SMART CAMPUS

A vision for an effective, efficient and sustainable campus

SURF

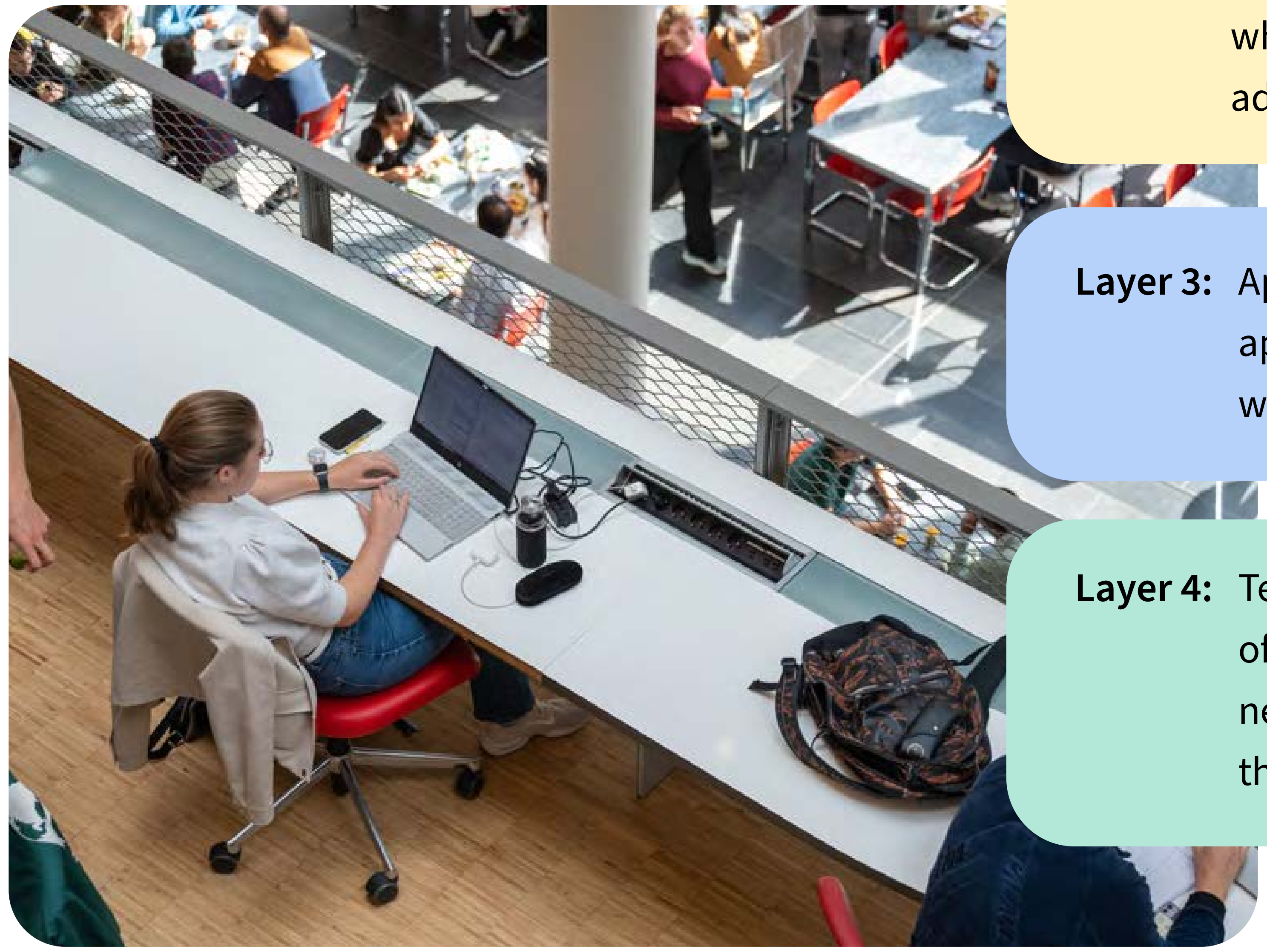
EXECUTIVE SUMMARY

This vision document on the smart campus gives direction to the further development of the smart campus, based on all the knowledge and experience that has been collectively gained over the past years. On the one hand, this vision is meant for the institutes, as a foundation for their own vision documents and/or to determine which next steps should be taken together. On the other hand, it is meant for managers in IT, facility management and real estate, to get insight into what the smart campus is and what this subject is about.

First, a definition of the smart campus is formulated. This definition follows from the objective and significance of the smart campus:

"The smart campus is aimed at using data and digital technology that is applied specifically to facilitate campus users, to improve space utilization and to optimize service delivery, in co-creation with education and research."

Next, the smart campus ecosystem is introduced as a model that contributes to an understanding of how the smart campus works, and to discuss what is needed per layer of the model to make the smart campus or an individual use case successful.



The ecosystem consists of four layers:

Layer 1: Users and services; in this layer the goal is to identify the users and their objectives and needs.

Layer 2: Organization and processes; in this layer the objective is to determine which parts of the organization or which processes need to be improved or adjusted in order to better serve the objectives and needs of the users.

Layer 3: Applications and information; in this layer the objective is to define how the applications (e.g. apps, dashboards, digital twins) should take shape, and what their requirements are.

Layer 4: Technology; this layer consists the data platform and the infrastructure of data sources (such as sensors and building management systems) and networks. In this layer it is determined which technology is needed to deliver the information needs and required functionality for the applications.

To help determine the future importance of, and the needs and requirements for, a smart campus, future scenarios from the Future Campus scenario reportx are presented. The various trends and issues described in this chapter can help institutions collectively determine the needs for the smart campus. To identify emerging technologies, technological trends are examined. New technologies such as Artificial Intelligence, Internet of Things and digital twins can accelerate the smart campus, enable new applications, and/or enhance existing ones, while the relationship with Big Tech companies requires attention.

Next, several use cases serve as examples of how the smart campus can add value for various users. Examples of use cases are: space optimization systems, availability tools, intelligent energy management, and wayfinding.

Based on a synthesis of the previous contents, the vision and principles are drawn up. These are then further elaborated in what they mean for each layer of the smart campus ecosystem.

The vision on the smart campus is described as follows:

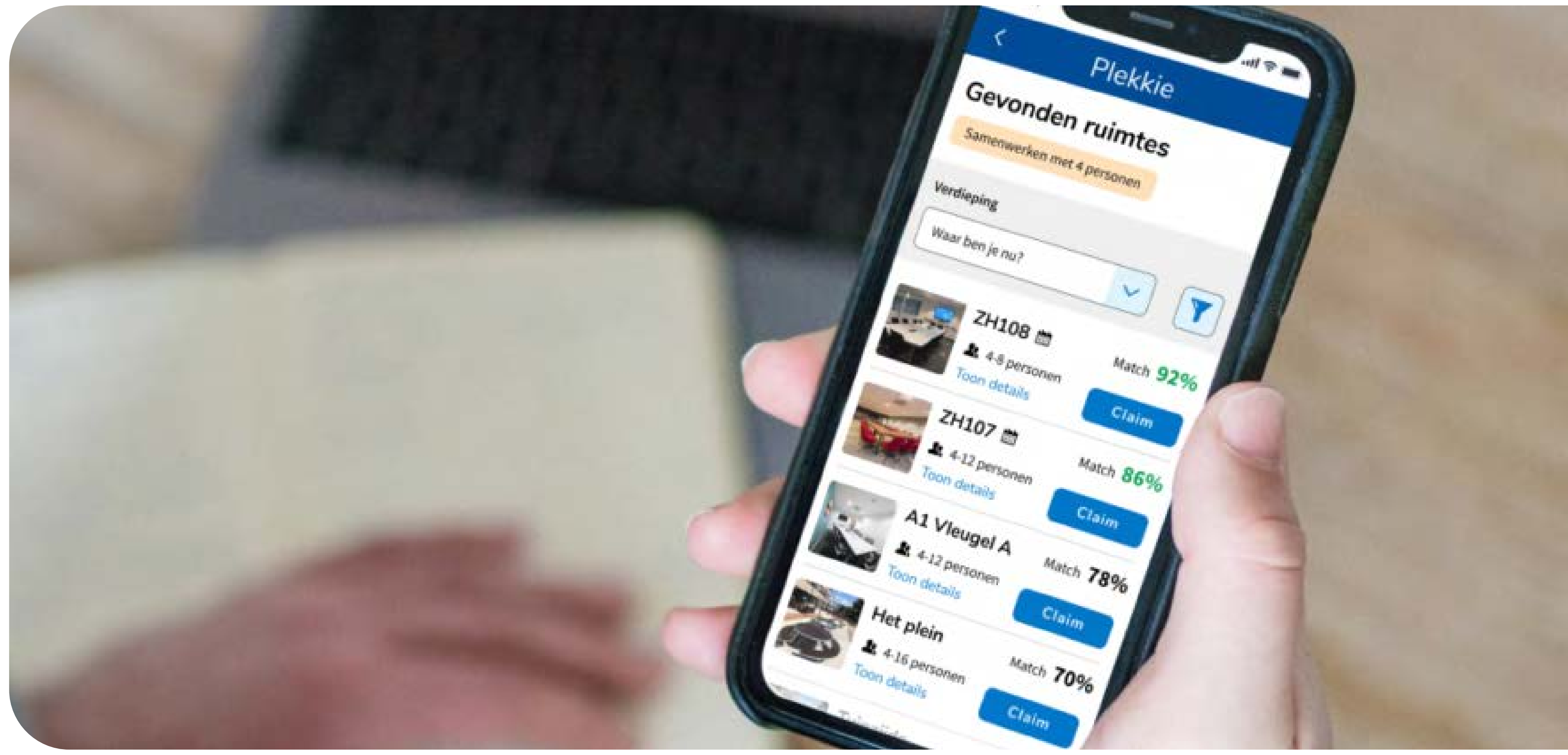
The smart campus is a campus where the combination of (existing) data sources, including sensors, is deployed for the benefit of students, staff, and visitors, enabling them to easily use and (digitally) interact with an efficiently designed and sustainable campus.

The smart campus has rules and a structure that guide its continuous development. These are designed not to be too restrictive, while simultaneously safeguarding the autonomy and security of the institutions and their users. Opportunities are recognized, stimulated, and taken.

The smart campus is being developed step by step through collaboration, adhering to five principles: user-centered design, interoperability, preventing vendor lock-in, modular architecture, and security and privacy.

Finally, tools are provided for getting started. SURF provides services and expertise to support the smart campus in various ways, with a focus on the technology layer. SURF facilitates community building, collaborates on various pilot projects with institutions, and develops services such as iotroam and, in the future, possibly an IoT network and/or an IoT data platform.

Based on experiences to date, the recommendations are: start small and with a clear vision; establish a sound governance structure; design the smart campus from the top down; When designing the smart campus, also carefully consider its management; utilize internal expertise and innovation; learn from the experiences of other institutions and collaborate where possible; monitor privacy and ethical compliance before, during, and after implementation; and improve your source data.



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Reading guide

For professionals working on the Smart campus and familiar with the subject matter, we recommend reading from Chapter 3 onwards.

For administrators and other stakeholders who want to read the document horizontally: each section begins with a gray textbox that summarizes the content of the section in a few sentences.

For readers interested in learning more about the Smart campus and what it means for them, we recommend reading Chapters 1 and 2 thoroughly, and then exploring the use cases in Chapter 4.

