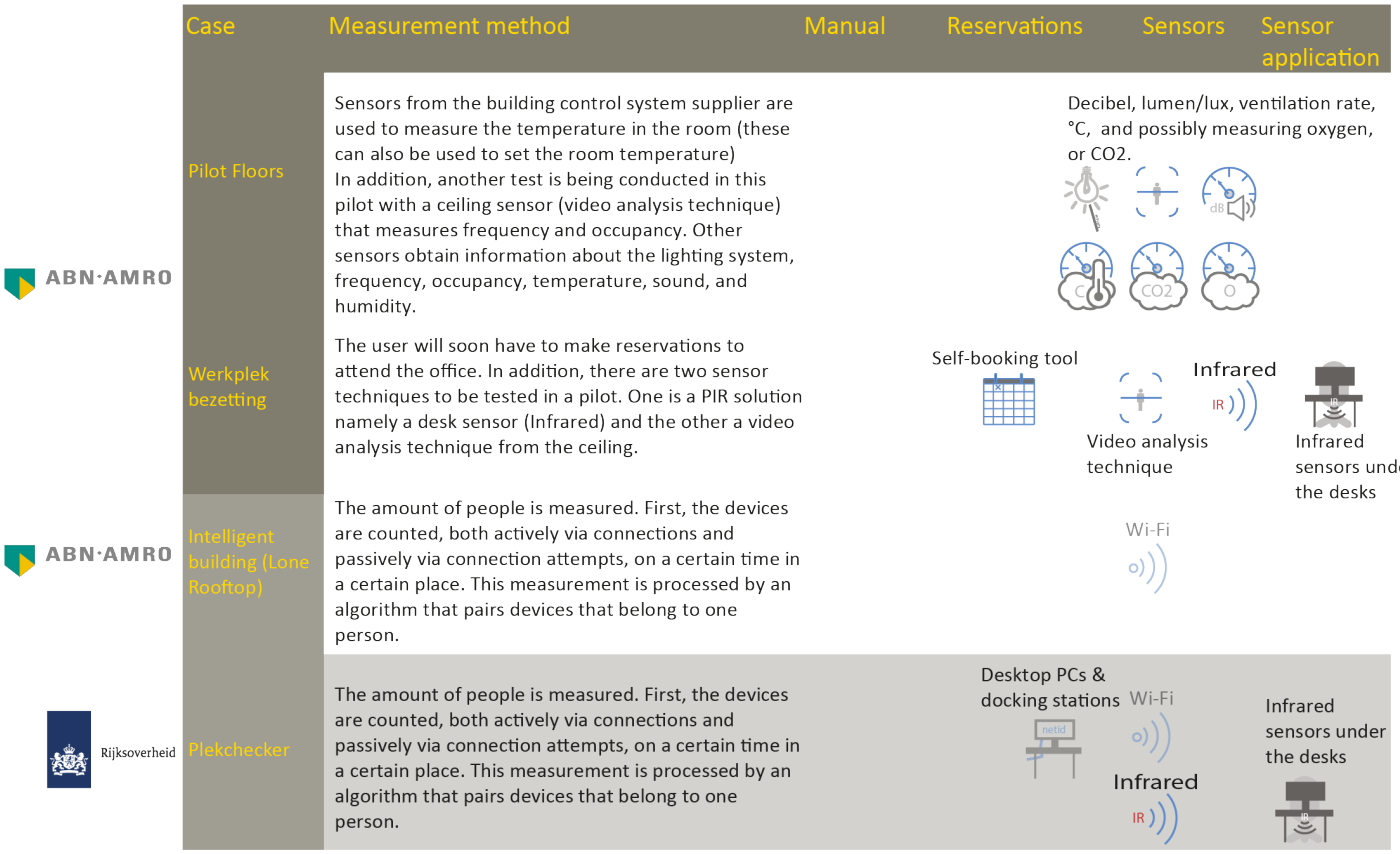


Figure 7-8: New and existing cases at two organizations with the different measurement methods applied (adapted from Valks et al., 2018)

Table 7-3: Comparison of numbers and percentages for the measurement methods of existing and new SCTs between the SCT 2.0 and this research.

Type	SCT 2.0		SCT 2021	
Reservations				
Self-booking tool	0	0%	1	100%
Outlook data	2	40%	0	0%
Reservations: check in by employees	1	20%	0	0%
Calender data	1	20%	0	0%
Reservations: check in by employees (QR & coded light)	1	20%	0	0%
Total:	5	100%	1	100%
Sensors				
Wi-Fi	5	24%	2	17%
Infrared	3	14%	2	17%
PC login	2	10%	1	8%
CO2	3	14%		0%
Camera	1	5%	1	8%
Temperature	3	14%	1	8%
Ventilation rate	0	0%	1	8%
O	0	0%	1	8%
Bluetooth	1	5%	1	8%
RFID	2	10%	0	0%
Software data	1	5%	0	0%
dB	0	0%	1	8%
Coded light	0	0%	1	8%
Total:	21	100%	12	100%

The SCT 2.0 research revealed that five of the nine organizations apply multiple sensors. What can be concluded from the figure, which is comparable to the SCT 2.0 research, that the use of multiple sensors is still popular. This is also evident in Table 7-3 despite the fact that there are four cases.

For the case (Werkplek bezetting) for the ABN, depending on the results during the pilot, the most accurate method will be selected. Since there is a greater measuring demand on the chair level, tests are conducted with sensors other than Wi-Fi, which is now applied with Lone Rooftop. In addition to one of the nine cases from the SCT 2.0 research that also utilizes reservations, this is the first case with a self-booking tool. This will be due to the demand for back-to-office capability during the COVID-19 period. Furthermore, the case (Pilot floors) at the ABN adopts similar sensors to align energy use for building use with the two comparable type of cases from the SCT 2.0 research.

With regard to the existing cases, nothing has changed at ABN, only that this case has not been used for the last three years because of the replacement of the Wi-Fi access points which took a long time. In addition, NLG indicated that they were not satisfied with the accuracy of the Wi-Fi as a sensor due to the height of the buildings so infrared sensors were applied.

Actuality of information

In terms of actuality of information, comparable actuality of information is applied for different cases. Figure 7-9 presents an overview of the different cases at the other organizations with a description and the actuality of information. In Table 7-4, the numbers are shown with percentages of the different information supply to provide an indication of the results from the SCT 2.0 research compared to this research.

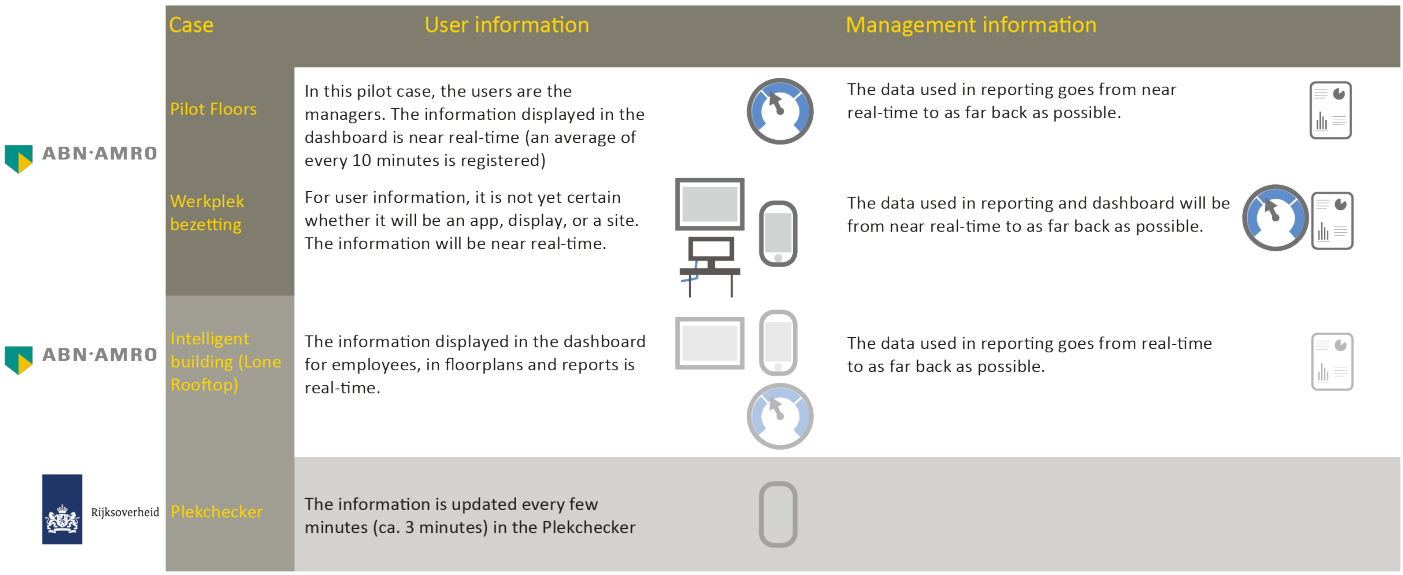


Figure 7-9: Per case with information about the actuality of information reported at one organization (adapted from Valks et al., 2018)

Type	SCT 2.0				SCT 2.0			
	user		Manager		user		Manager	
Webpage	2	18%	0	0%	1	14%	0	0%
App	6	55%	0	0%	3	43%	0	0%
Dashboard	0	0%	1	14%	1	14%	2	40%
Report	0	0%	6	86%	0	0%	3	60%
Display	3	27%	0	0%	2	29%	0	0%
Total	11	100%	7	100%	7	100%	5	100%

Table 7-4: Comparison of numbers and percentages for presenting the actuality of information of existing and new SCTs between the

From the figure above, it can be concluded that the actuality of the information is applied in a mostly similar way, despite the three different type of Smart tools. Similar to the SCT 2.0 research, management information is presented in a dashboard or report at the ABN, for the NLG, this is under development. The same applies to presenting user information where an app is the most chosen application.

The SCT 2.0 research indicates that four out of nine cases display real-time information; these are also the two comparable cases with the ABN case (Pilot floors). In this comparable Smart tool, real-time information is utilized but at the ABN, during the pilot, a method with near-real time information was still applied.

Access levels

For the last aspect, information was obtained for the access levels within the organization that have access to the use or information of the Smart tools. From the figure below, it can be concluded that the result is similar to the SCT 2.0 research, distinguishing between the accessibility of available information and use for managers and users. This is also apparent in the percentages despite the different types of Smart tools.

Case	Specification	Managers	Support	Users	Open access
SCT 2.0 pcs (9 cases)		7 41%	3 18%	7 41%	0 -
Pilot Floors	The dashboard and reporting functions are available to the managers. In the pilot, users do not yet have access to the data. This still needs to be facilitated.				
Werkplek bezetting	Information from the tool will be available for the employees, and they are able to reserve. The dashboard and reporting functions will be available to managers.			U	
Intelligent building (Lone Rooftop)	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.				
Plekchecker	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.			U	
SCT 2021 pcs (4 cases)		3 50%	1 17%	2 33%	0 -

Figure 7-10: New and existing cases at two organization with a description and method of access level (adapted from Valks et al., 2018)

From the figure, it can be concluded that different access levels are present for similar and different types of Smart tools.

Concerning the new case at ABN (Pilot floors), the SCT 2.0 research indicates that the two comparable cases aiming on aligning energy use with building use, all three utilize different access levels. With regard to the type of Smart tool where users can find a workplace or meeting room, it also appears that in the SCT 2.0 research the users have access to this, but three of the seven cases the managers

do not. This is the case in the new case at ABN (Werkplek bezetting) and in the existing case at the NLG this is still under development.

The figure also shows that the access level remained the same in the two existing cases.

7.5 Additional information

From here, results from the case study are displayed and analyzed that were not examined in the SCT 2.0 research. For the other organizations, there is no case on hold or where there has been no success. It does address the approach of reservation systems. In addition, the interviews investigated the extent to which the Smart tools applied to meet the needs and usage during COVID-19 and also potentially after the COVID-19 period.

Reservation system

In the case of the other organizations, it appears that a reservation system is not yet used for individual workplaces.
In the case of ABN, Planon was used -before the COVID-19 crisis- for reserving meeting rooms or registering complaint failures or reports. Since COVID-19, reservations have been made based on presence registration. In addition, research is being conducted into a tool that makes reservations possible, but it is not yet clear what exactly will be reserved.

Regarding the NLG, this still needs to be researched and implemented. It is expected that this year an interim solution will be used (such as Outlook reservation), and in two years, a permanent system will be implemented. This concerns the reservation of meeting rooms and workplaces. If this COVID-19 situation continues, then elevator reservation should also be considered. The biggest challenge here is not the technology but changing the way of working and the culture and creating support.