Introduction and Background

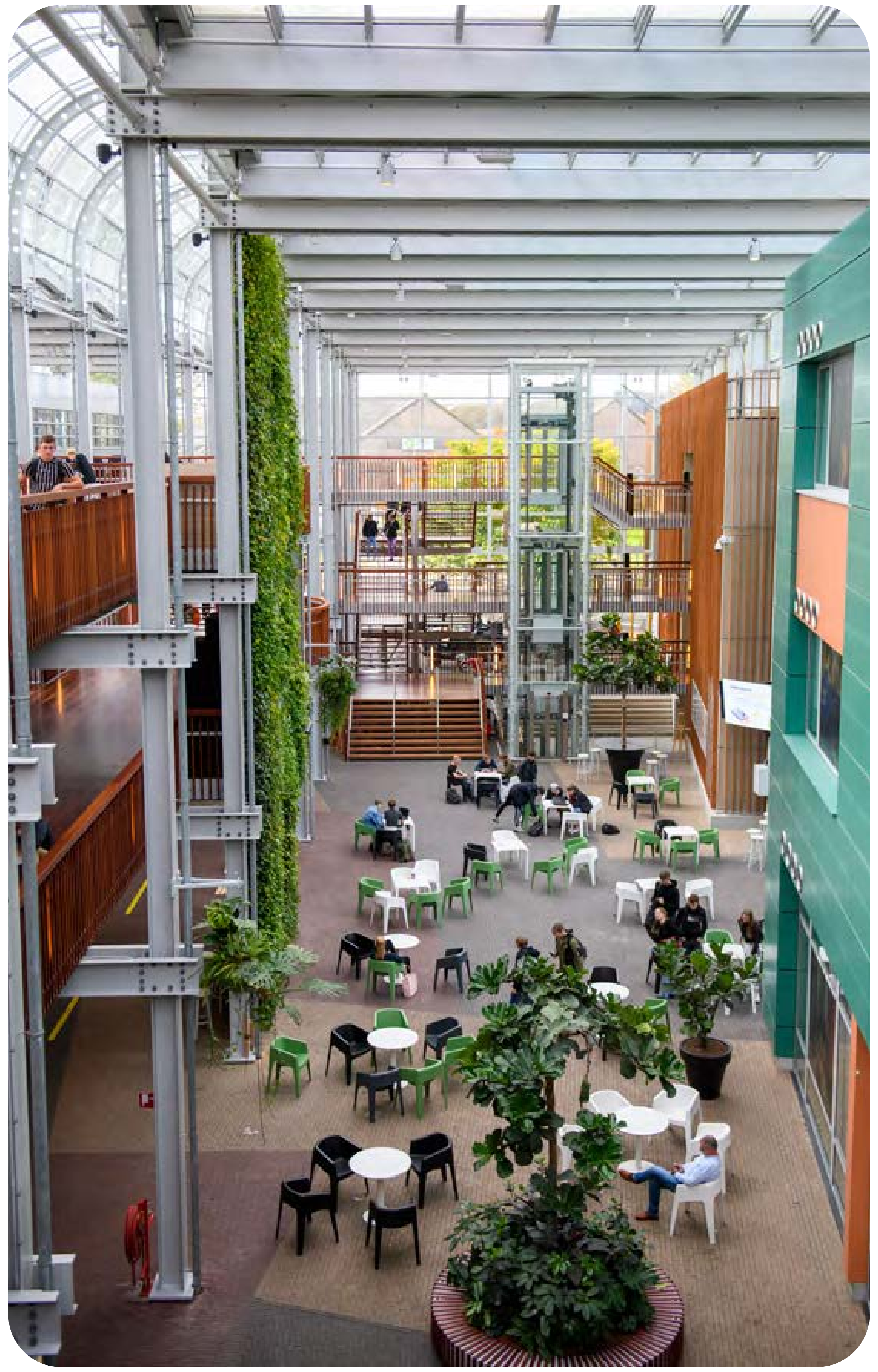
OBJECTIVE

In this vision, we provide direction for the further development of the smart campus, based on all the knowledge and experience gained collectively over the past few years. The vision is intended primarily for institutions, as a basis for their own vision and/or to determine how to move forward together, and also for IT, FM, and real estate managers, to gain insight into what the smart campus is and what's happening in this area.

Smart campus is a theme that in recent years has been gaining increasing attention from partner institutions: mbo institutions, universities of applied sciences, universities, academic hospitals and research institutes. It holds enormous potential: by improving information provision for users, by helping to make better use of buildings, by supporting the optimization of services, and by providing opportunities to collaborate with education and research.

However, it is also a complex theme due to the interplay between the organizational context, applications, and technology. At the same time, it requires a substantial investment, which precedes the returns. The returns from more efficient use of space and sustainability lie in the domain of real estate and facilities management, while the returns in terms of innovation, collaboration, and the institution's image lie in the primary process. Implementing the necessary IT infrastructure and systems, along with the associated expertise, lies with IT. The proper use of applications and the change in behavior regarding space use lies with students and staff. This interplay makes taking steps toward a smart campus a challenge. It requires courage and commitment from administrators, directors, real estate, facilities, educational logistics, IT, and, of course, students and staff to seize the opportunities that lie ahead.

In recent years, several institutions have become active in the smart campus theme and launched various pilot projects, recognizing the potential in this area. Data-informed working practices have also increasingly become a key component of the institutions' strategies. During and after the COVID-19 pandemic, the development of the smart campus accelerated due to the need for reservation tools and attendance insights. Some institutions have even scaled up from working on pilots and projects to programs, which are underpinned by visions, strategies, and/or program plans. SURF played a role in this by collaborating with various institutions in pilot projects and by working together with them within the Smart Buildings knowledge network, gaining insight into the current state of affairs at these institutions. A new dynamic is emerging in 2025: due to budget cuts in higher education and declining student numbers, the new opportunities presented by AI, and the increased focus on privacy, compliance, and strategic autonomy as a result of geopolitical developments.



WHAT IS A SMART CAMPUS?

"The smart campus is aimed at using data and digital technology that is applied specifically to facilitate campus users, to improve space utilization and to optimize service delivery, in co-creation with education and research."

In this definition, the smart campus can be seen as a journey in which the concept of smart campus is continuously developed. Interactions between people and technology are happening at an increasingly rapid pace, and even collaboration with organizations on and around campus can be sought.

A vision for a smart campus begins with the question of what exactly we mean by a smart campus. There are many definitions of what a "smart campus" is. These usually depend on the author's perspective and the intended users and services. For example, consider the following definition by Gartner:

"A physical or digital environment in which humans and technology-enabled systems interact to create more immersive and automated experiences for university stakeholders." [1]

This definition is deliberately formulated very generally, so that all kinds of campus developments can be positioned within it. When we look at the definitions used by institutions (translated to English), the smart campus starts to take more shape.

These definitions can be combined into the following definition:

"The smart campus is aimed at using data and digital technology that is applied specifically to facilitate campus users, to improve space utilization and to optimize service delivery, in co-creation with education and research."

In addition to this definition, it must be noted that there are other application areas that share common ground and/or overlap with the smart campus. The term "smart building" describes a similar development from the building level, "smart city" does so at the city level, and "smart hospital" does so for hospitals. For all these terms, as with smart campuses, there is no standard definition. Therefore, there is no clear way to determine whether a campus is smart or not. It can better be thought of as a continuous development of the interactions between people and technology within the campus system[4], in which these interactions occur faster and faster, up to in real time.

"The EUR smart campus is a site with buildings that is managed by using data and that (also through the use of data) facilitates the users, making use of old and new technologies." [2]

- Erasmus University Rotterdam

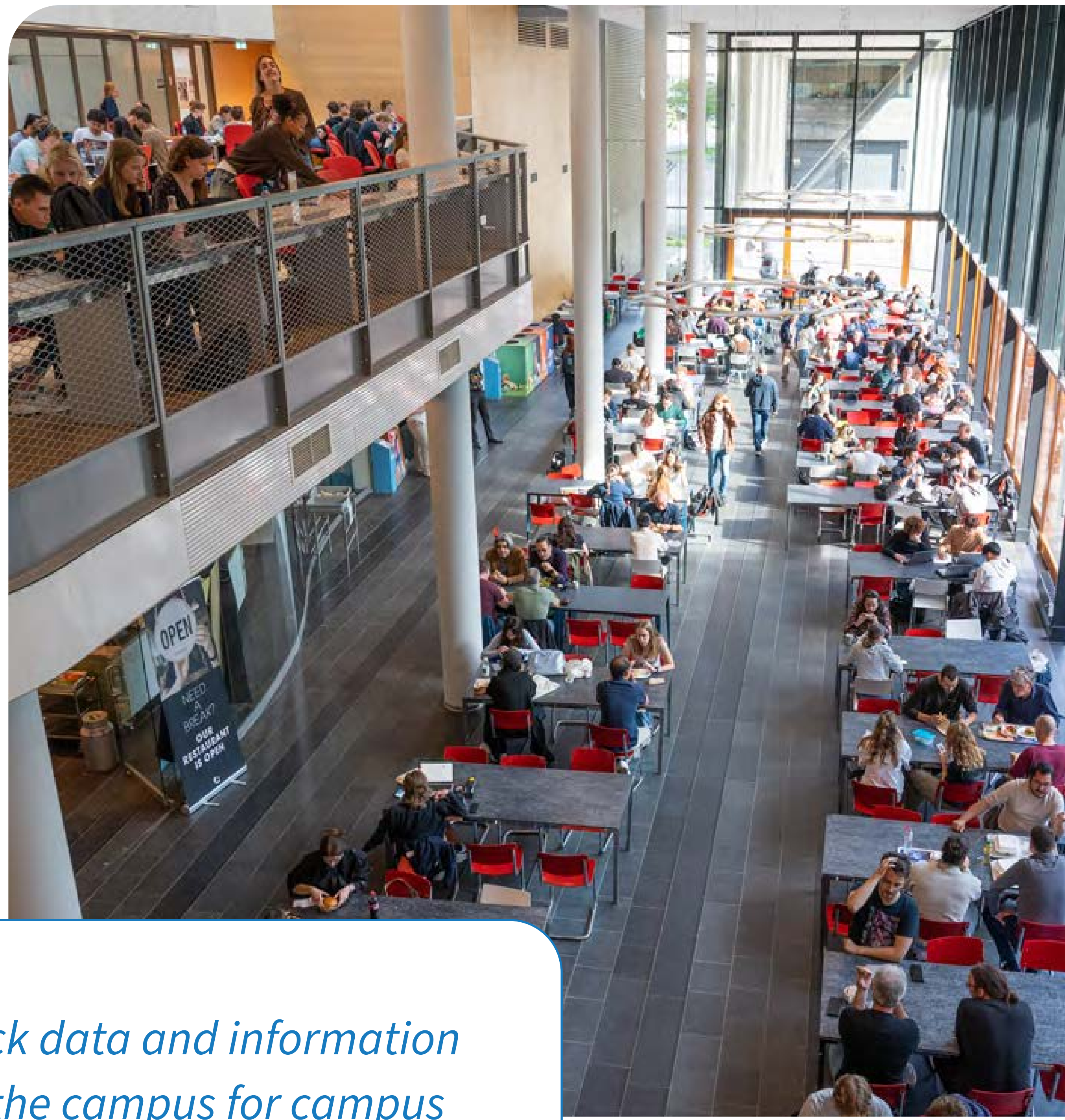
“The smart campus aims to leverage the next generation of (digital) technologies to:

- *enable a more sustainable campus*
- *optimize resources and infrastructure for campus services and operations*
- *enable co-creation of campus experiences and support the culture of education, research, and innovation.”*

- TU Eindhoven

Equally important is the question of where the boundaries of the smart campus lie. Is it a physical campus location, or is it the collection of smart buildings used by a single institution? And to what extent does the digital campus play a role? The smart campus is more than just a collection of smart buildings; some services are tailored to specific types of buildings or spaces – take, for example, an application that helps students to find study spaces. The boundaries between organizations can also blur or expand over time: institutions can use the smart campus to offer joint services to their users or share each other’s spaces. For these reasons, we view the smart campus as a (joint) journey, in which the smart campus is constantly evolving.

Finally, the question is which data and digital technology falls within the scope of the smart campus. This concerns the data and technology used for specific objectives: facilitating users, improving space utilization, and optimizing services. These are explained in more detail in the next paragraph. Thus, not all data and technology falls within the scope of the smart campus: for example, it does not concern the management of the Wi-Fi network, but it does concern the possible use of data about the use of that same network. It does not concern the use of XR technology in education, but the use of XR technology can influence the use of the campus in such a way that it leads to a further development of the smart campus.