To what extent do these SCTs meet universities' needs and use after COVID-19

During the interview, the universities addressed this question to ascertain whether a SCT was applied during the COVID-19 period, how it was appreciated, and what could be improved.

The responses from the interviews reveal that at ABN, the existing system (Planon) allowed monitoring of how many employees had signed in and were in the office through the check-in system. In this way, monitoring can be done at the building level. This is a system outside of Lone Rooftop, and since Lone Rooftop is not yet functioning, and the SCT was not used during the COVID-19 crisis.

NLG is satisfied with the current SCT, where COVID-19 modified the use case of Plechecker. This changed to analyzing whether there are not too many people in the building where employees could self-assess whether they could safely go to work.

ABN mentioned a reservation system as an improvement, which is currently being investigated. In addition, investigating the possibilities between Planon and Lone Rooftop so that reservations can be properly monitored in the future. A similar reason applies to NLG. Namely, a reservation system for workplaces to provide all employees with a structured service in one or two properties.

7.6 Conclusions

The purpose of this chapter is to answer the fourth and fifth sub-questions with the information from Chapters 6, 7, and 8. In Chapter 9 where the follow-up brainstorming session is discussed, certain aspects are confirmed where answers to these sub-questions are reinforced.

7.6.1 Fourth sub-question of the research



Dutch universities

From this chapter, it can be concluded that the cases from nine Dutch universities, four have discontinued, nine new cases arose, four cases still in use, and two cases of which information can be given at a later stage. It turns out that the progression of the new cases is partly due to rapid implementation in a short period of time.

The interviews with the Dutch universities revealed that considerable progress had been achieved compared to the foreign and other organizations. The opposite applies in terms of four cases that are on hold or have not experienced success during the implementation process. In space utilization, nine new SCTs have been implemented and the five existing (and still in use) SCTs have been expanded.

According to the cases with foreseen developments from the SCT 2.0 research, progress has been made either by initiating a pilot or because the developments have been completed. The adjustments at existing SCTs and the new SCTs have been applied to measure the maximum number of users in the buildings instead of achieving maximum occupancy for certain space types. In addition, to use the limited space as efficiently as possible and to offer students a possibility to study on campus, progression has been made with reservation methods. Finally, with regard to measurement methods, the cases for crowd management are not dependent on data from reservation systems. This did not occur in the SCT 2.0 research at the Dutch universities.

Universities abroad

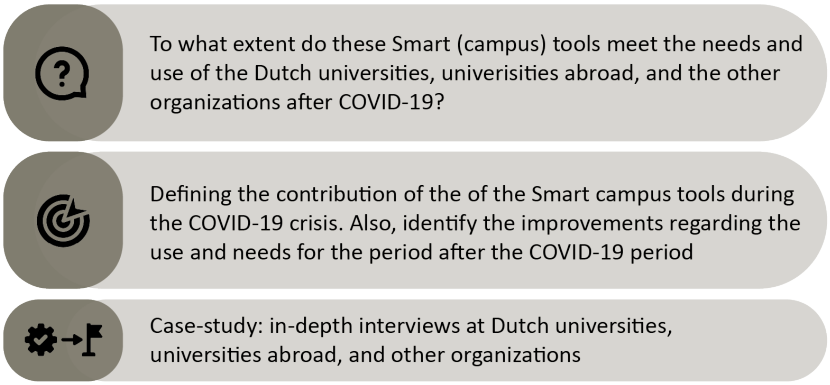
From the results from the case study at the universities abroad, it can be concluded that the interviewed universities abroad have achieved less progress in realizing new SCTs. One new case emerged from the interview at the Aalto. This case had been interviewed before but has not appeared in previous research. Regarding the progression of existing cases, AU's case is on hold. At the DTU, the progression has been made in terms of the measurement method. In addition to the expansion to all education buildings at the SHU, they have expanded Clocks with a dashboard that allows for better

monitoring of capacity through the COVID-19 regulation. Last, at the KU, the SCT has been extended to two extra buildings and modifications have mainly been made to facilitate back-to-campus in connection with COVID-19.

Other organizations

With regards to the progression at the other organizations, it can be concluded that two new cases have been initiated focused on space utilization at the ABN. In addition, the three existing SCTs are still in use and thus there has no delay or termination of SCT projects experienced. Furthermore, the emphasis in terms of progression is on the further development of the existing SCTs. However, it is remarkable that the existing case at the ABN has hardly been used for the past two years due to improved access points.

7.6.2 Fifth sub-question



The Dutch universities

From the interviews with the Dutch universities, it can be concluded that the existing and new SCTs have met their needs and use during COVID-19 times. It was mentioned several times that the back-to-campus was partly made possible by the use of SCTs.

In terms of improvements, in addition to further developing the existing and new applied SCTs, the focus is directed at better utilizing received data from SCTs for supporting users and decision-making. But also obtaining real-time information from sensors for study places. To indicate availability (in combination with reservation systems) and reduce no-shows for more efficient space use.

Universities abroad

From the interviews with the universities abroad, it can be concluded that the, four out of five universities are satisfied after the modifications to the existing SCTs, and this met their demand and use during the COVID-19 crisis. In the case of the AU, since the development of the SCT has been on hold, no SCT has been utilized during COVID-19. Also, the SHU, KL, and Aalto, by using the current measurement method, information could be obtained about the occupancy within the buildings. This could be monitored to keep track of the reduced capacity (according to COVID-19 regulations).

In terms of improvements, three universities abroad where SCTs are in use also identified room for improvement. With regard to the DTU and SHU, improving the information obtained from the SCTs, is also applicable. DTU would also suggest utilizing the functionalities of the cameras more effectively

once they are back at full capacity. Next, the SHU aspires to generate more insights into the use of spaces outside the timetabling system and use heatmaps to support the Back-to-campus phase. Last, the KU indicates that that there are aspects to improve for the middle and long term. Such as improving the synchronization time to enable action on no-show and early check-out.

Other organizations

From the interviews with other organizations, it can be concluded that both organizations are satisfied. The ABN did not utilize the SCT during COVID-19 but applied an alternative reservation function in the existing Planon.

In terms of improvements, the ABN and NLG indicated that actions are being taken for a reservation system. In addition, NLG doubts whether they still need the total portfolio with hybrid working.

PART IV



2ND BRAIN-STORMING SESSION

8 2nd Brainstorming session

This chapter reports on the genesis, participants, structure, and results of the second brainstorming session. A second brainstorming session was organized in early May. Notably, notable statements and results from the interviews of the cases (described in Chapters 5, 6, and 7) were formed into statements and questions. These were answered by 13 participants from seven different universities in the Netherlands and one from Belgium. Some of these participants were interviewed during the case study, and the other part was not.

The statements and questions presented were divided into several topics: the 'Back-to-campus' phase, reservation systems, SCTs in a hybrid environment, identifying new SCTs needs, and support for SCTs. The main findings regarding the responses to the questions and statement, and the striking statements during the discussions were collected and outlined per topic in the next paragraph. For the report of this meeting, consult Appendix 0.

8.1 Main findings

'Back-to-campus' phase

SCTs are more relevant during the COVID-19 crisis than before.

The first proposition involved identifying whether SCTs were considered more relevant during the COVID-19 crisis than before. From the 13 responses, it can be concluded that SCTs were relevant before the COVID-19 crisis but became more relevant during the COVID-19. Also shown in Figure 8-1.

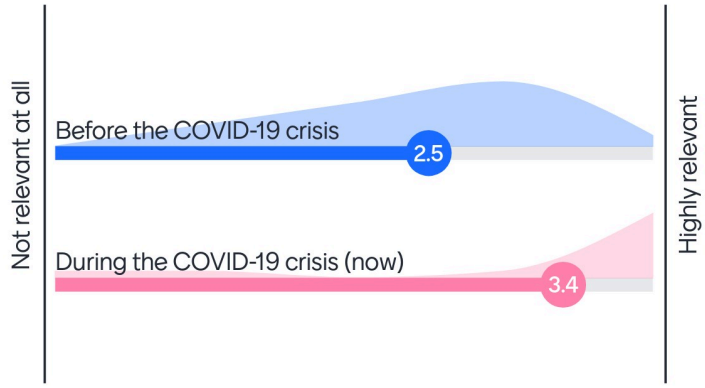


Figure 8-1: Relevance of SCT during the COVID-19 crisis (own figure from Mentimeter)

When considering the results from the first brainstorming session in November, there appeared to be six responses of which new SCTs have been obtained or are in the process of doing so and seven responses which are expanding existing SCTs since the COVID-19 lockdown (Valks, 2021). Combined with the result from Figure 8-1, these developments appear to have been more relevant than for the COVID-19 crisis.

Different themes that exist around SCTs

The second proposition revealed that there are several themes at universities around SCTs. The most frequently mentioned aspects are no-shows, privacy, occupancy of education spaces, and reservations.

Reservation systems during the COVID-19 crisis

From a discussion of the approach to the reservation, there appear to be different ways applied which were also noticed from the interviews. These include the difference in the use of slots, incentives or penalties, the quota of the maximum reservable hours/slots per week, how far in advance a user can reserve, and accessibility of users outside their university. These are all aspects with the aim of reducing no-shows. With regard to the aspect from how many minutes there is a no-show situation, there are also different approaches. These are between 15 and 45 minutes but this is still a matter of exploration. In addition, there is an approach at a university (which has been thought about at various universities) with a week limit per user for 20 hours per week. One notable statement made is that the no-show rate is not the most important indicator but how quickly time slots are reused by other users. In addition, difficulties are being experienced with current reservation tools with the supply of the number of specific spaces, by COVID-19 the demand emerge for spaces to 'Zoom'.

Other aspects that overlap with the results from the interviews are the presence of no-shows in the use of reservation systems during the COVID-19 period, the perceived no-show percentage was very scattered or unknown, and varied methods for measuring no-show. For the measurement method, it appears that nine out of twelve reactions utilize real-time information to measure space usage during the COVID-19 period.

SCTs in a hybrid environment

The responses indicate the greatest preference for showing available study rooms, teaching rooms, offices, and meeting rooms based on a combination of sensors and reservations. For teaching rooms, it should be clarified that there is an equal preference for reservation only.

In November during the first brainstorming session, two options for using a SCT for study places in the future based on sensors scored the highest (Valks, 2021). The other option was based on reservation data but there was no possibility for a combination of the two. When the results of Figure 8-2 are observed, it is interesting that the response to the second brainstorming session for showing availability of study places the combination option is significantly higher than for sensors only.

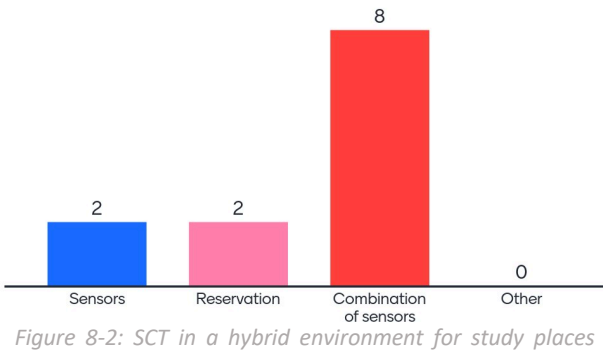


Figure 8-2: SCT in a hybrid environment for study places (own figure from Mentimeter)

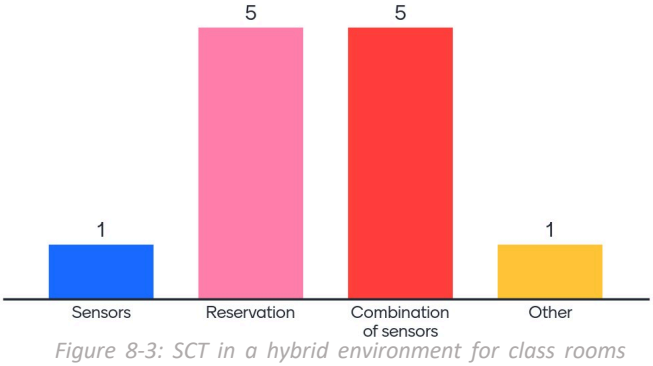


Figure 8-3: SCT in a hybrid environment for class rooms (own figure from Mentimeter)

In comparison with the SCT 2.0 study, it was not yet possible at Dutch or foreign universities to reserve individual study places and to see their availability. This was possible in a number of cases with project rooms or desktop spaces. On the other hand, there were three Dutch universities (one case a design brief) that applied a SCT to display study spaces in buildings, although their use was not measured. From the results of the case study, the interest in measuring study places increased and the use of reservation systems which is confirmed in Figure 8-2. Thus, compared to SCT 2.0, there is a change going on around study places and SCTs.
When considering the results from the first brainstorming session in November, there appeared to be a higher score for a SCT for measuring teaching spaces based on scheduled frequency and occupancy lockdown (Valks, 2021). But Figure 8-3 indicates that the preference changes to an equal preference for reservations and a combination of reservations and sensors.

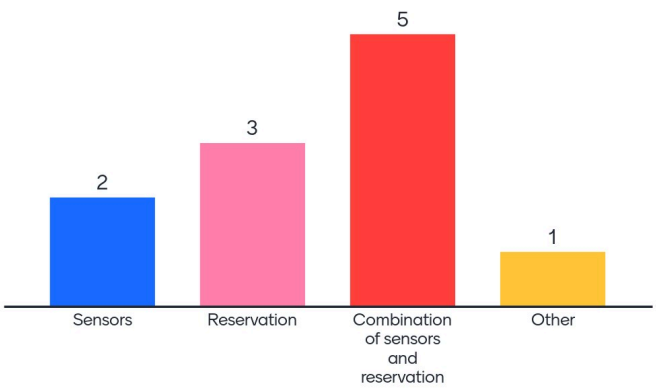


Figure 8-5: SCT in a hybrid environment for office spaces (own figure from Mentimeter)

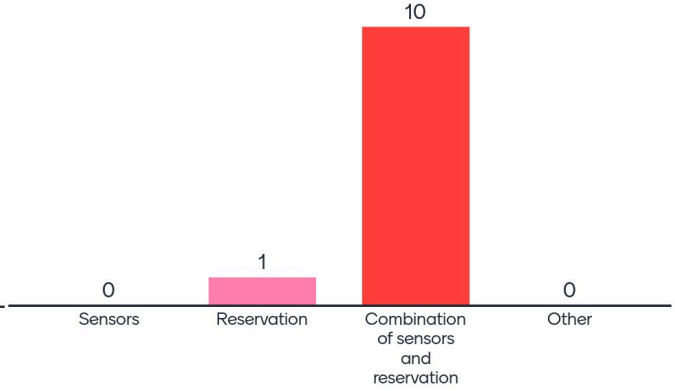


Figure 8-4: SCT in a hybrid environment for meeting rooms (own figure from Mentimeter)

From the initial brainstorming session, the responses appear to be similar to those in Figure 8-5 since the response was that the use of reservation and sensor data are seen as about equally promising for office spaces.

From these last two figures, there appears to be interest towards measuring use of office space and meeting rooms. Compared to the SCT 2.0 research, it appears that two of the nine foreign universities measure the use of office space and meeting rooms. This even applies to a lesser extent to the Dutch universities where no university measures the use of office space but two universities measure the use of meeting rooms. From the results of the interviews with international and Dutch universities, there also appears to be an interest in increasing the efficiency of the use of office spaces by measuring or reserving them. With respect to the needs of the attendees at the second brainstorming session, this appears to be confirmed again.

Identifying new SCTs needs

The responses show that there are new needs for supporting facilities processes and real estate policies. In addition, a similar need in the area of sustainability (energy management & predictive maintenance).

Support for SCTs

Responses during the first brainstorming session indicated increased support, at least at the administrative level, but the concerns of students and staff must be properly addressed (Valks, 2021). This may also have caused several tools to go through the process of implementing a SCT in a shorter time compared to the SCT 2.0 research.

In the second session, it became clear that universities use different methods to increase support for a SCT for its users. A common answer involves the end-users (communication or even decision-making) and clarifies the added value. As a second aspect, all participants agree that more attention is needed within universities for diligence in data collection, selection, and presentation.

8.2 Conclusions

The purpose of this chapter was to describe the main findings from the follow-up brainstorming session. This involved testing striking results and statements from the case study and gaining new insights by presenting statements and open-ended questions to the participants.

From this chapter, it can be concluded that SCTs became more relevant during the COVID-19 period than before. However, when this is compared to the hypothesis of this study, it can be derived from the changing context due to COVID-19. On the other hand, the measurement of space has been deployed differently than before COVID-19, where the safety of the users was mainly the reason rather than a hybrid form of education. However, it has been experienced that what is already observed with booking and no-show, that the importance with real-time information has increased. This is also evident according to the different room types where the combination of sensors and reservation were mentioned most often.

PART V

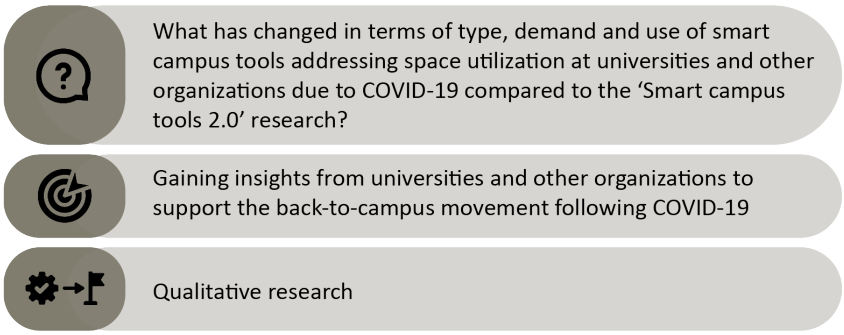


CONCLUSION

9 CONCLUSIONS

The purpose of this chapter is to draw up the conclusion derived from the results of the research. The answer to the main research question will be provided. In parallel, the hypothesis will be confirmed or disconfirmed based on the results of the research. In the third paragraph, in the discussion the results will be interpreted. This also addresses the reliability, limitations, and validity of the research. Finally, this chapter provides recommendations for further research and practice.

9.1 Main research question



This research inventoried how the use of SCTs at universities and other organizations has changed by COVID-19. In addition to providing insight into these actions, the developments that have taken place between the SCT 2.0 and this research are identified. To answer the main question, data was obtained from literature, seventeen interviews regarding cases of SCTs, and two brainstorming sessions. This research concerns twenty cases at Dutch universities, five cases at universities abroad, and five cases at other organizations.

Since the changes surrounding the COVID-19 virus occured, existing or new SCTs have contributed to the 'back-to-campus/office' phase. This has been achieved through reservation tools for individual study places and/or tools that display crowding indications in the buildings. This has facilitated the monitoring of the amount of users in the buildings and the ability to regulate capacity.

Type

- Compared to the SCT 2.0 study, through the modifications caused by the COVID-19 crisis, there are cases at Dutch universities that do not depend on data from schedule/reservation systems.
- The type of existing or initiated SCT is modified in many cases to enhance safety as an objective.

Demand

- With the change in demand at the management level by COVID-19, there is a growing urgency to manage the campus based on data (measuring to keep control) during the COVID-19 period.
- To meet the demand to study on campus, two implemented approaches can be identified by employing a reservation system with which students can reserve a study place or project room

or a crowding indication that creates insights for the user whether there are study places available and safe.

- From the interviews and brainstorming session, it appears that since COVID-19, the demand has increased for collaborations between facilities, management, or IT, since these departments focus on the use of SCTs too.
- New applications and foreseen developments show that the demand for real-time information for space utilization is increasing.
- With the insights of working from home, universities and other organizations have increased the demand to initiate reservation systems for workplaces.

Use

- At universities and other organizations, the use case for a SCT has mostly changed where existing sensors have been utilized to measure the occupancy in the buildings in order to monitor the capacity, instead of measuring to reach the maximum occupancy for space utilization.
- Since the introduction of reservation systems, a new form of occupying places without using them arose, which initially triggered the SCT study in 2015. This concerns reservations of study places that are not used afterwards (no-shows) due to inefficient space usage and other students who might have preferred to reserve and use this place.

9.2 Discussion

This chapter will discuss the results of this study. The main subjects that are explained are research design (1), the relationship between the existing theory and the results (2), the relationship with practice and the results (3), and the validity, reliability, and limitations of this research (4).

9.2.1 Discussion on research design

Brainstorming session

The first brainstorming session was prepared and held by Ir. Valks, who aimed to identify the current situation at universities regarding COVID-19. At this first session, participants from nine different Dutch universities and one Belgian university were present. This session was informed by previous research, four interviewed cases and desk research. Based on this information from different perspectives, it created reliable information. Since the COVID-19 crisis occurred just before the start of this research, this was an important source for refining the problem statement and contributing to the research questions.

Literature review

This research focuses on three topics around space utilization; campus management, SCTs, and COVID-19. Besides space management, which has been a well-known research topic for some time, there is a limited supply of scientific literature on campus management despite the increasing interest in improving space utilization in educational buildings. On this topic, Den Heijer's (2011) dissertation with comprehensive research on campus management has served as an important source.

Since this is research utilizes the SCT 2.0 research as the basis for mapping the adjustments made by COVID-19 and the progression between this and the SCT 2.0 research, existing scientific literature from these studies has been applied. In addition, in a short time, the range of scientific literature has expanded to include occupancy measurement, IoT, smart buildings, etc.
The third topic, the COVID-19 crisis what led to this investigation. Since this research took place shortly after the start of the COVID-19 crisis, little to no scientific literature was available focused on space utilization and campus management. Thus, the first brainstorming session was utilized as an important source of information from the practice.

In addition to updating previous research, the latter constitutes a scientific gap that this research aims to fill through new insights from the case studies. To ensure validity and the risk of biased information in this study, existing literature was applied, mainly obtained from the SCT and SCT 2.0 studies.

Case study

To obtain information for the case study, an interview protocol with semi-structured questions was established. In addition, the existing interview protocol from the SCT 2.0 research was utilized to obtain information from a newly initiated SCT. The approach and steps of the case study is described and substantiated in Appendix II. Further, the first step of processing these data was to fill out the similar template for SCT at Dutch and foreign universities and other organizations applied as in the

SCT 2.0 research. Subsequently, cross-case analyses were applied to process and analyze these data. Some of these figures were based on the SCT 2.0 research. In this way, the data could be processed and analyzed in a similar structured way. Sixteen interviews were conducted to gather the required information. In seven cases, due to lack of time or knowledge (too early to share information), no new template was created. These cases are listed in the case descriptions as known SCT but not included in this research.

For the reliability of obtaining the correct data, the interviewee received the interview protocol and the corresponding templates in advance. In this way, the interviewee had the opportunity to prepare and avoid unexpected questions. Then after processing these interviews, each participant had the opportunity to review and provide feedback on the draft files -interview report and templates. In addition, the majority of the interviewees had previously been interviewed during the SCT 2.0 research or present at the first brainstorming session. Thus, they were aware of the study or were familiar with the existing templates. Recently, the relatively small sample size for other organizations (for feasibility reasons) still provided valuable insights from different perspectives. The sample size for universities in the Netherlands and abroad supported a broader perspective since it involved a broader scope of nine and five interviews.

The interviewees seemed interested in the results since changes had been made in a short time at many universities and other organizations. The experiences and methods chosen were often unknown to each other. This was also evident in the willingness of some interviewees to participate in the second brainstorming session. Due to the COVID-19 crisis, the interviews were conducted via Teams, which was experienced as pleasant although it felt more impersonal.

The method of collecting, processing, and analyzing the information from the interviews proved to be an effective method for achieving the objective of this research.

2nd Brainstorming session

The follow-up brainstorming session was dedicated to presenting statements based on the results of the interviews and the first brainstorming session. Thus, in addition to gaining new insights, this session was also organized to assess the reliability of this information obtained. During this session, participants from seven Dutch universities and one Belgian university were present. This sample size created responses to the statements and questions from different perspectives. The participants seemed enthusiastic and interested in the results and the discussions that created new insights. Based on a 96% response rate, almost all statements and questions were answered by the attendees.

In addition to updating previous research, the latter constitutes a scientific gap that this research aims to fill through new insights from the case studies. To ensure validity and the risk of biased information in this study, existing literature was applied, mainly obtained from the SCT and SCT 2.0 studies.

Overall

To increase the validity and reliability of a qualitative study such as this research, a combination of methods was employed.

In terms of findings, results did emerge that had not yet been described in the theory. Such as the aspects surrounding the new form of "no-show" in reservations or the actions at the campus management level around SCTs in a pandemic such as COVID-19. Because of this lack of information but to increase the reliability to map the impact and adjustments on the campus by COVID-19, the first brainstorming session served as a starting point. This session was structured according to previous research, four interviewed cases and desk research.
Then, partly from the results and approach of this first brainstorming session, an interview protocol was created for the case study. This method was applied in a consistent manner by utilizing the same interview protocols and the interviews were always conducted in the same setting. Also, criticality during and after the interviews was maintained by asking questions (on the mail afterwards) about striking statements or results and in addition, the templates were reviewed by Ir. Valks.