By using smart technologies, we can unlock data and information that contribute to the user-friendliness of the campus for campus users, the reduction of energy consumption, the improvement of space use, the more efficient deployment of assets and services, and adding value to our education and research. We do this while respecting privacy values and legitimacy.” [3]

- Amsterdam University of Applied Sciences

THE SIGNIFICANCE OF A SMART CAMPUS

The smart campus delivers added value to institutions by improving the well-being of students and staff and ease of use of the campus for them, by using resources more efficiently, implementing sustainable and energy-efficient practices, and by applying living labs and co-creation with education and research.

Generally speaking, a smart campus can be seen as a concept that delivers added value to an organization and its users. Without added value, no one would invest in it. For public institutions, this added value goes beyond simply reducing costs (or increasing revenues), but also includes contributing to stakeholder satisfaction, sustainability, stimulating interaction and collaboration, and so on.

The definition of a smart campus, which is introduced in the previous paragraph, states that the smart campus offers added value on three pillars[5]:

1. Well-being and ease of use

This application area focuses on improving the provision of information to students, staff, and/or visitors, enabling them to take better (and more informed) action on campus. Wayfinding applications within buildings help users navigate to specific rooms. Other applications utilize sensor data and/or a reservation system to help locate available study spaces, workstations, or meeting rooms. In hospitals, asset tracking applications are used to help staff quickly locate specific mobile equipment. These applications contribute to time savings (productivity), satisfaction, and improved space utilization on campus.

2. Efficient use of resources

This application area focuses on improving coordination between campus use and campus services. At the strategic level, this means improving strategic real estate decisions based on the insights gained from the smart campus. A significant amount of campus space is claimed by individuals, groups, or organizational units, such as programs or faculties, but is often not used optimally. By developing dashboards and reports that provide insight into space usage in relation to other campus characteristics, the campus can be designed more effectively and efficiently. At the tactical and operational levels, various business processes take place, such as cleaning, catering, security, emergency response, and so on. These can all be better aligned with actual use, also by supporting them with dashboards and reports to provide insight into actual use and adjust processes accordingly.

3. Sustainability and energy-efficient practices

This application area focuses on improving coordination between campus use and energy management. With information about space usage, building management systems and energy grids can be better controlled. This makes the campus more sustainable and efficient. At the same time, it's important to note that the smart campus also has counterproductive effects: for example, it requires more data storage and infrastructure, resulting in an increased need for raw materials and energy. This should also be part of the business case.

Based on the definitions of the institutions, a fourth pillar is added:

4. Living labs and co-creation

This application area focuses on the participation of education and research in the smart campus. It is valuable for students at every education level to work with these innovations during their studies, and for researchers there are numerous opportunities to collaborate and apply their knowledge to their own institutions. For example, electrical engineering students can participate in the development and evaluation of sensors, mechanical engineers can contribute to their application in control systems (such as building management systems), and computer scientists and industrial designers can contribute to the development of applications and the application of AI techniques. Implementing these applications in organizations, using methods like nudging and gamification, is then of interest to architects, facility managers, organizational psychologists, and public administration experts, among others. The smart campus also generates data that is relevant to all kinds of scientific questions. These activities positively contribute to student development and strengthen the innovative capacity of institutions. They can even lead to new applications within the smart campus!

The smart campus aims to continuously strengthen these four pillars with data and technology. Each of these pillars individually adds value to the campus, but together they stimulate innovation, collaboration, and enhance the institution's image. This also allows the smart campus to have a positive impact on attracting students, staff, research funding, and collaboration with business partners.

Efficient use of resources

Optimizing the use of resources to reduce waste.

Sustainability and energy management

Implementing sustainable practices and improving energy efficiency.

Living labs and co creation

Involving education and research in the development of a smart campus.

Wellbeing and ease of use for students and staff

Improving the experience and comfort of campus users.

CHAPTER 1

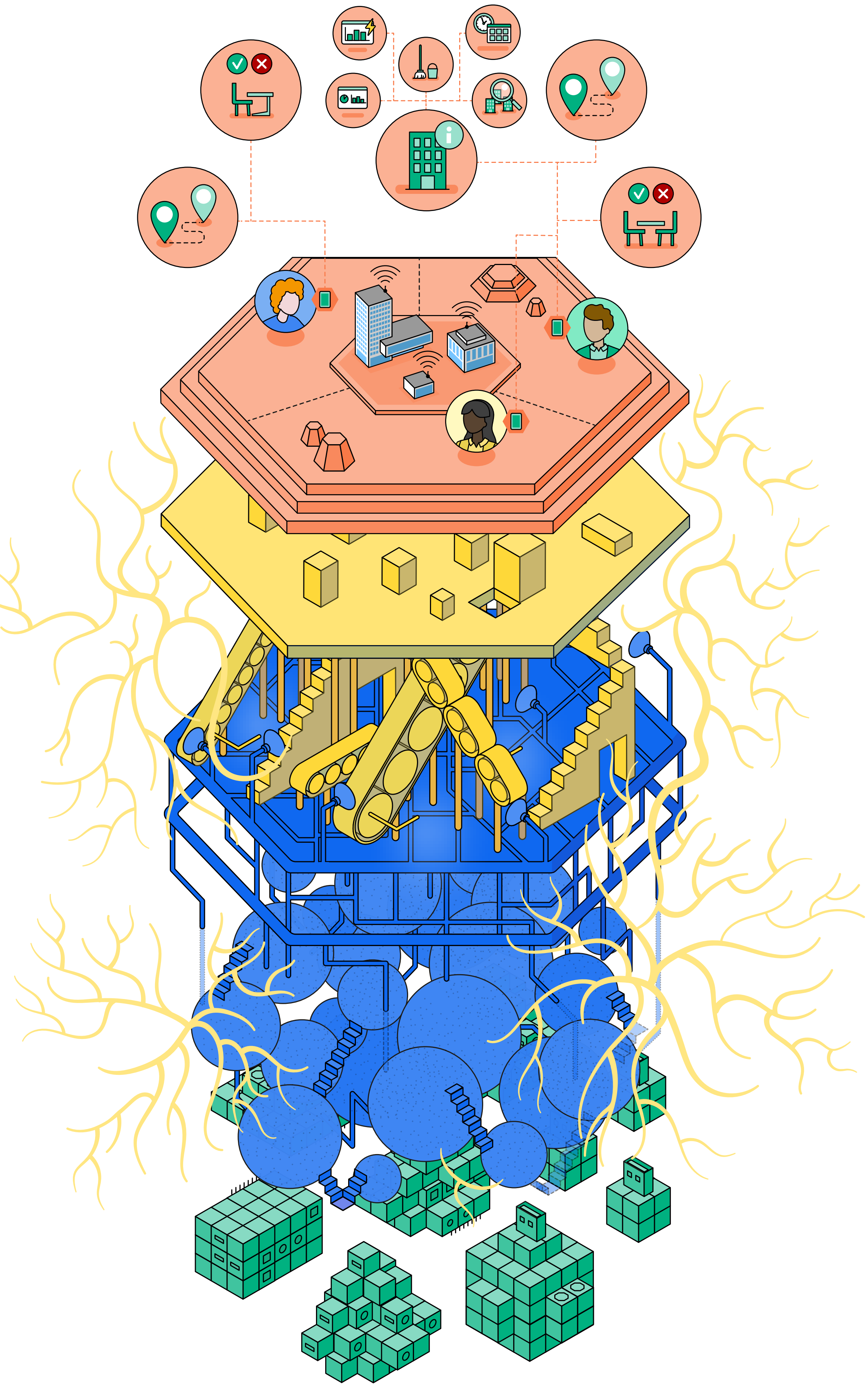
The smart campus ecosystem

INTRODUCTION

The ecosystem of a smart campus consists of four layers: Users and services, Organization and processes, Applications and information, and Technology.

Implementing a smart campus involves a lot of effort. In order to provide structure in this complexity, we use a layer model to describe the smart campus ecosystem. The ecosystem of a smart campus consists of four layers, visible in every IT infrastructure.

- Users and services
- Organization and processes
- Applications and information
- Technology



In the smart campus, attention must be paid to each layer within this ecosystem. Each layer has its own dynamics, with different types of services, dimensions, and expertise. Responsibilities also typically lie elsewhere within each layer. The layer model contributes to understanding how the smart campus works and supports discussions about what is needed in each layer to achieve success. This can be both within and outside the institution. The report “Interoperability of Education” visualizes the ecosystem and its dynamics: see the image on the next page.[6]

1. Users and services

The goals and needs of students, staff, and visitors. The smart campus focuses on these goals and needs.

2. Organization and processes

Processes and organizational structures which are designed and implemented to meet users’ needs and help them achieve their goals. Processes and/or organizational structures can, or sometimes even must, change to improve the current situation.

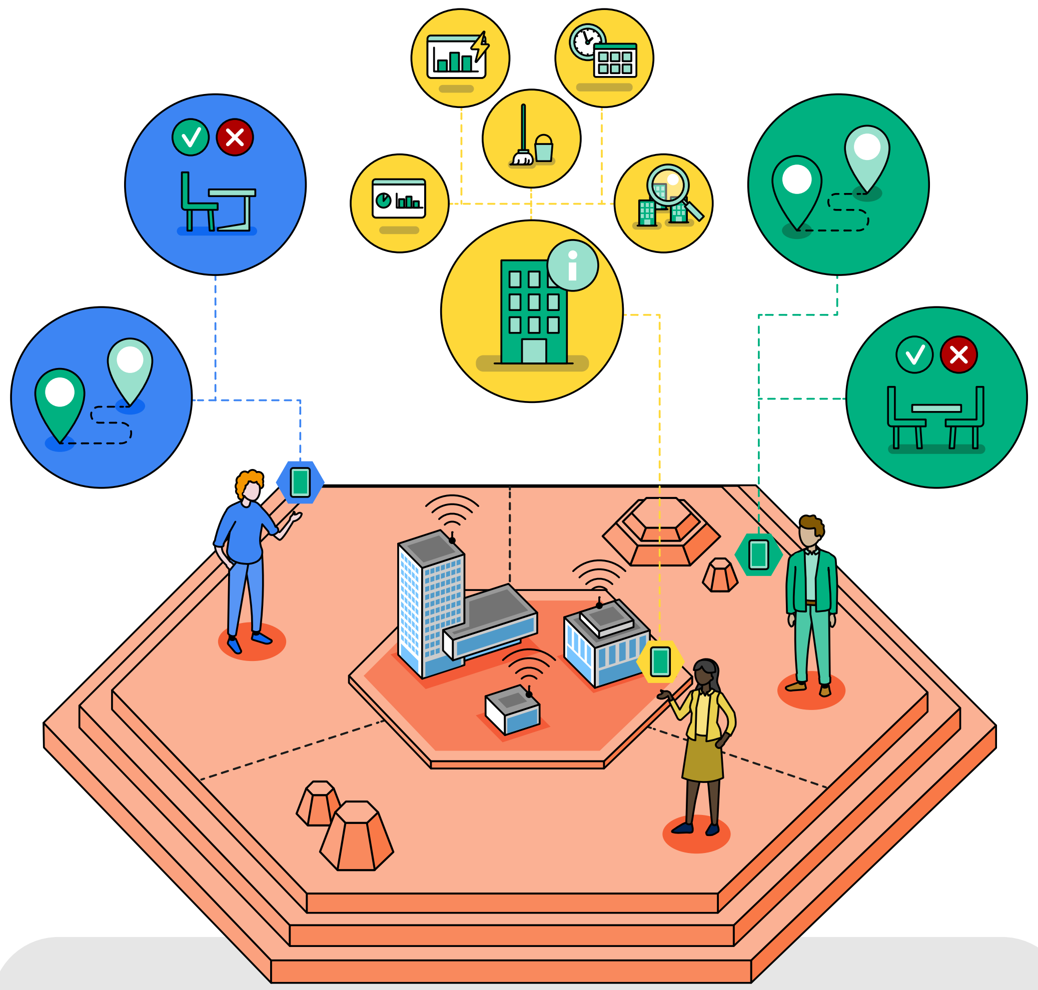
3. Applications and information

Applications and information that help users within processes and organizational structures. In the smart campus, these include apps, dashboards, and reports that provide users with the information they need at any given time.