The statements and questions in the follow-up brainstorming session were created from the initial brainstorming session and the case study. Notable statements and results were included in the second brainstorming session to test validity. By also applying a number of similar statements, remarkable changes could also be charted in the period between November and May.

In terms of overlap in the information obtained from the case study and the brainstorming sessions, results matched previous findings and thus the information matched the different methods. In terms of improvements, the candidates of the second brainstorming session received an invitation one month before the follow up session. In doing so, an effort was made to invite the same candidates as for the interviews and the initial brainstorming session, to ensure validity. Many of the attendees were also at the first session, the interviews (of Dutch universities) or both but possibly if the invitation had been sent earlier that there would have been a higher turnout with the same participants. This session was focused on the Dutch universities so it will be an improvement to organize either a combined session with Dutch and foreign universities and other organizations.

In addition, the case study participants had the opportunity to check the processed information and provide any feedback. Of the sixteen interviewees, five parties did not respond, even after a reminder. For these five parties, this would have been a possible improvement in reliability.

9.2.2 Theoretical- and practical implications

This paragraph describes first the observations from the literature study, which covered Chapter 3. This section aims to establish the relationship between the outcomes from the research and the theory. Furthermore, the second section discusses the findings of the case study and the brainstorming sessions.

The increase of different (use of) space types & the measurement method

During the research with space utilization as a focus, several space types passed by. Whereby the description of six space types from the first SCT research (Valks et al., 2016) research was applied as a basis. Based on the results in relation to existing literature, a number of examples where used designations for space types vary in certain studies. In the research of Valks et al. (2019) an overarching word is applied to study places, namely study spaces. But individual study places in a study landscape may vary in the most appropriate measurement method compared to project spaces. The same applies to existing tools described in the existing templates of SCT 2.0 here is sometimes also an overarching word described, such as education spaces. In addition, the results revealed that project spaces were defined as individual study places by the COVID-19 crisis in connection with the regulations surrounding the 1.5-meter rule. Since COVID-19, the focus has increased on individual study places but interest has also grown in monitoring or reserving work places (office space). In the existing templates, the word workplace is often applied but for spaces where student groups can 'collaborate'. While the term work place actually serves for an employee to work on campus. Possibly in the future work places and study places are mixed but that is not yet the case.

The definition of a SCT was expanded during the first SCT research with the why, what, and how (described in Chapter 0). Since the use (three forms of space use described in Chapter 0) and the demand for different types of spaces is changing, the type of space possibly also belongs in this list since this also determines which type of sensor is most suitable for this type of space. Most suitable again depends on aspects like accuracy, price, function possibilities, or privacy.

Added value

The goal of a SCT is to add value to the campus and its users. The thirteen objectives with the corresponding KPIs (described in Chapter 3.1), which have been applied from the framework of Den Heijer's dissertation (2011) were employed in this research. The first objective that did not occur in these thirteen objectives but was mentioned in nine out of seventeen (new and as additions to existing cases) of the cases is enhancing safety. This will be a relation to the regulations and the health of the users around the COVID-19 crisis. Since this was mentioned often, this goal was noted in the templates for the cases mentioned, although it differed from the existing thirteen goals.

A standalone reservations system as a SCT

Earlier during the literature review, the definition of a SCT and what constitutes smartness. From the results of the case study, standalone reservation systems appear to be in use. The purpose of a SCT is real-time information for more efficient use of space. But a tool where there is no measurement method for identifying whether a place is used, or by utilizing a QR code (manually) contributed in the COVID-19 crisis as a more efficient space use. Despite the fact that there is no real-time data acquisition. There has been research done on SCTs, but critics possibly disagree that a reservation tool is a SCT. But since this has been an important tool and has allowed for the efficient use of space, it has been included in this study.

Furthermore, there are other notable aspects surrounding reservation systems. With respect to the results from the interviews and brainstorming sessions, a new form of no-show was experienced (het

digitale handdoekje). Various methods are applied but, for example, few real-time information sensors for individual spaces. In this way, it is difficult to identify whether a user has used the place or not. In addition, it is striking that there are no objectives mentioned around the reservation tools for reducing finances or footprint CO2. Literature has indicated that spaces that are booked and not used cost money and other resources. In the study by Ibrahim et al, the Space Charging Model is explained using a case for lecture rooms (2011). This could be a method to reduce no-shows with reservation systems.

Use of a SCT

The current findings support the relevance of SCTs. These reveal that the use of SCTs in multiple cases enabled the "back-to-campus" movement in the COVID-19 crisis. In this, parties appeared to be able to scale quickly and make it manageable through the information obtained from the SCTs. This also offers potential in case another epidemic breaks out.

From the case study results and brainstorming sessions, there appear to be applications employed that are building dependent. In the case of Wi-Fi as a sensor, which proves to be inaccurate with certain building shapes but is perceived to be accurate. This aspect plays an important role in the operation of a SCT and thus is location-dependent.

In addition, the information from this study can be applied to implement targeted interventions on the utilization of SCTs. Lessons can be learned from the mistakes and reasons for no success while implementing a SCT.

Last, decisions made at universities and other organizations also go in conjunction with its users' demand and carrying capacity. The applications and methods that emerge from the results do not guarantee that they can be applied immediately by other users.

perception that space types and users of organizations differ substantially from universities

It is remarkable that a number of times in interviews with Dutch and foreign universities it is mentioned that tools are programmed for offices and that this does not go together with the different users and spaces of universities. Universities vary in shape, size, and supply of spaces but this is also the case with offices. Such as the variety of spaces from quiet workplaces, call cells, flex spaces, small workrooms, meeting rooms, collaborative spaces, to sometimes even a library. In which also different users use the office from cleaners, different layers of employees or support staff, to board members. Why is the reason that, universities are more complicated because many more different types of users are involved with their preferences, is often used as a reason that implementing a SCT?

9.2.3 Research limitation

Although this study sheds new light on the changes from the SCT2.0 study and reflects the changes from the changes in COVID-19, this study also has limitations.

The first limitation of the research is the lack of the empirical part. During the research proposal, there was an ambition to add an empirical observation when the situation around COVID-19 would allow it. In this way, the observations from practice could be linked to one's observations. By studying the situation at a university or organization, knowledge could be gained based on (sensory) observations or experience. Since SCTs are a privacy-sensitive component at universities and organizations, falsification is possible. This allows existing theories to be rejected and, where possible, replaced by better. This allowed existing theories to be potentially rejected and, if possible, replaced with better ones.

A second limitation of the study is that choices and applications may have been implemented in a short time and no longer apply after the lockdown period. On the other hand, the past crisis may also give an advantage that choices and SCTs have been developed that would otherwise have taken longer. Nevertheless, these are still uncertainties that may mean that the results from the case study after the COVID-19 crisis are not, still partially, or still valid. In addition, universities and organizations are making decisions or improvements around, for example, reservation systems and their approaches. During the interviews in March and April, it turned out that there were still uncertainties about certain aspects and foreseen developments in several cases. During the follow-up brainstorming session, it became clear that certain decisions had already been applied. Just like technology changes quickly, changes have already taken place within two months. Therefore, certain aspects may already be outdated in this research.

Another risk is that the interviews were conducted only with management employees rather than other users. The experiences among students may be different from what is thought at the management level, despite some cases involving students in the process.

A third limitation is the fact that this research only included large universities and organizations. The results may not be generalizable to smaller entities. Small schools or organizations often have a different organizational structure and culture that allows them to learn and anticipate a changing environment and the use of technology differently.

Concerning qualitative research, another risk is processing and analyzing the data. Although the information was obtained by means of a combination of research methods and the information processed according to a specific format, there is a risk. This is about the observations and interpretations of the researcher may cause subjectivity, misinterpretation, or information allocation of the data obtained. To minimize this risk, the processing of the interviews was validated with the interviewee and a combination of research methods is applied to increase liability.

9.3 Recommendations for further research

Conduct a repetitive research

Between this research and the SCT 2.0 is a 3-4-year time frame. In this time frame, there have been interesting adaptations and applications that could be analyzed. Several cases indicated that this study was just too early to provide more clarity. In this case, certain decisions still had to be made, depending on the new way of studying or working, before these decisions could be translated into a SCT. Thus, it is interesting to conduct a small repetitive study after the lockdown and possibly extended in a few years. This may lead to modifications of current applications and arguments about why certain applications, whether or not to continue, would be very valuable.

Conduct research with the other cases from the SCT 2.0 research that were not investigated

In this study, some of the cases were re-examined. A major part has been researched for the Dutch universities, but this does not apply to universities abroad and other organizations. In doing so, a more reliable conclusion can be drawn regarding the difference in progression between Dutch universities and universities abroad and between universities and other organizations.

Conducting a quantitative study to identify the effects the smart tools

In an interview, the question was addressed as to whether any statistics are already known about the reduction in exploration costs when using a SCT. To answers to these types of questions, it is recommended that a quantitative study be conducted. In this way, statistical evidence can be provided to prove the effects of applying a SCT. It will provide even more insight if the situation before and after integrating a SCT is mapped. In addition to the financial aspects, the reduction of CO2 should also be made clear. Possibly these two aspects will create more support among users and management when considering investments.

Conducting an empirical research component

As indicated, the COVID-19 crisis constrained the possibilities of empirical observation. This is recommended to link the observations from practice to one's observations. By studying the situation at a university or organization, knowledge could be gained based on (sensory) observations or experience. Since SCTs are a privacy-sensitive component at universities and organizations, falsification is possible. This allows existing theories to be rejected and, where possible, replaced by better. This allowed existing theories to be potentially rejected and, if possible, replaced with better ones.

Conducting a detailed design study

It was confirmed from the 2nd brainstorming session that there is a need for more attention to diligence in data collection, selection, and presentation. In addition, the interviews revealed that the procurement strategy is perceived as difficult. Thus, it is recommended to conduct a design study focusing on defining frameworks with requirements and principles for both of these aspects to utilize a SCT. This could be very useful for practice and may well consist of two separate design studies.

9.4 Recommendations for practice

This paragraph will describe the recommendations for practice generated from the two brainstorming sessions, case study, and theory.

Monitor progress of SCTs to determine the benefits

The research examined the existing tools that are still in use to determine the benefits in line with the objectives. The striking aspect of this question was that few benefits could be mentioned that contributed to the predetermined objectives. Thus, the recommendation to monitor the process so that the benefits are revealed. This can create trust and support for the use of SCTs.

No-show ('Het digitale handdoekje')

It is not yet sure how education will look like and in what capacity we will return to the campuses for study and work. During COVID-19, many universities experienced the new way of no-show using reservation systems. During discussions, opinions emerged that it is more important to provide a no-show spot quickly with a user than the occurrence of the no-show itself. But problem-solving is the process of leading to a solution to a problem, in this case, the user who doesn't show up. A recommendation is that with real-time information, no-show can be monitored and free spots can be displayed in real-time. But in addition, it is also important to be aware of the financial consequence of a no-show. This applies to all education spaces where spaces that were booked but not used contribute to wastage of lamps, electricity, fans or air conditioning, and therefore cost money. Perhaps a Space Charging Model could be considered to show the user the financial consequences of not using a reserved space which may increase awareness that a space is not free. In addition to financial implications, this also affects other resources, such as sustainability.

Note with the ability to make reservations in advance that the further in advance the more likely the user is to forget the reservation. This could include sending a notification the night before the reservation for a reminder. Also, apply a time period when there is a no-show when the user does not show up, from the follow-up brainstorming session it can be concluded that 15 minutes was fast but a period between 30 and 45 minutes was considered as realistic. Next, it should be clear whether the user is then allowed to use this place spontaneously or by making a reservation if it is understandable that there is a no-show. Soon we will arrive at a situation where there will be students who see the benefits of reserving an individual spot, and those students who would like to obtain a spot spontaneously. Per university, it depends if space is scarce, but try to establish a balance between reservable study places and places for spontaneous use. But be aware of the hazard of losing spontaneity by limiting flexibility.

Approach to increase user support

To create support, users should be involved in the process. In addition, involving representatives of the student council in the decision-making process can also be considered. Another recommendation is to present the benefits of SCTs for the user and what it can contribute to reducing the CO2 footprint. Integrating the world of building management systems, the IT environment, and smart building solutions will lead to sustainable and healthy buildings. Try to clarify this impact. In addition, for the trust and privacy aspect, act as transparent as possible to the users. Show the operation of different sensors.