4. Technology

The technology that feeds the layer containing information and applications. This begins with various data sources and the necessary (network) infrastructure to connect them. Think of sensors, various systems, and wireless and wired networks. Then, the data platform is where the data from all those sources is collected, organized, processed, and stored for the various applications.

USERS AND SERVICES



The first step in designing and implementing the smart campus is to clearly understand the users and their objectives and needs. Students, staff, and visitors each have their own goals and needs, in which the smart campus can support them.

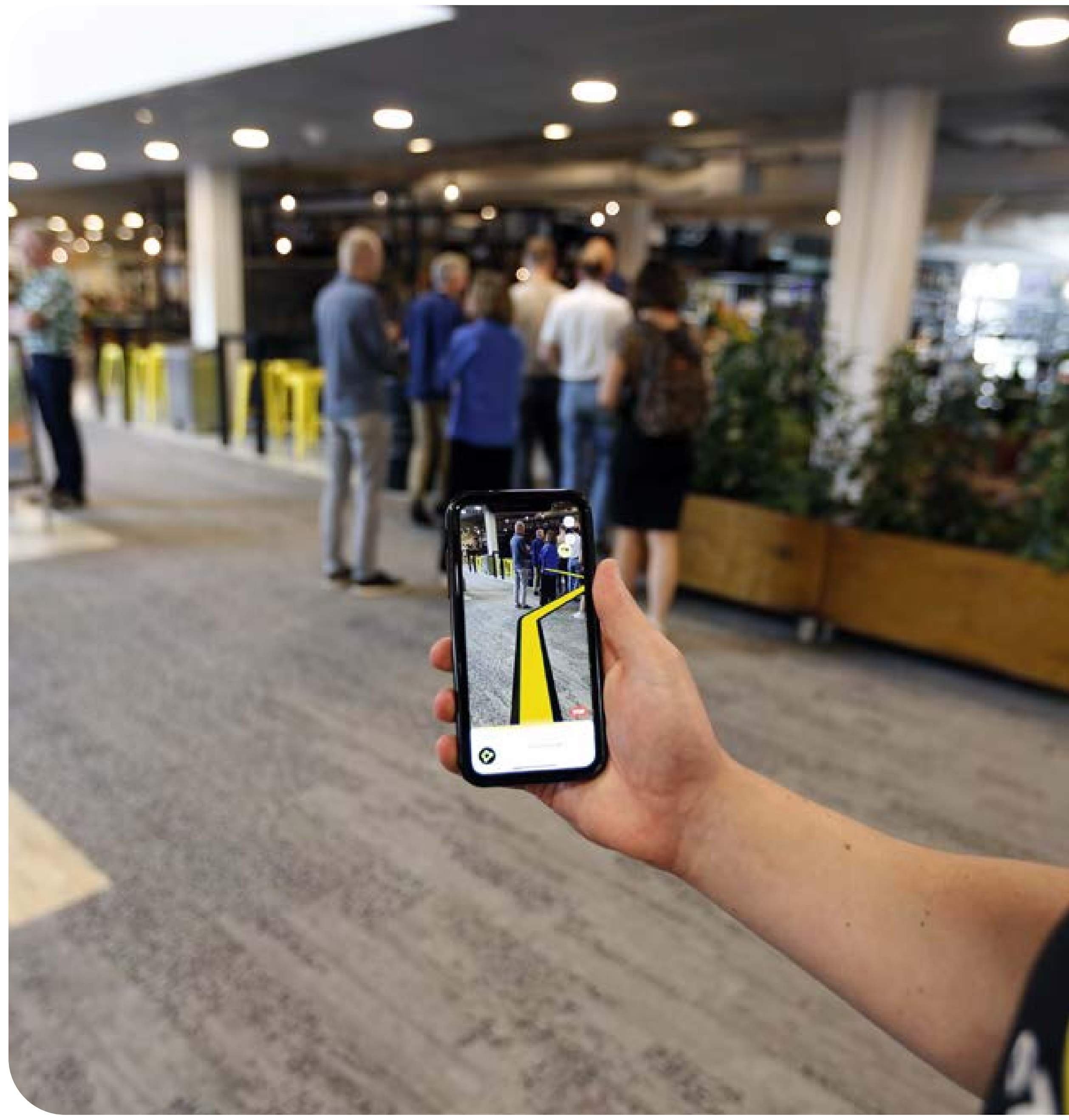
The first layer of the smart campus ecosystem consists of users and services. These primarily represent the goals and needs of students, staff, and visitors on campus. A thorough understanding of users, their goals, and their needs is essential for the success of any service provision, including the smart campus. It makes no sense to design applications that do not serve the goals and needs of users. This is therefore the first step in shaping and realizing the smart campus.

Students come to campus to attend classes, collaborate on projects, and learn, and they want to know where they can do this (pleasantly). They need information about where their classes are held, where available study spaces are, where facilities like printers, lockers, and so on are located in the buildings, and what the indoor climate is like in the rooms. They may also need directions to unfamiliar buildings, for example, if they have to attend a class there.

Employees come to campus to teach, conduct research, provide care, or facilitate education and research in some other way. They also come to meet each other. Employees want to know where to park, where meeting rooms and sometimes workspaces are available, what the indoor climate is like at those locations, and sometimes also how to find directions in unfamiliar buildings.

Visitors come to campus to explore future programs, as guests for appointments or events, or, in the case of academic hospitals, as patients. They need accurate information about parking and public transportation, as well as directions within the buildings, to ensure they arrive at their appointments on time.

Within all these groups, there is a specific distinction: users with special needs. They require additional information, for example, regarding wheelchair access, the location of elevators and accessible restrooms, low-stimulus study areas, and so on.



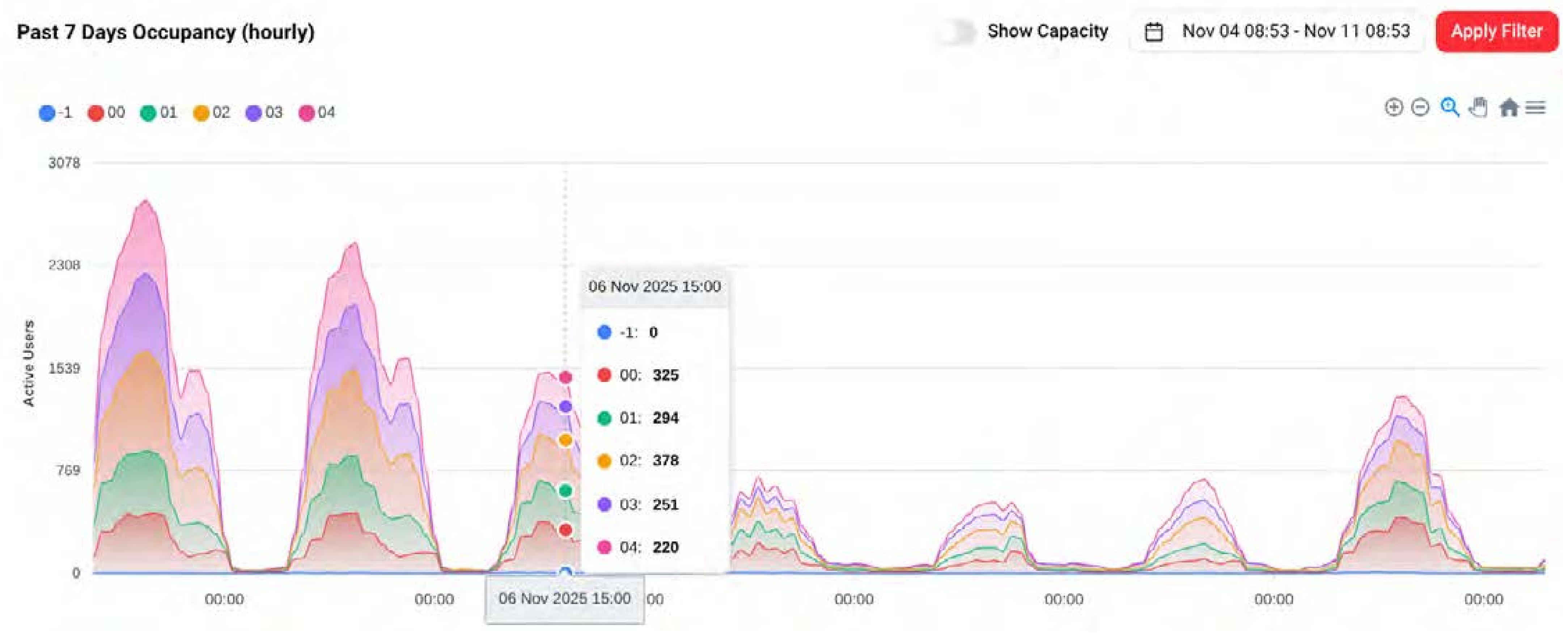
In addition to students, employees, and visitors, there are a number of other types of employees with specific goals and needs.

- Employees in the real estate and/or housing department who are responsible for the organization's accommodation. They need accurate information about the real estate portfolio to advise the organization. This includes information on the number of teaching spaces, workstations, laboratories, etc., the cost of these facilities, and how well they are utilized. This information can be used to determine whether a building (or part thereof) should be disposed of, whether additional buildings should be built, or whether the current portfolio could be better utilized.

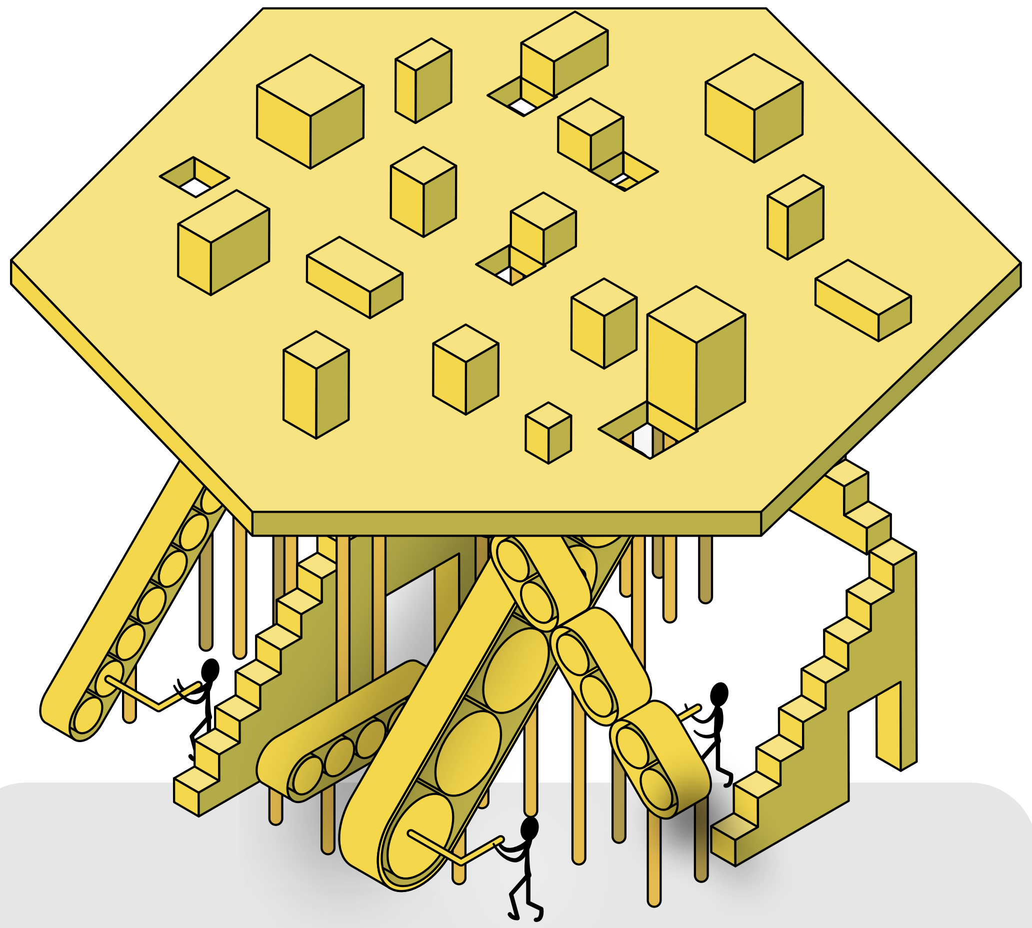
- Staff members of the Education and Student Affairs department responsible for scheduling educational activities. They need accurate information about all scheduled educational activities. This includes information on the number of students the course should be scheduled for, the availability of the instructor(s), the room requirements, and so on.

- Employees in the real estate, accommodation, and/or facilities departments who manage operational processes: energy management, cleaning, catering, maintenance, security, emergency response, etc. They need information to assess whether the services meet the needs of users and to maintain them at the appropriate level. Are the buildings sufficiently heated and ventilated at the right times? Are catering purchases aligned with needs? Is maintenance performed at the right times? Are certain items malfunctioning, such as lighting, or are sensor batteries low, etc.

University of Groningen's crowd indicator



ORGANIZATION AND PROCESSES



Organizations and processes are designed to meet users' needs and help them achieve their goals. In this layer, the goal is to determine which organizational components and processes need to be (re) designed and how, to better meet the users' goals and needs.

The next layer consists of the processes and organizational structures designed and implemented to meet users' needs and help them achieve their goals. With or without a smart campus, a vast world already exists behind the goals of the users (and the organization) – the entire educational and research organization and all its processes are already designed to help students, staff, and visitors achieve their goals. This layer of the ecosystem focuses on embedding the smart campus within the organization: which organizational components and processes need to be (re)designed and how, to serve the goals and needs of users?

In the context of the smart campus, the most relevant organizational units are those that manage the campus and provide services within it, supported by all the processes established for this purpose. These are departments such as Real Estate/Housing, Facilities Management, and Education and Student Affairs. They service a campus where students, staff, and visitors come to achieve their goals, with facilities tailored to their needs. They are under constant pressure to do this effectively, efficiently, and sustainably, so that the institutions can allocate more resources to education and research. For this reason, the smart campus holds enormous potential for them. Research repeatedly shows that teaching spaces and offices can be better occupied and utilized. The smart campus could help them achieve this together with the users[7]. The smart campus can also ensure that energy provision is better aligned with actual use; sometimes this also applies to cleaning and catering purchases. However, this often means that the processes themselves will also change. We will explain this further with an example.

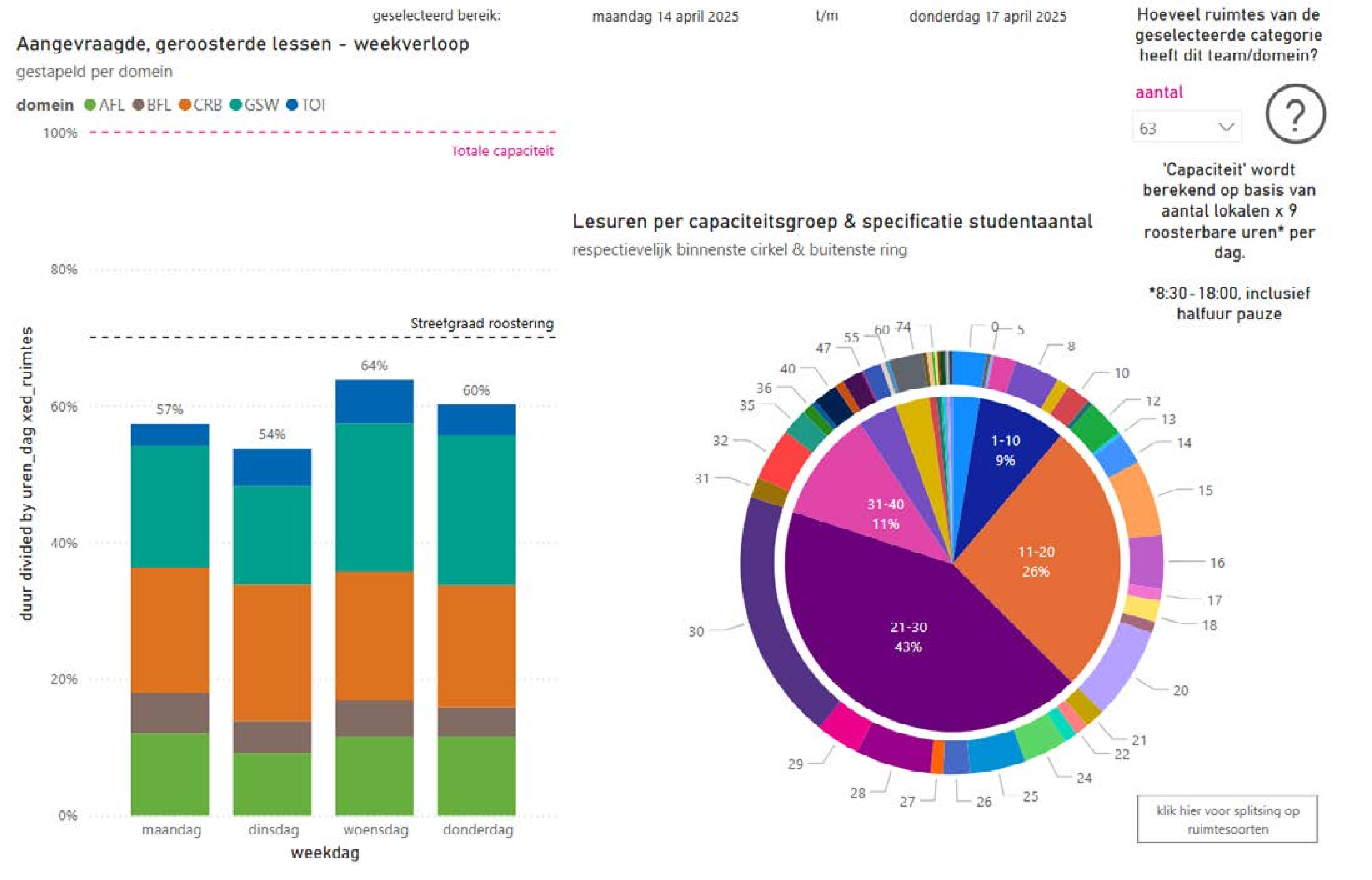
Scheduling teaching rooms is a specific process that is frequently discussed in the context of the smart campus. Stakeholders see that many teaching rooms within an institution are unused during the semester, and even if they are, they are far from full. Conversely, there is always a certain inefficiency in scheduling: courses can only be scheduled if both the student group and the instructor are available, and at that same time, a room must be available that accommodates the group size and has the appropriate facilities. Much is already set before the

scheduler comes into the picture: the course and subject coordinators have already created a draft of the schedule based on the curriculum, specifying which days the students will be doing what, and the scheduler has limited flexibility in deviating from this. Finally, the number of students present determines the final outcome.

In the smart campus a feedback mechanism can be introduced in the scheduling process: by measuring which bookings haven't actually used the space, discussions can be held with the teaching staff about the indicated need for the coming year. The same can be done for the group size estimates, which determine the required room size. Another option which is being mentioned is "dynamic scheduling," in which the rooms assigned to activities can be shifted throughout the semester to ensure the best possible match between group size and room size, and/or to free up rooms for events.

Both options can lead to more efficient use of classrooms, thus positively impacting the quality of education. However, they do require a significant change in the scheduling process. Whereas previously the scheduler was instructed by the educational department to schedule a set of courses at more or less specific times for specific group sizes, in a scheduling process with a feedback mechanism, they will have to consult with educational and subject coordinators to determine what is needed. With dynamic scheduling, the scheduler will have to continuously monitor and adjust the schedule throughout the teaching period to optimize use, and ensure that users are informed of any changes. And we haven't even considered the use of AI yet, which offers even more possibilities for improving educational scheduling.