Shared knowledge

The interviews and brainstorming sessions revealed the importance of sharing knowledge. From the figure below, it appears that certain universities and other organizations are curious about some overlapping aspects or that are related. Based on this figure, follow-up sessions can be organized to share knowledge more often or among themselves.

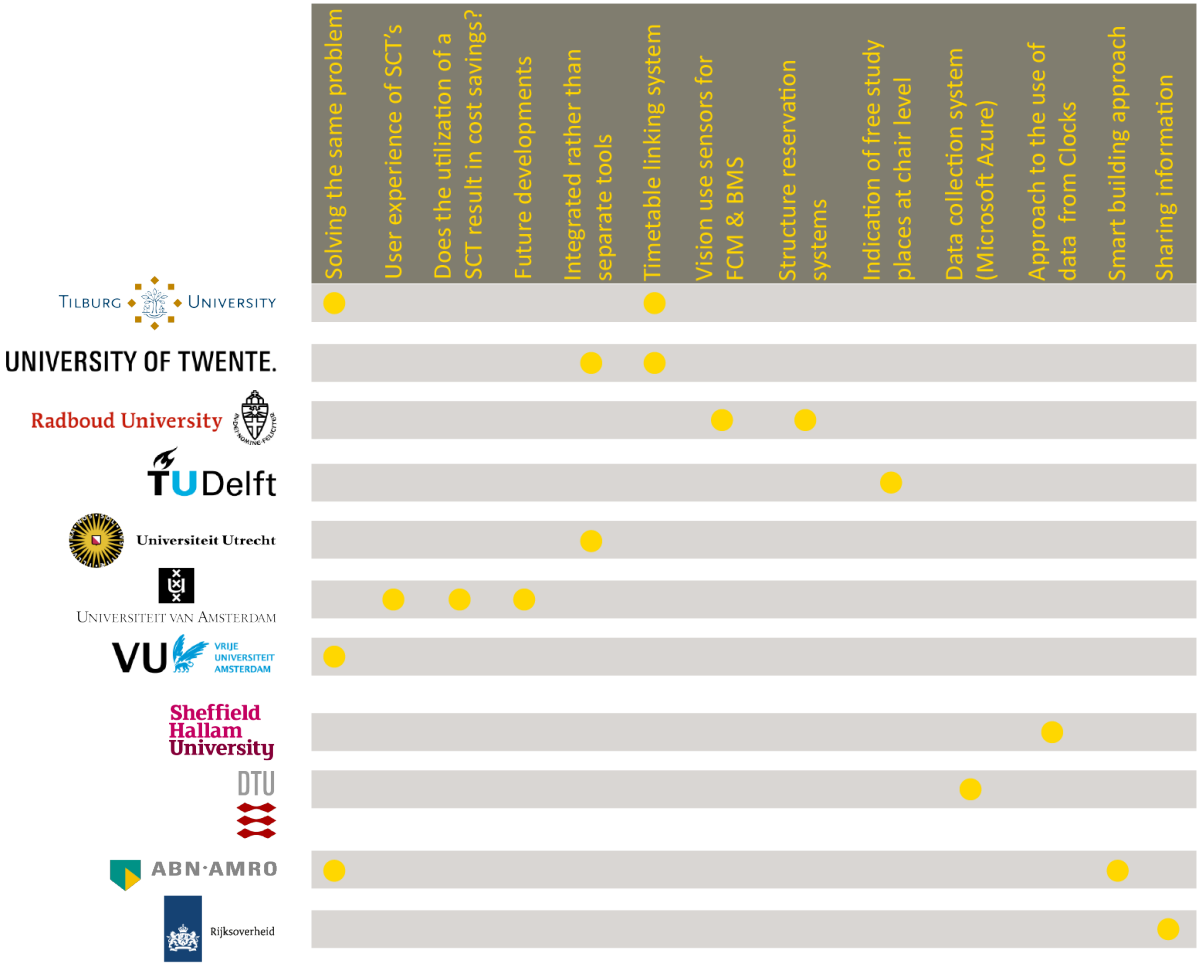


Figure 9-1: different: The aspects that the interviewees are curious about (own figure)

Learn from the failures or limited progress

Figure 5-17 and Figure 6-13 present the reasons for no success during implementing a SCT. Learning from the mistakes made will contribute to the speed and improvement of the process in the follow-up process.

In addition, universities are still exploring whether external consultants should be brought in for certain implementation phases. It is a beneficial approach to acquire knowledge early on in the process to brainstorm and achieve a satisfactory end product. Steps are being taken that create new values for universities and organizations where previously no thought was given to connecting certain aspects. Try to create solutions together with suppliers that are not only connected but also share data.

To conclude, an irritation that often occurs is that applications are designed for offices. The research shows positive signs towards engaging a start-up that is often willing to develop a tool specific to the customer's needs.

10 REFLECTION

In the reflection, the author's reflection is presented to the research subject. In this, there are several topics that are explained: Relationship of the research topic within the faculty, research methodology and process, dissemination and audience, and relevance.

10.1 Research topic

10.1.1 Relationship of the research topic within the faculty

This study is carried out as part of the Management in the Built Environment department. Of the 27 possible chairs at TU Delft, the chair of this study is Real Estate Management. This chair is focused on users in the built environment. This takes into account changing goals in organizations and society, economic feasibility, and sustainability challenges. Then, at REM, six suggested themes can be selected. This research has relationships with three themes; CRE alignment, Workplace management, and Campus management. However, the main emphasis and focus were on campus management, also called ‘Managing the university campus’.

I was temporarily part of the campus research team, which was established for the research 'Smart campus tools', published in 2016. During this research, the main focus was on the 'products' of the SCTs. Whereas the follow-up research 'Smart campus tools 2.0', which was published in 2018, focused more on the SCT processes. In these research studies, interviews were conducted at universities in the Netherlands, universities abroad, and other organizations. Since this research is a repeat of the SCT2.0 research in which -a small portion of- the same cases were analyzed, this explains the relationship of my research within the faculty.

10.1.2 Proposition

Due to the changed context resulting from COVID-19, increased demand for a hybrid form of education has been generated, the measurement of space use will become more critical after COVID-19 than before. This was the proposition I had set at the beginning of the research. Looking back now, it was found that the use of SCTs during the COVID-19 crisis were more relevant than before. It cannot yet be ruled out whether this will be the case after the COVID-19 crisis. I do still expect with a mix of space usage that measuring space usage due to the fluctuant users on campus will be more important than before.

10.2 Research methodology and process

Brainstorming sessions

The purpose of the first brainstorming session was to generate information for the first sub-question and problem statement. In terms of problem definition, the impact of COVID-19 for universities became clearer, and what participants suggested about the short- and longer-term effects. Since the problem statement became more concrete through this session, the first brainstorming session served as the basis for the research.

Literature review

The purpose of the second phase, the literature review, was to understand the main concepts of the research. Namely, aspects surrounding the campus, its management, added values, and SCTs.

Some difficulty was experienced in maintaining structure in the review of the literature. In addition, the basis of the literature review was already there with the previous research. Still, I thought that I had to find and use sources from other authors myself, which sometimes made it more difficult than necessary.

Case study

For the third phase of the thesis, case studies have been analyzed and interviewed for the qualitative research. This method was also used in SCT 2.0, and the same method was used to obtain comparable information. These case studies were conducted at Dutch and foreign universities, and other organizations to create insights focused on space utilization into the changes in the type, demand, and use of SCTs and assess progress. Through the cooperation with Ir. Valks, many universities and organizations had been approached quickly to identify about the readiness of an interview. In the end, thirteen parties were interviewed and analyzed. To gain more insights into the organizations, I would have preferred to also focus a bit more on the organizations. In the end, conducting interviews was fun to carry out and was an enjoyable experience because everyone was very interested and helpful

2nd Brainstorming session

The purpose of the follow-up brainstorming session was to present the draft results and test striking results and statements using propositions. The period just before this session was busy to ensure that the presentation and theses were well written down.

10.3 Overall process

Research starts with a research proposal, a small design process where there is always a reflection on whether the right direction is being taken. Is the research grounded? Isn't it interesting, or maybe it's more challenging to go in that direction?

The research proposal reminds me of a combination of representations that I have illustrated in one image. It's a combination of the double diamond method (Soulis et al., 2017) and the illustration of the squiggle design process (Newman, 2011). My experience in the first part of the double diamond (the discovery phase) looked too static compared to the chaotic feeling. Thus, this combination. This felt like chaos with no concrete goal, and reading literature continued. In this process, I have been stuck for a long time, difficult to make decisions and choices. The co-inception of this is that I found it difficult to set up research about which so much has been written by my supervisors that I made it more difficult for myself. However, this is unnecessary of doing research.

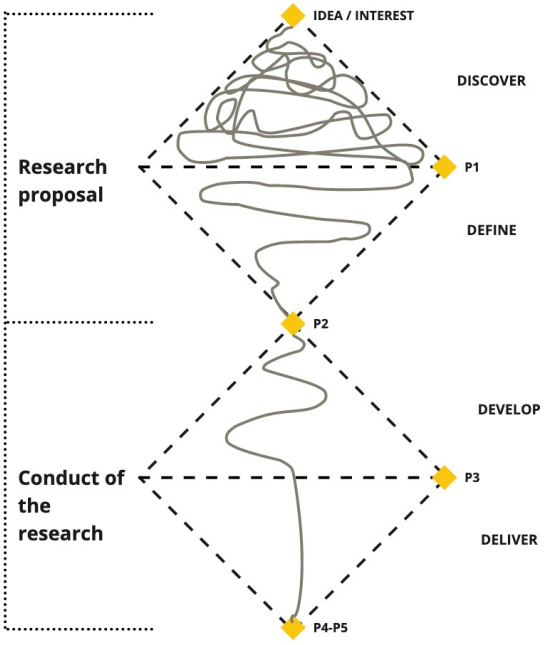


Figure 10-1: Double diamond method. Adapted from Soulis et all. (2017) and Newman (2011).

Around P2, the approach became more concrete and the goal clearer. Due to the ambition to interview many cases, I immediately started scheduling the interviews after P2. This with the support of Bart, who made the first contact with the candidates of the interviews. In this way, there was a quick response in most cases. The plan was to conduct three interviews per week, including processing the information obtained and gave structure. On the other hand, processing the information from the interviews took longer than expected due to the templates. However, this ensured that the analysis was quick due to the structured nature.

End of March at P3, 90% of the interviews had been conducted and processed. After receiving the supportive feedback, P4 was scheduled two months later. During this period, the analysis, preparation of the brainstorming session, implementation, and processing were to be carried out. Thanks to using the structured templates and cross-case figures, the analysis of the data obtained went smoothly. By organizing this brainstorming session, I learned a lot about writing statements more concisely and concisely to avoid discussion and ambiguity. I could have used this earlier in the thesis writing process as well. After all, the enthusiastic participants and the discussions that arose did give me the energy to move forward. Looking back over the period between P3 and P4, with the number of holidays, it was a somewhat unsettled period to concentrate, but a lot of progress was made on the report.

When I look back now, I realize that research is part of a process, even though it is sometimes frustrating and ignorant. Actually, as Dorst and Cross (2001) indicate, an important aspect of creativity is working through the processes of discovering, defining, and framing. I have realized that I can look for a long time on a small scale but that it is instructive to make choices and keep the process clear by analyzing it on a larger scale from time to time to keep an overview. Personally, I have found that I

struggled with writing substantive English sentences, the connection between the literature and the results from the case study. Still, I am very satisfied with what I have accomplished in the past and my job.

Still, it remains a special time to survey COVID-19. When conducting interviews, the distance has an advantage for staying structured during an interview. Still, it is so much more impersonal and the atmosphere compared to the real thing is different. Thanks to the guidance during meetings from Alexander, Alexandra, and Bart, I received important input to sharpen the goal and approach interesting perspectives. The weekly meeting with Bart gave the feeling of commitment since thesis writing is otherwise very alone in the times of COVID-19. Graduation during COVID-19 was experienced without distraction, as it was not allowed to continue, and thus, there was -what it is called among students- no: FOMO (Fear Of Missing Out). Yet, it was experienced that due to this monotonous life, the pleasure of graduating and the energy to go for it reduced more throughout the lockdown period. I have elected to work 20 hours a week in addition to graduating (more than I had thought beforehand), but this provided a positive distraction. All in all, an instructive process, and satisfied with the results.