Scheduling dashboard Inholland University of Applied Sciences

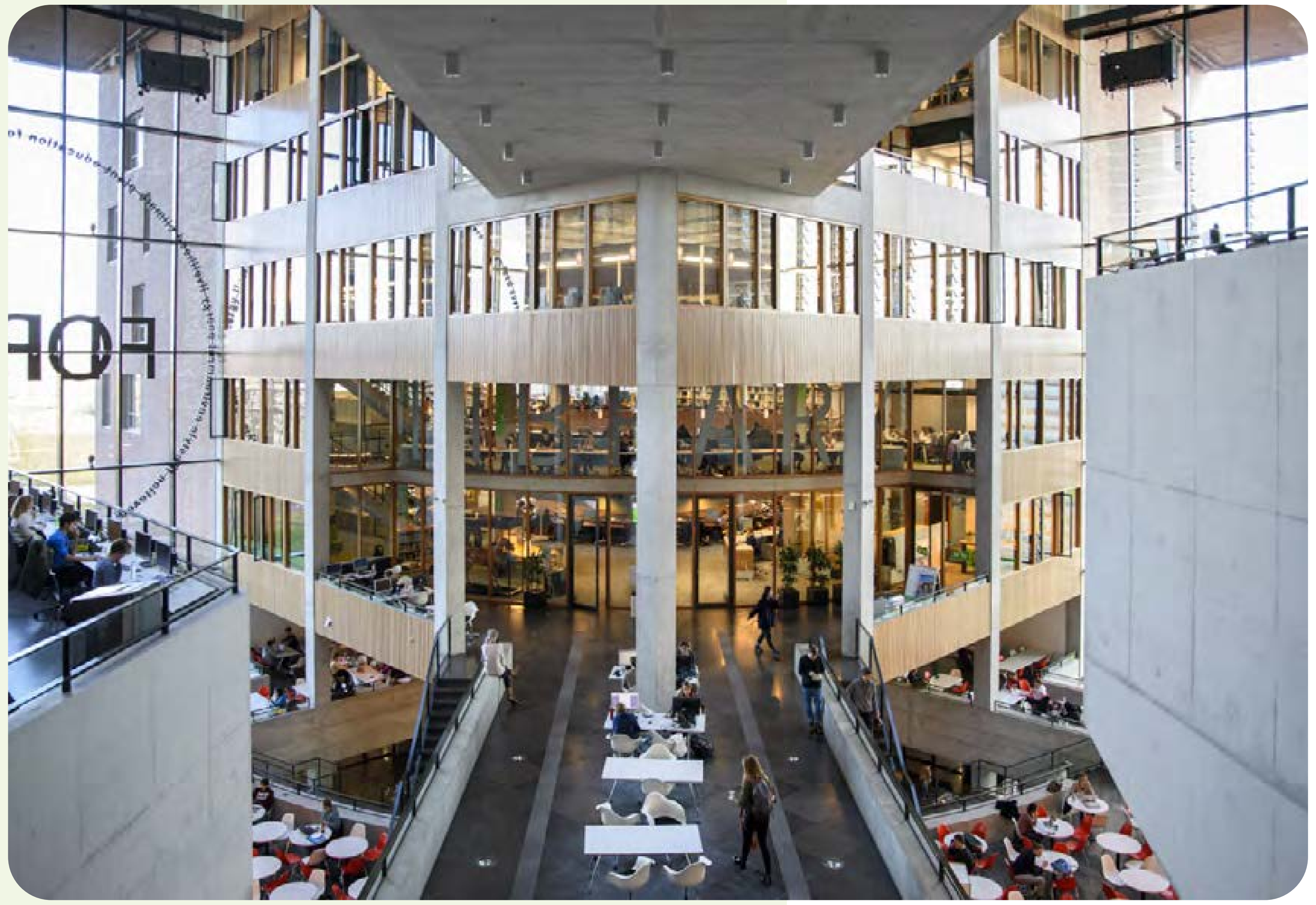


Innovation in the scheduling process

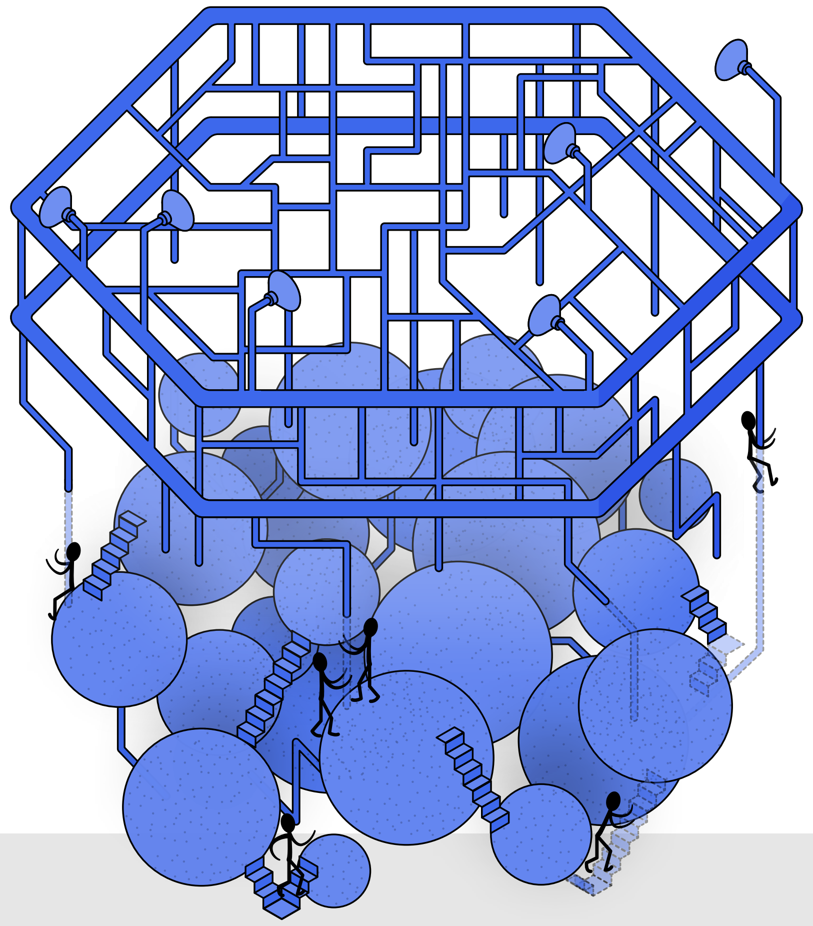
Wageningen University began improving the frequency and occupancy of its classrooms in 2015 by implementing the Position Intelligence Engine developed by Lone Rooftop (now Hubstar). This application uses Wi-Fi activity to determine the actual use of classrooms. This information is then compared to the timetable.

To ensure that the classrooms are truly used more efficiently, the organization has adjusted its processes. Schedulers use the tool primarily to detect no-shows. When no-shows are detected, they communicate with the teacher to determine the reason. Based on this feedback, schedulers can also decide to free up the room for subsequent weeks or move the course to a smaller room. The required room capacity for the course can also be adjusted in the following year's schedule based on actual occupancy.

These are all actions that previously weren't performed this way. Implementing the tool therefore leads to a change in the schedulers' work, and these adjustments result in more efficient use of space.[8]



APPLICATIONS AND INFORMATION



Applications and information provide users with the information they need at any given moment. The goal in this layer is to define how these should look and what requirements they should meet. In the smart campus, this layer consists of apps, dashboards, reports, and software applications such as BIM and digital twins.

In the application and information layer, applications are developed that provide users with the information they need at a given moment. Think, for example, of apps or websites where students can consult their schedules, or where students and teachers can exchange information about their course or curriculum. Also, data is transformed into information in this layer, by combining or enriching data. This information can then serve as the basis for processes or applications. The goal of this layer is to define what the applications and/or information should look like and what requirements they must meet.

In the smart campus, this layer consists of apps, dashboards, reports, and software applications for various purposes. By apps, we mean those applications that are primarily aimed at students, staff, and visitors in general. These are smartphone apps or websites where they can find specific information. For example, there are apps that help users navigate buildings with interactive maps showing various facilities. Using sensor data, these can also provide insight into the location of available lecture halls, study spaces, workstations, and meeting rooms, and whether these rooms can be reserved. They can provide insight into the indoor climate or release unused spaces. These apps contribute to well-being and ease of use.

Dashboards are visualizations designed to display data from various sources in a comprehensible and concise manner. This allows users to discover trends, patterns, and insights. Dashboards are very helpful in managing daily operations. For example, dashboards in and of building management systems provide information to building managers, enabling them to take action when CO_2 concentrations become too high or malfunctions are reported. However, they can also be used more strategically. For example, dashboards that show space utilization over longer periods of time can be used to inform investment decisions, such as expanding locations or reducing capacity at existing ones.

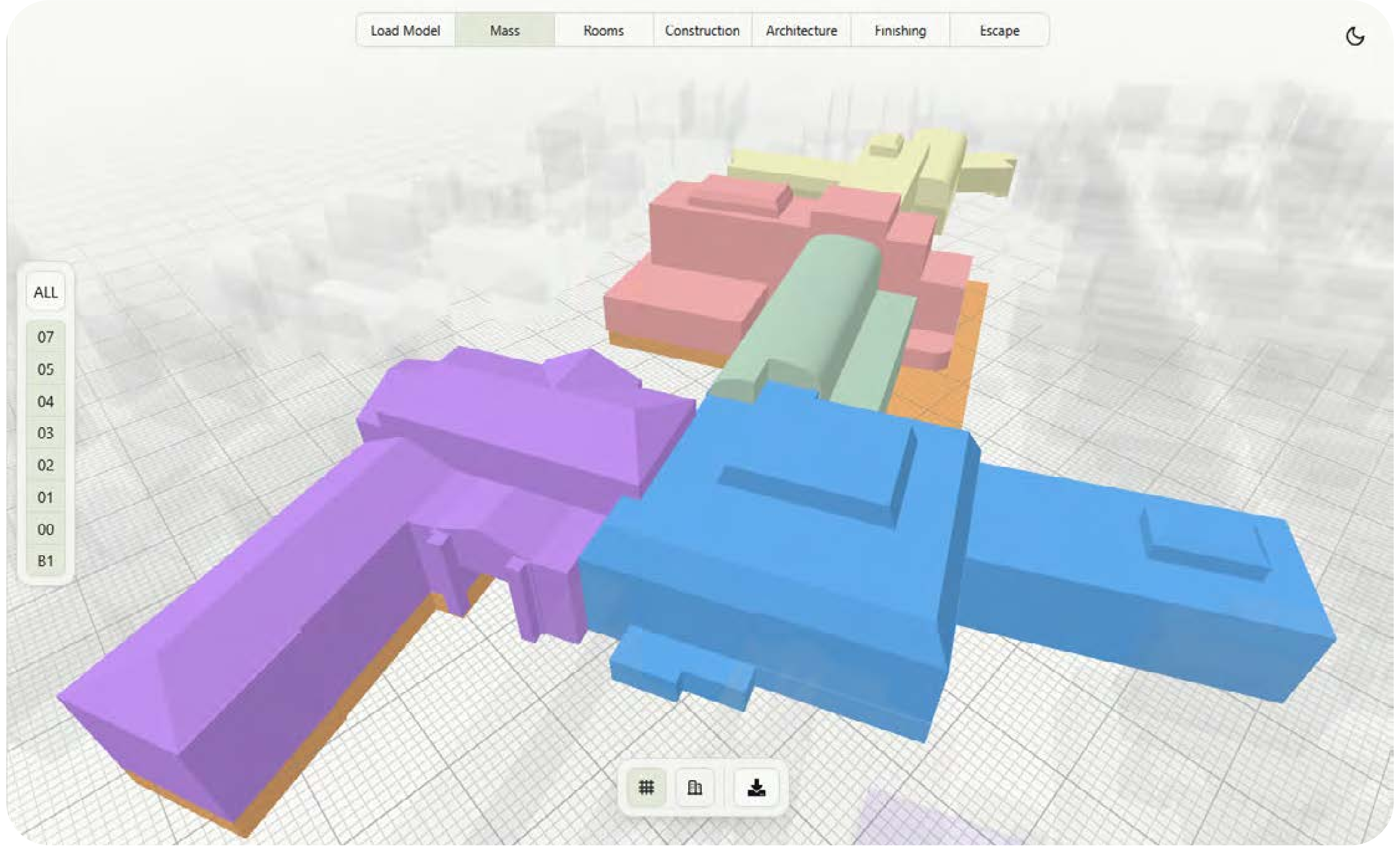
In other cases, it is necessary to display specific information for each building, a large series of rooms, or other data in a list view. In that case, reports are needed. These are often detailed exports of the

same information you would find in aggregated form in dashboards. Reports are created for the same purposes as dashboards, but provide the user with more detailed information and more options for adding descriptions of trends, patterns, and insights. Therefore, they have a more tactical and strategic focus and they contribute to sustainability, energy management, and more efficient resource utilization.

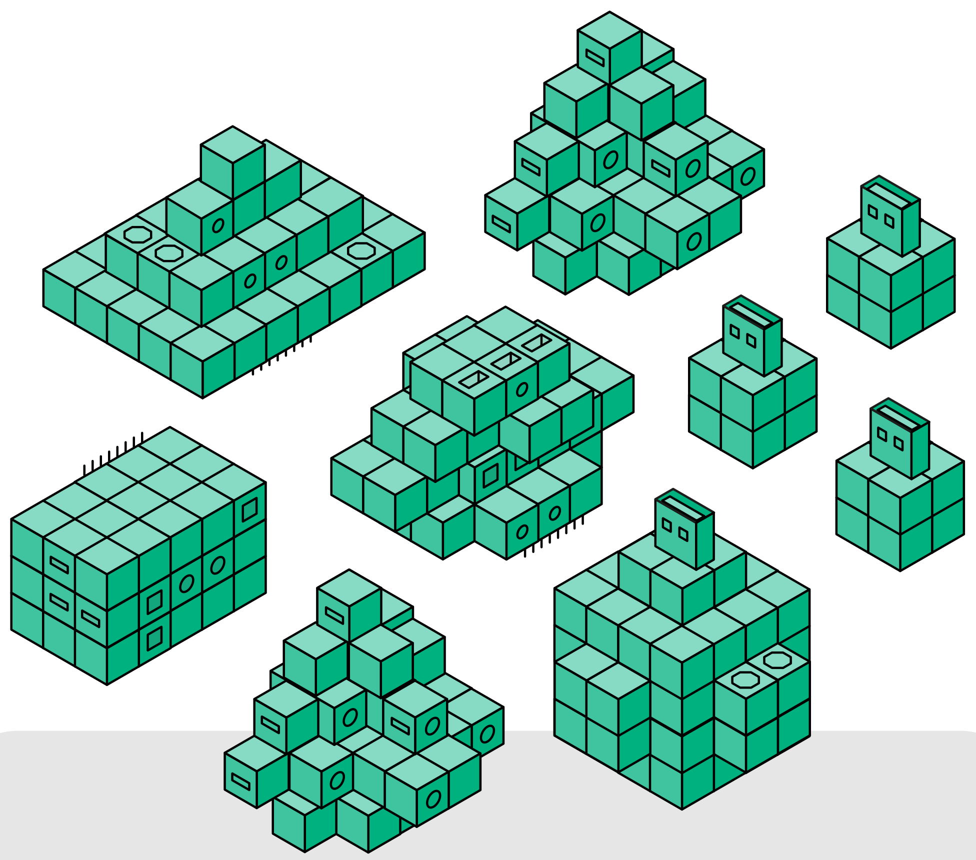
Finally, there are specific software applications that can be considered part of the smart campus. For example, there are applications that allow building management systems to be controlled based on real-time data and possibly even AI. Another highly relevant application is the building information model (BIM). This is a digital (3D) model of a building, in which the building is constructed from various objects containing information. BIM is particularly well-known in the construction industry, where it is used by architects, installers, structural engineers, and others for collaboration. A BIM model can be visualized in 3D, for example, with filters to display the various types of information. Because these models contain detailed information about a building, they can also be used in the building management phase.