10.4 Applicability

This section reflects on the potential applicability to particular users.

Campus (public real estate) managers

The way of education has changed in a short time at many universities with the emergence of COVID-19. Campus managers have made changes in terms of the use of space on campus as a result. In this study, seven Dutch and three foreign universities were interviewed. The results and insights about the progression, demand, and use of SCTs relative to the SCT2.0 research and during the COVID-19 crisis create insights for follow-up choices for campus managers. In addition, relative to SCT2.0 research, this study identified the reasons in cases where implementation achieved little or no success in implementing SCTs. This includes approaches to reservation systems at universities.

Corporate real estate managers

Since this research also included interviews with three other organizations focused on space utilization approaches and Smart tools, the results are also applicable for corporate real estate managers. The importance in offices has increased to use Smart tools for the ‘back to office’ phase and the follow-up phase for the possible reduction of office space, in the interest of using space more efficiently. The results of this study do not provide a guide to the next steps for CREM but offer insights into the developments and applications on-going at the interviewed cases.

Developers and investors

The results showed that universities and other organizations are satisfied with the capabilities of SCTs during the COVID-19 crisis. In addition, areas for improvement were identified where developers could especially contribute. Furthermore, it has also become clear that data has been used in a new way to monitor safety for users. These kinds of insights into opportunities and areas for improvement offer potential for investors. The technology market is moving fast, but there is still a lot of potential for improving space use and reducing CO2 in the current real estate market.

Municipalities, government, and events industry

The research has increased the growth towards applying data from sensors that monitor space usage in decision making for campus managers. In the news, it has become known that sensors are being used to create insights for follow-up purposes at certain municipalities and test events. The insights into the use of sensors at universities and other organizations also provide insights for these agencies.

10.5 Relevance

The research should contribute to social and scientific relevance. It will be reflected what the added value of this research is for both aspects.

The purpose of this research is to gain insights from universities and other organizations to support the back-to-campus (office) movement following COVID-19. Also the aim to determine whether universities or organizations utilize SCTs due to the changes in demand and supply (as a result of COVID-19). In doing so, the goal is to contribute to the recently created gap in scientific knowledge caused by COVID-19. In addition, to map the developments in the intervening years of this and the SCT2.0 study. In terms of scientific relevance, this study has given the insights of universities and partly of international universities and other organizations. In addition, it has identified the problems in not successfully implementing SCTs. This has not been traced more often since SCTs have been a topic of the past decade. In the SCT2.0 study, a further recommendation was to conduct that study again in a few years to analyze the progression, which has been performed.

This research contributes and provides insights into the changes and actions carried out during the COVID-19 period. As the study results revealed, the focus is mainly on the functional aspects, with supporting user activities, and increasing user satisfaction being the most common goal. By creating insights into how other universities apply certain functions, other universities or other organizations can learn from this to benefit the users.

In addition, SCTs contribute to the efficient use of space where ultimately the goal of many parties is to create a technical layer in which SCT sensors communicate with the building management system. When applicable, lighting, ventilation, and heating can be controlled based on the schedule, reservations, or presence. This will enable a reduction in the CO2 footprint, which has been an important issue for the last few years.

Further, awareness of resident safety was at the top of the COVID-19 crisis. The purpose of this study is also to create awareness of what can be achieved in terms of safety through the utilization of real-time information. The results revealed that partly due to the deployment of SCTs, it was possible for users to 'back to campus/office' for certain periods.

In this way, this research will contribute to organizational- and universities' decisions, contributing to the period after the COVID-19 crisis. Whereby it is not excluded that other forms of pandemics may arise in the future whereby possibly, due to the insights of this research, quicker action can be taken with a reduced impact on the users of universities and other organizations.

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11 APPENDIX

I. Previous research results
II. Approach and documents applied for the interviews
III. Report of the 2nd brainstorming session

I. PREVIOUS RESEARCH RESULTS

To show what has changed compared to the previous survey, this appendix provides an overview of the universities who have indicated in advance that they are interested in further research and which information/results from SCT and SCT 2.0 are used to supplement.

University	Source	Phase	Duration	Scale	Why	What	How	Level of access	Resolution of Space	Resolution of Time
Erasmus University Rotterdam	SCT	Implementations (SCT2.0) Development	-	Campus wide	- Functional: Helping students finding a place (SCT2.0) - Strategic: Insights of available hours of education spaces	- Frequency - Occupancy	- Reservations:EUR group study rooms app (SCT 2.0) - Own development	- Users	- Education spaces	-
Leiden University	SCT	Implementations but pilots in The Hague	-	Campus wide	- Functional: find free PC places Reduce no-shows in education spaces and increase frequency and occupancy rates	- Frequency - Occupancy ZRS-Cube to compare bookings and actual use (frequency and occupancy). Own reporttool for the data	- Sensors: PC login in The Hague: Lone Rooftop and BeSense. Manual: Separately in de eductations are manual counts	- Users find free pc places (employees and students) - Support (FM)	- Study places - education spaces	-
Radboud University Nijmegen	SCT	Implementations	-	Campus wide	- Functional: Find/book Shared spaces and students/employees book/find places	- Frequency - Occupancy	- Reservations: Planon & Web Room Booking (of small conference rooms)	- Users (employees and students) - Support (FM)	- Project rooms	-
Tilburg University	SCT 2.0	Design brief	Expected	Two buildings, 5.000m2 first phase	- Functional: Find/book studyplaces/rooms/classrooms for employees/students - Physical: Efficient use of workplaces and spaces.	Expected: - Frequency - Occupancy	- Reservations - Sensors (Unknown)	- Unknown	- Study places - project rooms - meeting rooms	- Real-time (space use)
Twente University	SCT 2.0	Several pilots and implementations (saving energy and sustainability) and research project (scheduling education)	2017 - Present	Five buildings, 5.360 m2	- Functional: improve the way how education is scheduled - Physical: Saving energy and sustainability	- Frequency - Occupancy - Identity (privacy by encrpyted hash code per day per person/ID)	- Reservations - Sensors (Unknown)	- Support (technicians and researchers)	- Education spaces	- Minutes (every six minutes the information wil be updated)
1. Delf University of Technology	SCT 2.0	Implementation (education spaces) and pilot (library)	2014 - Present	Two buildings, 26.000m2	- Functional: Information for users about amenities in the library and posibility of reservations in project rooms, which indirect improve the collaboration.	- Frequency: meeting rooms by reservations and sensors (in use) - Occupancy: 100 workplaces (real-time) - Activity?	- Reservations: Mapiq (library) - Sensors: Infrared sensors for activity at 100 workplaces & 10 meeting rooms. Lone Rooftop (education spaces)	- Managers (specific individuals can acces PoweBI) - Support (backend to the reservation tool) - Users (students and employees can make reservations) - Open access (location and availability of space and blueprints)	- Project rooms - Study places	- Days - Real-time (information in the PowerBI dashboard and the webpage is near real-time).
2. Delf University of Technology	SCT2.0	Plilot	2016-Present	One buliding, 2.500m2	- Physical: Optimising the m2 - Financial: Improvements by priority target - Functional: Improvements by priority target	- Frequency - Occupancy - Identity (privacy by anonymised data)	- Reservations - Sensors (Wi-Fi, amount of connected devices and location of device)	- Managers, few team members and 2 people (access to Clocks and PIE dashboard) - Support, scheduling team (access to Clocks)	- Education spaces	- Days (Clocks visible real-time but data per period) - Real-time (PIE dashboard)
Eindhoven University of Technology	SCT 2.0	Implementations. Pilot (register the early leave and no-show by detecting the actual frequency)	2016 - Present	213.000m2	Physical: Support increase of number of students and employees. Functional: findability and reservations of available space	- Frequency	- Reservations: Planon (book my space), the kiosks, selfservice and Outlook - Sensors: with infrared sensors (lightning) for detection precence and no-shows. - Manual: Separately in de eductations are manual counts	- Support - Users	- Meeting rooms - education spaces - Flexible workplaces	- Days - Real-time (selfservice, kiosk and app)
University of Amsterdam	SCT 2.0	Expansion	2015 - Present	six buildings, 105.184m2	Helping students finding a place to study and book and also space use monitoring	- Frequency (project rooms and education spaces) - Occupancy (PC spaces)	- Reservations: Mapiq and for the availability is Syllabus - Senors: Desktop PC spaces usage	- Users (booking rooms by employees and students with NetID) - Open access (location of spaces and floorplan)	- Whole building	- Days - Real-time (information in the PowerBI dashboard and the webpage is real-time).
Vrije Universiteit Amsterdam	SCT 2.0	Implementation Pilots (Library)	2016 - Present	Zeven buildings, 276.484m2	Efficient use of workplaces and spaces and improve the primary processes.	- Frequency (project rooms and education spaces) - Occupancy (PC halls)	- Reservations: Study Spot and Syllabus for availability project rooms and education spaces Lone Rooftop (library) - Sensors: PC halls, pc login	-Users (Study Spot by VU login)	- Study places - education spaces - project rooms	- Real-time (info in the app)

II. Approach and documents applied for the interviews

The existing information from previous research is used as a starting point for the interviews, in which they will be updated to reflect the changes due to COVID-19. Therefore, the same protocol as for SCT2.0 will be completed when new SCTs are initiated. In addition, the developed interview protocol for this research, and consent form will be displayed.

Steps taken per case in the data collection

This appendix presents the steps related to data collection. To start, the same approach was applied for the seventeen interviewees to obtain the answers in the same way.

1. The participants were first approached by Ir. Valks to ask if they were open to participating in my research. The reason for this was that Ir. Valks knew these people or had interviewed them before and that this might result in a quicker response and planning of an interview. In this mail traffic, the participants were already informed what my research entailed.

2. When the participants wanted to contribute, the semi-structured interview protocols were provided as well as the existing template(s) created during the SCT 2.0 research, and the consent form. This was shared prior to the interview, allowing the participant the opportunity to review the files, ask questions when there was a need, and return the consent form signed when they agreed.

3. The interviews were conducted in Microsoft Teams. In the interview, two different interview protocols consisting of semi-structured questions were used. First of all, the interview was started according to the 'interview protocol Smart Campus Tools 2021'. This involved first going through the first question and sub-questions. If it appeared at the second question that a new SCT have been developed for space utilization, the 'Existing interview protocol SCT 2.0) was gone through. This happened per new SCT. Then the questions from the "interview protocol Smart Campus Tools 2021" were completed starting with question three. Between the semi-structured questions there are differences in open and closed (multiple choice) questions. The following table shows this distinction by interview protocol.

Type of question	Interview protocol Smart Campus Tools 2021	Existing interview protocol SCT 2.0
Open	1.a.i, 1.a.i., 2.a, 3.d, 4	1, 2, 4, 5, 8, 9, 10, 11, 12,13 14a,15a, 16a, 17a 19a, 20, 21
Closed	1.a, 1.a.i.1, 2, 3.a,	3, 6, 7, 14, 15, 16, 17, 19

4. Then for processing the interview, a report was prepared for each interview and where this was the situation, the modified existing or new templates. Since transcribing the interviews was not employed, the draft version was provided to the participant to review and provide feedback or agree.

5. Then the data from the interview report and templates was incorporated into this research report.

1. The steps for obtaining the information from both brainstorming sessions will now be described.

2. At the first brainstorming session, the author of this research did not attend the preparation but did attend the session and contributed to the processing of the report. Because information from this session did use what consisted of questions, the table below shows a summary of the open and closed questions.

Type of question	First brainstorming session	Follow-up brainstorming session
Open	-	2, 11, 13
Closed	1, 2, 3, 4, 5, 6, 7, 8, 9	1, 3, 4, 5, 6, 7, 8, 9, 10, 12

3. For the preparation of the follow up brainstorming session, notable draft results and statements were first prepared. Then, statements and questions were formed to present certain concept results to find out if the answers were constant. Furthermore, open-ended exploratory questions were asked to find out how participants thought about certain aspects.

4. The second brainstorming session took place in Zoom, where statements and questions were asked using Mentimeter. These were open and closed questions where the distinction is shown in the table above. In addition to the questions and statements, there was an opportunity for discussion. This session was then also recorded in report form and provided to the participants to give them the opportunity to provide feedback. For this report, reference is made to Appendix III. This is a draft report because the final report has not yet been determined and has been translated into English.

Consent form for SCTs 2021 research

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [DD/MM/YYYY] or read to me. I have been able to ask questions about the study, and my questions have been answered to my satisfaction.	□	□
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions. I can withdraw from the study at any time, without having to give a reason.	□	□
I understand that taking part in the study involves an audio-recorded interview transcribed into a summarized report and a visualization of the interview. The audio recording will be destroyed after translating the recording into the stated output documents.	□	□
Use of the information in the study		
I understand that information I provide will be used for a master thesis report. In addition, the output may be used in presentations of the research.	□	□
I understand that personal information collected about me that can identify me, such as [e.g., my name or where I live], will not be shared beyond the study team.	□	□
Future use and reuse of the information by others		
I permit the summarized report and visualizations that I provide to be archived in the 4TU Centre for Research Data to be used for future research and learning. The interviewee's name and the organization he/she works for will be anonymized in these documents. It is not yet known which access restrictions will apply to this data.	□	□

Signatures

_____	_____	_____
Name of participant [printed/digital]	Signature	Date

For participants unable to sign their name, mark the box instead of sign

I have accurately read out the information sheet to the potential participant and ensured that the participant understands what they are freely consenting to the best of my ability.

_____	_____	_____
Researcher name [printed/digital]	Signature	Date

Study contact details for further information:

Name: _____

Phone number: _____

Email address: _____

Please tick the appropriate boxes	**Yes**	**No**

Interview protocol Smart Campus Tools 2021

1. Around 2017-2018, information was collected on smart tools with the results from the template (template 1)
    a. Is this smart campus tool still in use? If no,
        i. What are the reasons for this?
            1. What was the stage of implementation?
            2. What is the reason for no success or little progression?
            3. What lessons were learned, and how would things be done differently in the future?
            4. Is there any potential in the Smart campus tool for the future?
    b. How did this Smart campus tool contribute to the back-to-campus phase?
        i. How satisfied are you with the solution? What could be improved?
    c. Are there any changes to the information in the template?
        i. Has the demand for information changed? Is the phase different? Has the scope changed? (use of sensors, objectives) Has the management information been further developed? Etc.

2. As a result of the Corona crisis, have you acquired or developed other SCTs for space utilization?
    a. What are the features of this Smart campus tool? (Walkthrough template 2)
3. Is there a reservation system used for study places, offices, or classrooms?
    a. If so, was this already used before the corona crisis?
    d. How is the reservation system handled?
        i. Are slots used? If so, how many slots per user can be reserved?
        ii. How far in advance is it possible to make a reservation?
        iii. What is the percentage of no-show? How will this be handled? Are incentives or penalties used?

4. What would you like to find out from other universities regarding SCTs for reservation systems or space utilization?

Existing interview protocol SCT 2.0

The used existing interview protocol created for the SCT 2.0 study was used during this study when it appeared that new SCTs were started. This protocol is shown on the following page.

(name smart tool) - university / organization

Interview	Field no.	Fields in template
	2	**Project description**
vraag		Could you indicate how the initiative for this smart tool was taken (problem) and why this smart tool has been chosen (solution)
answer		
	2	**Phase**
question		In which phase of implementation is the smart tool?
options		
answer		
	3	**Scale**
question		Could you indicate how large the application area of the smart tool is, in m2 Gross Floor Area, amount of seats and amount of buildings?
answer		
	4	**Duration**
question		Since when is the tool in use at your organisation?
answer		
	5	**Functions**
question		Which functions does the smart tool have?
options		
answer		
	6	**Space types**
question		For which space types is the smart tool used?
options		
answer		
	7	**Foreseen developments**
vraag		Are there foreseen developments in the near future - amendments or improvements to the existing tool, replacement, etc.?
answer		
	8	**Investment costs (per m2 GFA)**
vraag		Could you indicate what the investment costs of the smart tool are, in € per m2 gross floor area?
explanation		
answer		
	9	**Operating costs (per m2 GFA)**
vraag		Could you indicate what the operating costs of the smart tool are, in € per m2 gross floor area?
explanation		
answer		
	10	**Benefits**
vraag		What objectives are defined to be achieved with the tool, and what is the progress on these objectives since implementing the tool?
explanation		
	12	**User information**
vraag		Could you indicate what information is available to the user and how the tool works?
explanation		
answer		
	13	**Management information**
vraag		Could you indicate what information is available to the campus manager and how the tool works?
explanation		
answer		
	14	**Why: Objectives**
vraag		Could you indicate to which goals the smart tool contributes?
options		
answer		
	14a	**Why: Objectives**
vraag		Which goals have priority? How are they achieved?
answer		
	15	**What: Measurement**
vraag		How is space use measured with the smart tool?
options		
answer		
	15a	**What: Measurement**
vraag		What exactly is measured? How is privacy addressed?
answer		
	16	**How: measurement method**
vraag		Which measurement method(s) is/are used?
options		
answer		
	16a	**How: measurement method**
vraag		How does the measurement method work?
explanation		
answer		
	17	**Actuality of the information**
vraag		How up-to-date is the information reported in the smart tool?
explanation		
answer		
	17a	**Actuality of the information**
vraag		Could you further specify how up-to-date the information in the smart tool is? Are there differences between functions?
answer		
	19	**Access levels**
vraag		Who has access to the smart tool?
options		
answer		
	19a	**Access levels**
vraag		Who has access to which function of the smart tool?
answer		
	20	**Side notes**
vraag		Could you share some of the experiences with the smart tool, or other information which you think could be of interest for campus managers?
options		
answer		
	21	**Images**
vraag		Could you send a number of images of the smart tool? 1 general image, 2 user information, 3 management information
answer		

III. Report 2nd brainstorming session

The brainstorming session was in Dutch but the report has been translated into English. From the next page, the report is presented.

Draft Report: Smart campus tools 2021 session

May 11, 2021; 15:00 - 17:00

Campus research team
Bart Valks, Alexandra den Heijer, Lars Cazemier, Monique Arkesteijn, Alexander Koutamanis



Introduction

This meeting on Smart campus tools was organized to discuss again - together with colleagues from universities - the developments at universities. The reason for this meeting, like the previous one, was to share knowledge about the developments regarding smart campus tools in the COVID-19 period.

Since the last meeting, Lars Cazemier started the data collection for his graduate research. This research is an update of Bart's research from 2017-18, in which he inventoried various smart campus tools. In this meeting, the (preliminary) research results of Lars' research will be discussed, with various statements being presented to the attendees during the discussions.

The program of this meeting was as follows:

Programma

- Concept resultaten onderzoek Lars		
- Back-to-campus fase	(+stellingen)	- 10 min.
- Reserveren	(+stellingen)	- 40 min.
- Smart campus tools in een hybride omgeving	(+stellingen)	- 30 min.
- Nieuwe behoeften achterhalen	(+stelling)	- 5 min.
- Draagvlak voor Smart campus tools	(+stellingen)	- 10 min.
- Afsluiting en nabeschouwing		

Attending universities

The following universities were present at the meeting. In this report, their input is represented by the following abbreviations:

LEI: Leiden University
KU: KU Leuven
MU: Maastricht University
RU: Radboud University Nijmegen
TIL: Tilburg University
TUE: TU Eindhoven
TUD: TU Delft (researchers)
UU: Utrecht University
UvA: University of Amsterdam
VU: Free University of Amsterdam

1 Introducing research - Smart campus tools 2021

The meeting will start with a brief introduction of Lars' thesis research, 'Smart campus tools 2021'. The COVID-19 pandemic prompted the follow-up research on smart campus tools. Because of COVID-19, universities and other organizations had to start meeting a different need with their smart campus tools: organizing a limited return to campus for users, while respecting the maximum capacity on campus.

To identify the ways in which universities have dealt with this, Lars used the Smart Campus Tools 2.0 research (from 2017-18) as a basis. The update of this survey thus not only reflects how the use of Smart Campus Tools has changed by COVID-19, but also what developments have additionally taken place in the intervening years.

Based on 13 interviews, the results presented here were produced. These interviews also supported to shape the statements presented. In addition to interviews at Dutch universities, Lars also interviewed universities DTU, Sheffield Hallam, and Aarhus, as well as the organizations ABN AMRO and the central government.

The results show a diverse pattern. The interviews reveal new smart tools, modifications of existing smart tools, and smart tools that have been put on hold. A number of examples are highlighted:

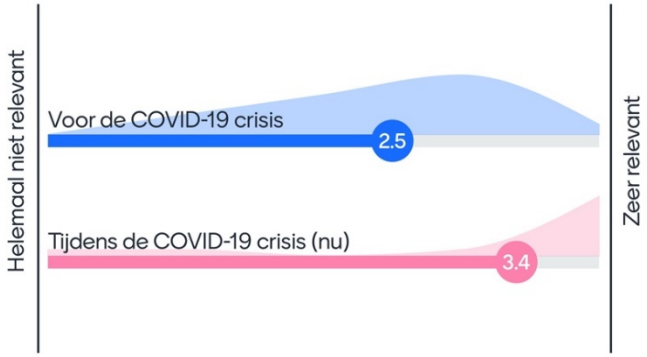
- New: Mazemap + Swycs, Planon (Radboud); Smart tool to find study places in the university library;
- New: CampusCrowdMap (Twente)[1]; Smart tool that displays a crowding indication in the buildings, based on the maximum capacity according to COVID-19;
- Existing: Lone Rooftop + Tableau (Sheffield Hallam); here, a report on Lone Rooftop was developed in Tableau to provide quick insights into the crowding in all buildings based on the maximum capacity as per COVID-19;
- On hold: Study Spot (VU); This smart tool, originally intended to provide insight into available teaching rooms for self-study and the reservation of project spaces, was discontinued because students and staff could make reservations in a separate dashboard but the two systems did not communicate with each other.
- On hold: Research on adaptive scheduling (Twente); This smart tool was developed as part of a research project on adaptive scheduling within the university. This has not been pursued because the university's experience is that no developer can currently develop a tool that is compatible with suppliers' software for timetablers.

[1] https://apps.utwente.nl/campuscrowdmap/

2 Back-to-campus phase

After the discussion of the examples, the first proposition follows. Given the changes in the field of Smart Campus Tools, the proposition aims to find out whether Smart Campus Tools are more relevant during the COVID-19 crisis than before it. During the November brainstorming session, universities already indicated that support for Smart Campus Tools had increased, and that they were very active in this area. The interviews revealed that Smart Campus Tools supported in the "back to campus" phase.

1. Thesis: How relevant are/were Smart campus tools in the period



Participants indicate that Smart Campus Tools are more relevant during the COVID-19 crisis than before. In addition, for the second slider, the distribution of votes is conspicuously to the right, while for the first slider, a distribution can be seen. For the second slider, there is one response with not relevant at all, but for the COVID-19 crisis it is: possibly the Smart Campus Tools are not in use there during the COVID-19 crisis.

Following proposition 1 is an overview of the results of the interviews compared to the 2017-18 research. Of the cases that Lars documented, the picture is as follows.
At the Dutch universities, much progress has been made and seven new tools have been implemented. In contrast, of the seven existing tools, four have been discontinued.

In most cases at foreign universities, little progress has been made. The same applies to the organizations, although they are busy further developing the existing tools or new solutions.

Note: This is a comparison of cases interviewed both in this study and in 2017-18. No conclusions can be drawn from this because not all cases from 2017-18 were interviewed. In the November '20 session, four cases were discussed with three cases showing how active universities are in developing their smart campus tools.

Several reasons for this were mentioned in the interviews, including a lack of knowledge, the collaboration between IT and management, scope change during the process, and different expectations about the accuracy of the technology. This forms the basis for the second proposition.

2. Question: What is the theme going on with you around Smart Campus Tools?



The second proposition produced the following Wordcloud. With the clustering of responses, the following themes can be distinguished:

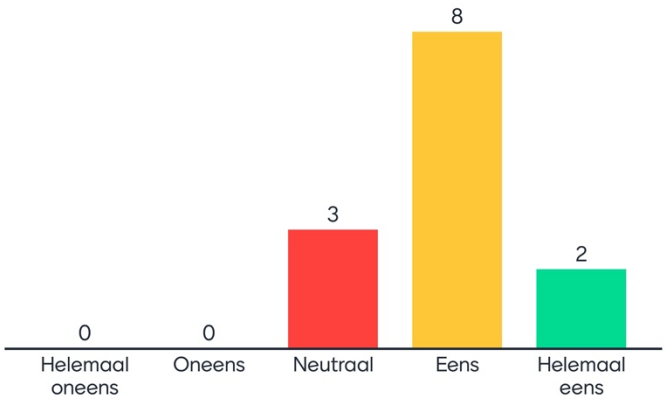
(1) Occupancy, frequency and no-show (mapping this in relation to maximum capacity COVID-19 and/or the question of which sensor is most useful for this in a particular situation)
(2) Reservation systems (both for students and employees, also relatable to service delivery)
(3) Method of providing information (including interface, campus-wide information, few clicks)
(4) Hybrid education / hybrid working
(5) Crowd control campus management

After proposition 2, the results regarding reservation systems are shared. The interviews revealed that 6 out of 7 universities implemented reservation systems during the crisis. In each case, this reservation system is there to allow students to study on campus based on a reduced number of study places; In a single case, this is for work places.