BIM models are a form of digital twin, or they can be a part of one: they are digital representations of physical buildings and enable all kinds of simulations (with additional software). Other digital twins can also view BIM as one of their sources, or use other types of data, depending on the specific underlying need. For example, a digital twin of an entire campus's energy system has little use for all the object information in BIM that is unrelated to the energy system.

BIM viewer University of Groningen



TECHNOLOGY



The technology, consisting of the data platform and the infrastructure of sensors and networks, is the foundation of the smart campus. In this layer, it is determined which technology is needed to meet the information needs and functionality of the applications.

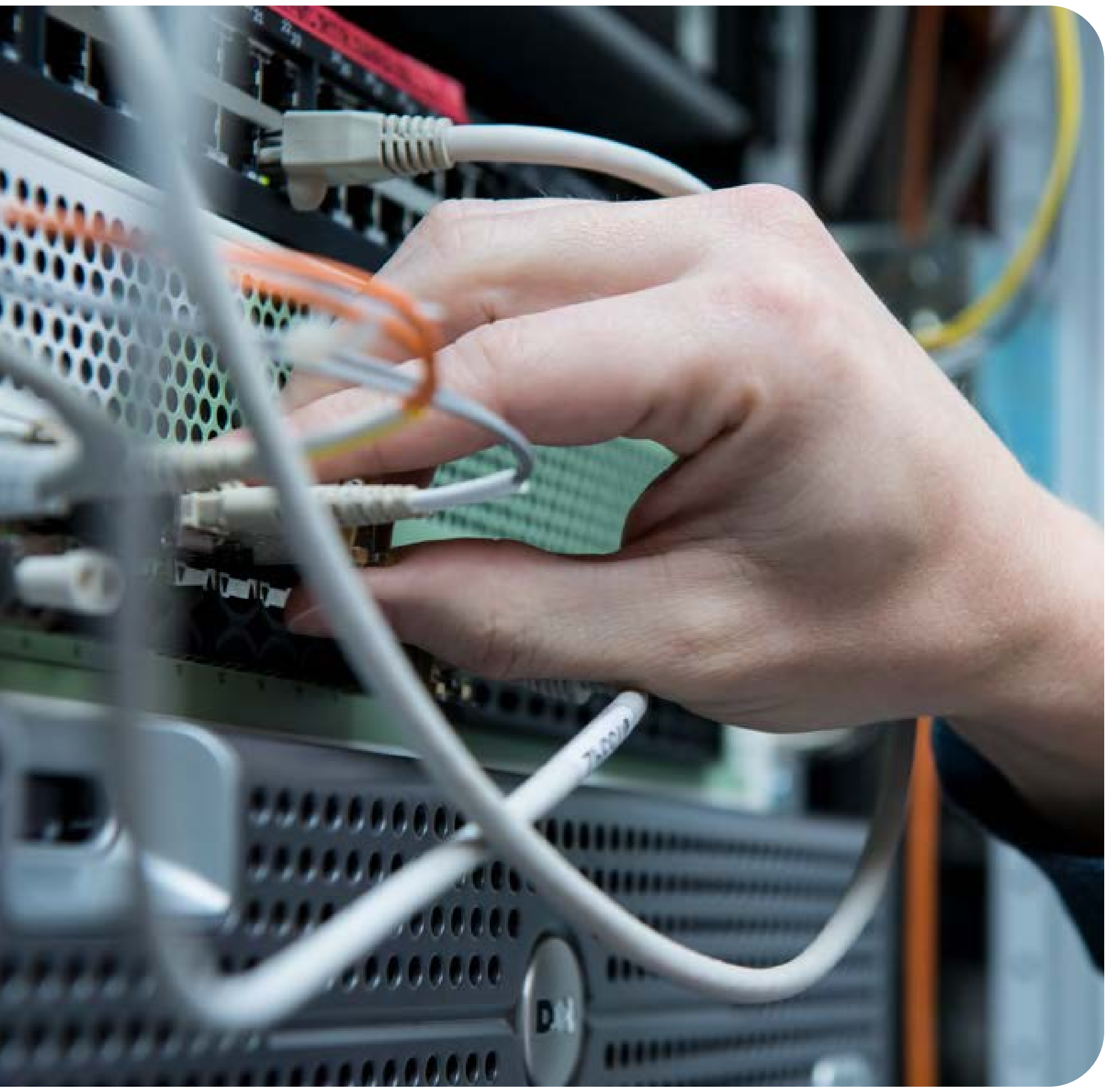
Data platform

The data platform is the location where all the necessary data is collected, organized, processed, and stored for the various applications. Because the smart campus uses various data sources, the data platform is a vital component: it is the means by which the information from these systems is accessed and compiled. This can easily involve many different types of data and systems: Wi-Fi or network data, reservations, data about rooms and surface areas from FMIS systems, energy consumption, user numbers, sensor data, and so on.

Data platform requirements can vary by application. For example, compare the requirements of periodic reporting based on specific data sources to a reservations application. Periodic reporting doesn't require communication back to the data platform, and continuous data updating isn't essential. Conversely, a reservations application requires near-real-time information, and new reservations must be communicated back to the data platform.

Many institutions already have a data platform for Business Intelligence (BI), for analyzing historical data to support business operations or for management reporting such as the annual report. For these functionalities, data sources do not need to continuously communicate with the data platform, and it is not essential, for example, for the data platform to be back online as quickly as possible in the event of an outage. Therefore, it is likely that a smart campus requires a different platform, or that the existing platform needs to be adapted or expanded. Until now, the trend has been for both platforms to exist side by side, but that they are linked together primarily by sending smart campus data to the BI platform.

Nowadays, it's highly likely that institutions are using cloud-based data platforms. Big tech companies like Microsoft, Google, IBM, and Amazon are active in this space, offering institutions the option of configuring their data processing and storage in the cloud through "Platform as a Service" (PaaS) or "Infrastructure as a Service" (IaaS), potentially combining these with the necessary server, network, and storage capacity.



These providers offer high-quality services with considerable flexibility, but they also pose risks related to data sovereignty and vendor lock-in, leading more and more institutions to reconsider these services[9]. We will address this in more detail later in this document.

Infrastructure

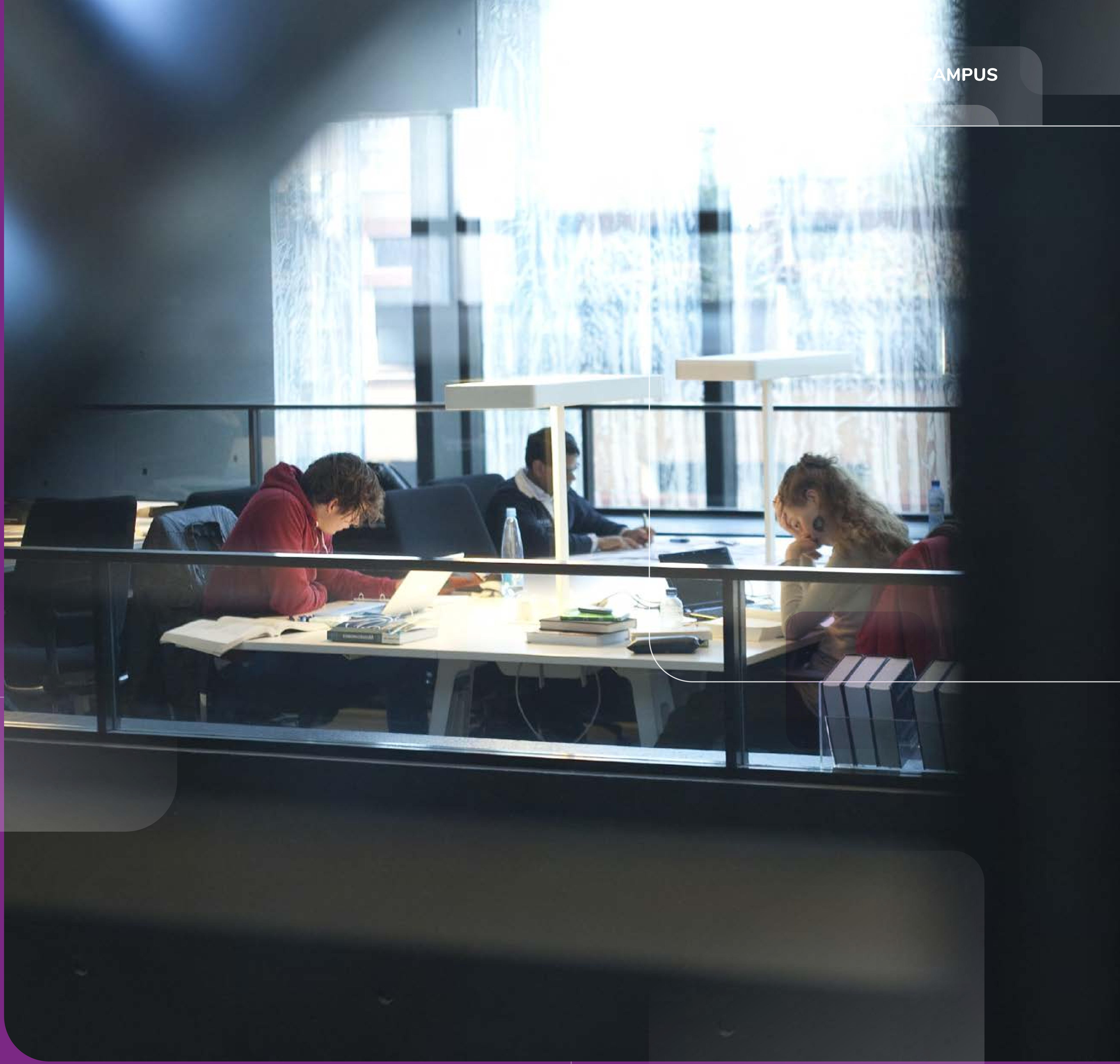
The infrastructure consists of the data sources and the required network infrastructure to connect them to each other and the data platform or platforms. This includes sensors, wireless and wired networks, and firewalls to control traffic flows.

Sensors continuously measure various characteristics of the campus. This is already happening in the present. For example, infrared sensors in lighting fixtures detect the presence of someone in the area beneath the fixture, so the lights can switch on if necessary. Card readers on doors activate when a user holds a campus card against them to assess whether the card has access to the relevant space. CO2 sensors record the CO2 concentration in a room, so the building management system knows when to increase ventilation. The data from these sensors also provide information about the use of rooms and/or the number of people in them. A more precise picture of usage may require more sensors or different types of sensors, or data from other systems such as the Wi-Fi network. A new type of sensor offers the advantage that institutions can better tailor it to what they want to measure, but it does mean an investment in new infrastructure that will then need to be managed.

Besides choosing the type of sensor or data source, consideration must be given to how to connect it to the data platform. This requires network infrastructure with communication protocols. Just as with sensors, there are also a variety of connectivity methods. Regarding communication protocols, there is a distinction between open protocols and proprietary protocols. Generally, open protocols offer flexibility and interoperability, while proprietary protocols sometimes offer better performance because they are developed for specific applications.

The most common methods are connectivity via a wired or wireless IP network. However, other media are also used for sensors; in home automation, communication protocols such as Bluetooth and Zigbee are widely used. In the development of the Internet of Things in companies and institutions, LoRaWAN (an example of an LPWAN network) is frequently used. In building management systems, BACnet and Modbus are frequently used communication protocols. These can usually be connected to other networks via an IP or LoRaWAN network. A smart campus will therefore almost certainly encounter multiple types of networks and communication protocols.

Exploring the future



TRENDS FOR USERS AND THE ORGANIZATION

Future scenarios help to determine the future importance of, and the needs and requirements for, a smart campus. A smart campus can add value in all scenarios, but the question is how users and institutions view the future. The various trends and issues described here can help institutions collectively determine the needs for a smart campus.