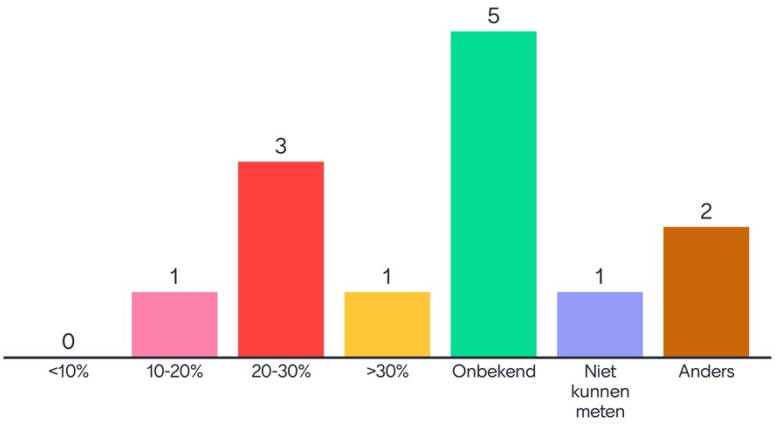
Reservations

During the interviews and the previous meeting, it emerged that high numbers of no-shows occur with these reservation systems, and that various ways are being explored to reduce them. This is referred to as "digitaal handdoekje leggen," after the "handdoekje leggen" that prompted the Smart campus tools research to begin in late 2015. The next two statements focus on attendees' experiences with no-shows.

3. Statement: We experienced no-show at reservation systems during the COVID-19 crisis



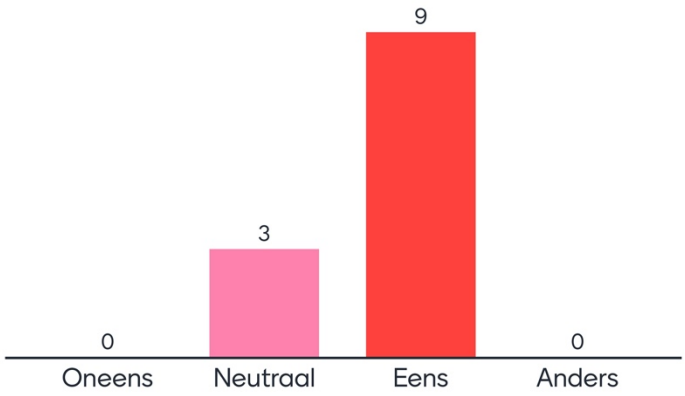
4. Statement: The percentage of no-shows we experienced with reservation systems during the COVID-19 crisis is



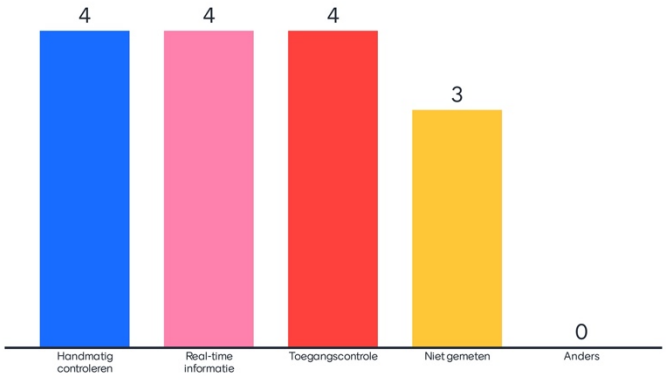
The statements show that no-show is actually experienced almost everywhere. Half of the respondents who experience no-show can indicate how much that percentage is, while for the others the exact percentage is unknown. When 'neutral' is indicated for the first statement, the response to the second statement is 'cannot measure' or 'other'.

This is followed by two statements about how information about campus use was collected.

5. Statement: Real-time information was used during the COVID-19 crisis to measure space use



6. Statement: We measured no-show during COVID-19 based on ...



These statements show that real-time data has been used frequently to measure campus usage and determine no-shows. The last statement confirms a finding from the interviews that no-show is determined in multiple ways.
It can already be seen from the results that manual checking, real-time information and access control are used. There are also universities that combine multiple sources: one university uses manual control and real-time information, and another university uses access control, manual control and real-time information.

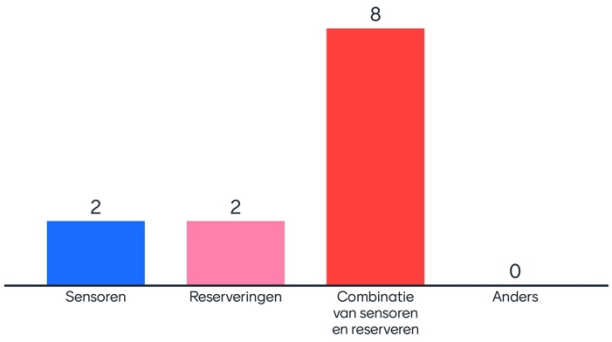
3 Smart Campus Tools in a hybrid environment

Following the previous statements about reservation systems, the following is a look at the period following the COVID-19 pandemic. A scenario is assumed here in which the university facilitates all three campus models: traditional, network and virtual. This means that smart campus tools must facilitate two needs: on the one hand, the user who is on campus and looking for an available work/study place, and on the other hand, the user who wants to come to campus from home, and is looking for some form of assurance about an available work/ study place. The tension between these two needs has been presented in the form of a proposition for four different space types: study spaces, teaching spaces, offices and meeting rooms.

7. Statement: In a scenario of hybrid studying, Smart campus tools show (preferably) availability of **study places** based on:

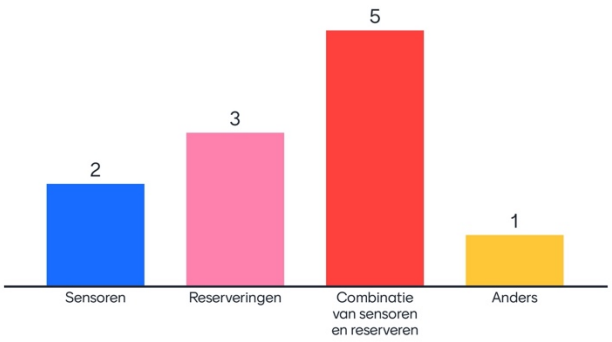
The response to this statement shows that there is an appetite for a combination of sensors and reservation at study sites - i.e., facilitating both of the needs mentioned above. What is interesting, and contrary to expectations, is that the response to the 'combination' option is so much higher than to 'sensors' alone.

8. Thesis: In a scenario of hybrid studying, Smart campus tools show (preferably) availability of **teaching spaces** based on:



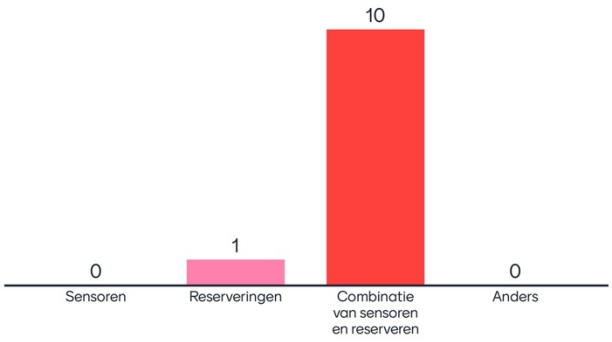
From the response regarding teaching rooms, opinions are divided between reservations and a combination of sensors. Due to the presence of scheduling systems, it is not surprising that almost all participants choose an option with scheduling systems. If a combination is chosen, it is possible to schedule more dynamically or to optimize the schedule for the coming year based on occupancy and utilization. With reservations or with a combination it is possible to open up teaching rooms for self-study when they are not in use for teaching.

9. Statement: In a scenario of hybrid studying, Smart campus tools (preferably) show **offices** availability based on:



The response regarding the offices shows a varied picture. In any case, the reactions show that the image of the traditional office is shifting - when everyone still has their own workplace, reservations and/or sensors are not necessary. Most participants prefer a combination of reservations and sensors for this option, as they do for the study environment.

10. Statement: In a scenario of hybrid studying, Smart campus tools (preferably) show availability of **meeting rooms** based on



From the response to this statement, the vast majority prefer a combination of sensors and reservations. This provides the opportunity for impromptu meetings to quickly understand no-shows so they can make use of those meeting rooms.

Identifying new needs

After the statements about the smart campus tools in hybrid working and learning environments, we briefly discuss new needs that emerged in the interviews: including the development of existing tools, the real-time measurement of individual study places and the analysis of the data for crowd management. In addition, the interviews revealed that since COVID-19, more collaborations have emerged between facilities management, management, IT or HR. See the figure below for an overview of the developments indicated in the interviews:



Then this is also asked about again in the form of a proposition.

11. Question: What new needs do you foresee regarding functionalities in Smart campus tools?



The responses show that there are new needs for supporting facilities processes and real estate policies. In addition, a similar need in the area of sustainability (energy management & predictive maintenance). Observations that follow from the discussion:

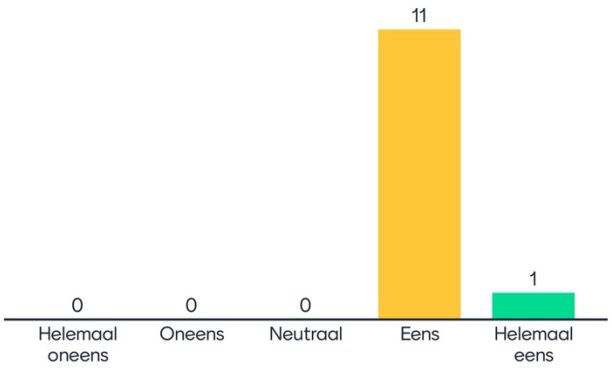
- UU: The integration of the world of building management systems, the IT environment and smart building solutions, will lead to sustainable and healthy buildings.
- RU: No-show leads to wastage of ventilation, lighting and heating. Those who also link sensors for availability to the building management system make a huge impact!
- LEI: Wondering how many smart tools can actually contribute to sustainable use. This is always dependent on the building: the desired effect is not necessarily and automatically achieved.

Support for Smart campus tools

The last two statements are about the support for smart campus tools. This is linked to various examples from society, where huge amounts of data are used from various sources. These come in the news both positively and negatively, which can influence user support - for example, how crowd control helps to regulate crowds in inner cities, while there have also been recent municipalities in the news for unauthorized use of Wi-Fi tracking.

The first statement was formulated in response to the news surrounding the government's COVID-19 dashboard, and the discussion about what variables are included in it, how they are reported, etc.

12. Statement: More attention is needed within universities for diligence in data collection, selection, and presentation



Responses to the second-to-last statement indicate a need. Observations that follow from the discussion:

- LEI: Above all, a shared starting point is needed. Now everyone is looking for this, which is a waste of time and energy. Every privacy officer interprets the rules of the Dutch Data Protection Authority differently. Uniformity would be good. For example, we have deliberately chosen not to use Wi-Fi connections for measurements (see the Enschede case study). Our privacy officer uses pretty strict principles: if there is another way, no privacy-sensitive data may be used (such as Wi-Fi data).
- RU: This is taken up seriously by IT at our place. For example, we monitor the traffic at the floor level based on Wi-Fi connections (distinction between employees, students and external staff). The privacy control is very strict, the personal data are not included from the export from the network system and the privacy is guaranteed because we only display totals.

The second and final proposition is linked to user support.

13. Question: How do you increase user support for Smart campus tools?



There are several responses to this statement.

Design:

- Design the smart tool in such a way that it clearly creates added value for the user (and emphasize this) / Demand-driven design;

Design Process:

- Involve the user in the development of the smart tool, or even in its decision-making;

Communication

- Inform the user of the goals with which the smart tool is implemented, such as sustainability and user support;
- Naming the social aspect enabled by the smart tool (more sharing);
- Quickly answer user questions.

Closing

A brief closing will follow the final proposition, thanking all participants for their contributions. It is not yet known when a next meeting will follow. It is expected that Bart will defend his thesis in late September/early October - we will make sure that the participants are invited for that as well (physically or online).