Scenario thinking: Future Campus

For a vision on a subject like smart campus, it is important to have a perspective on the future. The value a smart campus can add to educational and research institutions depends on how the campus develops.

Thinking in scenarios helps with this, as it provides a picture of what is and isn't desirable. The Future Campus report is used for this purpose[10]. The four scenarios were developed by identifying various drivers and trends and, with input from various stakeholders such as students, teachers, managers, support staff, suppliers, and architects, developing them into scenarios. Each scenario is briefly described below, slightly adapted for application to this context. The images were generated using AI.

The growth scenario

The campus is a symbol of economic growth and technological progress: a vibrant and innovative environment. Education is flexible and personalized, and business processes are changing rapidly. Sustainability and innovation are harmoniously integrated into this.

At the same time, privacy and well-being are under pressure, and institutions are struggling to keep up with innovations. The challenge is how to balance all these innovations with human values. This scenario is essentially evolving further from the current situation.

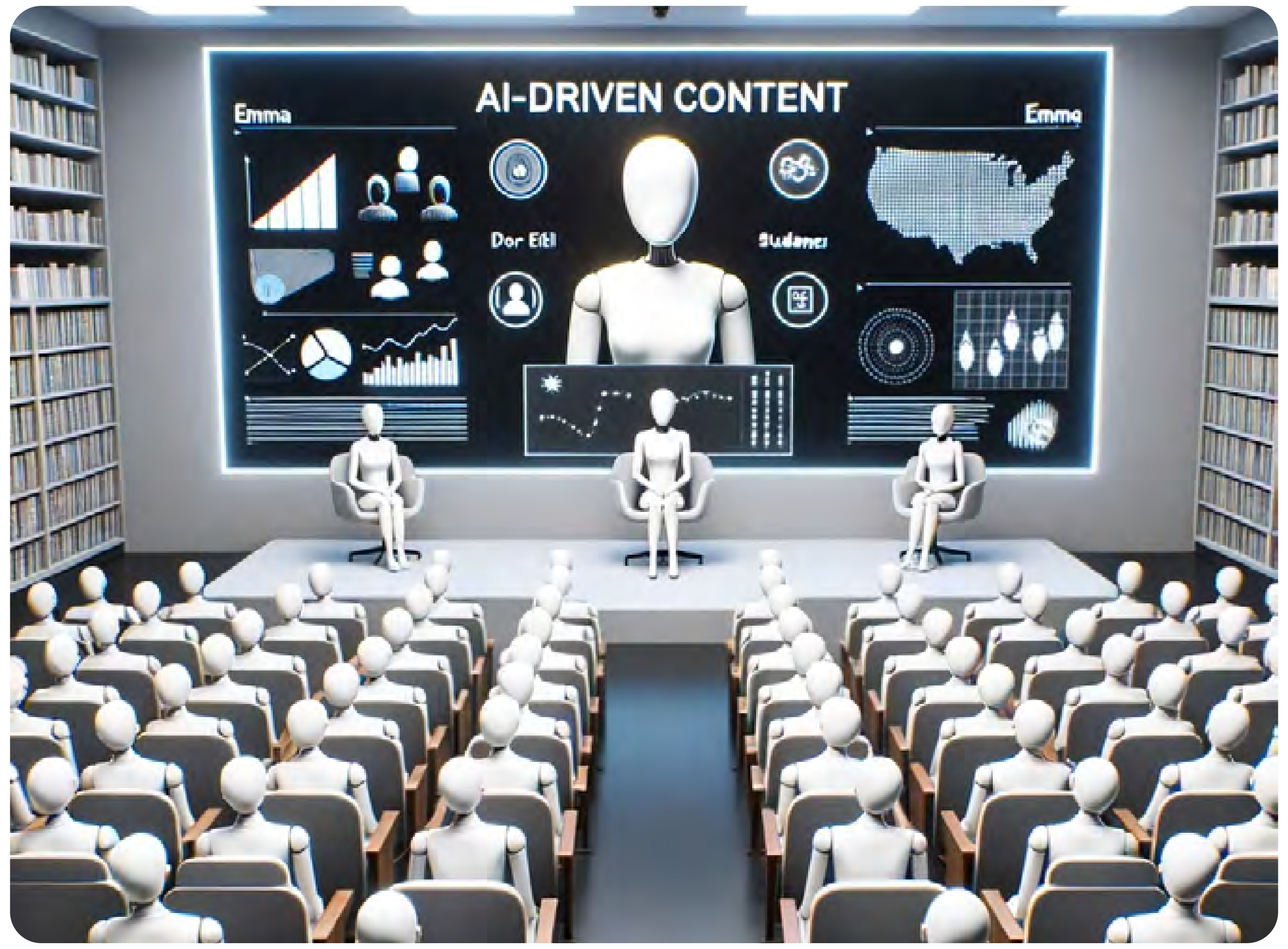
The discipline scenario

The campus is a sustainable, inclusive knowledge hub. Education and business processes are characterized by strict regulations and structure, with an emphasis on public values, privacy, and sustainability. This is shaped top-down by the government to find the balance between human values and technological progress. The challenge in this scenario is how to provide flexibility and room for innovation within such a structure.

The transformation scenario

Educational and research institutions are transforming to a new normal, where the term “campus” no longer refers to a physical location, but to an ecosystem for learning and innovation. Students and staff have greater control over their own learning journeys and personal development, and lecturers and managers take on the role of coaches and facilitators.

The collapse scenario



The campus is a symbol of technological domination and decay. The physical campus has become an outdated and neglected space, while the virtual learning and working environment has become a compulsory and isolating landscape dominated by tech giants. Personal connection and autonomy have given way to profit and control.

Application to the smart campus

The smart campus can play a role in all four scenarios. The question is: how do users and the institution view this? The scenarios raise the following questions:

Open versus closed

How does the institution view its role and how does it exercise this role? Is the institution an open, democratic space for discussion and where there is room for bottom-up initiative, or is it a closed institution with strict rules, managed top-down?

The smart campus can play a role in both open and closed environments. In an open environment, the smart campus adds value by bringing people together, and community building and living labs play a significant role. In a closed environment, the smart campus plays a key role in top-down management; here, it must be prevented that steering turns into control, as in the dystopian collapse scenario.

Standardization versus flexibilization

How much autonomy do students have in determining their curriculum, or do employees have in determining their work, hours, and locations? Will the individual have more autonomy in the future to determine what they want and need, or will the organization have more control over what's best for the collective?

This issue has a significant impact on the requirements users place on the smart campus. An employee who can decide when to work on campus has different needs for information about workstations and meeting rooms than an employee who is always on campus. A student who compiles their own course package at various institutions will likely be hampered by the varying information provided by each institution.

The interaction between humans and IT systems

Do we want this interaction to increase further, or not? Or will we see more variety emerge, with people and institutions choosing moments or places to be offline and online?

The smart campus is a development based on the use of digital technologies and therefore presupposes a constant or increasing interaction with IT systems. This can include interactions via laptops and smartphones, but also, for example, with a personal AI agent. Counter-movements are also visible: for example, secondary schools banning smartphones in the classroom or moving away from digital systems for recording grades. Institutions that want less interaction with IT systems might therefore not adopt a smart campus, but the smart campus could just as easily be focused on specific parts of the campus. The desired relationship with the big tech companies also plays a role in this issue.

In addition, there are other conceivable aspects that affect users and organizations. In 2023, UNL identified nine trends that would push universities out of balance[11], and in 2025, SURF developed eight themes in which disruption could lead to changes in education[12]. Uncertain student influx, study financing, the digitization of (academic) work processes, contact between students and lecturers, the aforementioned flexibilization, and larger-scale and more specialized research are the trends that will impact how students and staff learn and work, and how they use the campus. These trends can also change existing processes and structures at the institutions.

Finally, business operations are continuously working to improve the effectiveness and efficiency of processes and resources. Real estate is a prime example: buildings have become more expensive per square meter over the years due to increased quality requirements. Buildings now contain more building services with a higher complexity, high-quality ICT facilities, and they are much better insulated. A larger share of infill (such as ceilings, plumbing, and kitchens) and machinery also means that buildings age more quickly[13]. Institutions therefore continuously look at how they can best utilize the existing campus.

Operational services are also exploring how the smart campus (or similar developments) can help optimize service delivery through IT. This even pits the increasing use of IT against human service delivery. The questions are: are we moving toward automation, efficiency, and distance between the user and the organization, or (instead) do we choose for human, personal, and interaction? And: what will be the driving force behind service delivery? Will it be professional intuition and craftsmanship, or data-driven technology and AI? Or will we opt for a combination?

Many organizational aspects can and will change in the future, impacting the smart campus from both the perspective of users and the organization. Therefore, it is important to discuss these issues and ensure a shared vision of this future, including the role of the smart campus within it. The trends described here can serve as a guide for these discussions. The document “Responsible Tech: On Public Values and Emerging Technologies” and SURF’s Value Compass also offer helpful tools.[14]

TECHNOLOGICAL TRENDS AND DEVELOPMENTS

New technologies can accelerate the smart campus, enable new applications, and/or enhance existing ones. In the past, the advent of the smartphone was such a development. Currently, Artificial Intelligence, the Internet of Things, and digital twins are the technologies that are expected to have the greatest impact on the smart campus, and the relationship with Big Tech companies is a key development that that requires making choices.

In the application and technology layer of the smart campus, it is crucial to consider recent trends and developments in the technology space. We do this based on the SURF tech trends report[15]. The most relevant trends for the smart campus are AI and Edge computing. We briefly highlight these trends here; for further in-depth information and other trends, please refer to the report.

New technologies can accelerate the smart campus, enable new applications, and/or enhance existing ones. For example, the recent arrival of the smartphone has led to several major changes. Smartphones offer users numerous opportunities to interact with their environment through apps. Demand for these apps has increased dramatically, along with connectivity requirements. Furthermore, every user interaction via their smartphone has become a potential data point. There have also been developments in sensor technology to measure various environmental variables—both from the smartphone itself and from the environment the user interacts with. The smartphone has thus led to a demand for new applications, but also to new types of data that can be used for various purposes.

The most relevant trend for the smart campus is Artificial Intelligence (AI). AI has the potential to be the next game changer. AI also has a strong influence on the broader education and research sectors. According to IBM, AI is "a collection of technologies (including machine learning, deep learning, and generative AI) that enables computers and other machines to simulate human learning, understanding, problem-solving, creativity, and autonomy."[16] Relevant developments within AI include: the construction of more complex models (so-called Franken models), more efficient training and implementation of AI models, the use of AI to access data that is difficult to access, and working on the reliability and accessibility of AI.

There are many ways in which AI could enhance the smart campus, particularly in using collected data to make predictions and/or provide advice. It could provide users with suggestions for study places and workspaces based on their preferences, offer asset managers suggestions for space optimization, or perhaps even improve the control of building management systems.

In addition, two important trends are mentioned within the theme of Edge computing. The first trend

is the "Internet of Things" (IoT); this is a relevant application for the smart campus. IoT is "the interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications"[17]. Thus, what IoT enables is monitoring, analyzing, and acting on real-time data. The second trend is the use of digital twins. These are virtual models of something in the real world, such as a power plant, an airport, or a campus, using data from sensors, simulations, and historical performance data. Digital twins build on the development of the Internet of Things and can be used for analysis, but also for simulations and tests that are physically impossible or too expensive to perform in the physical world. In the smart campus, these digital twins can add value for analyses of, for example, the real estate portfolio, the energy system, but also various types of services such as visualizations for users.

The third major trend in the report is the role of Big Tech companies. This is addressed in the tech trends report under the theme of Networks, where these companies are expanding their role by acquiring physical infrastructure, such as submarine cables. Big Tech companies are expected to become major shareholders in this infrastructure within three years. By combining this with their other services, their service level becomes so high that dependence on it potentially leads to vendor lock-in. It also entails risks related to digital sovereignty. A similar development is occurring in buildings, where suppliers are focusing on "Everything over IP," making this physical infrastructure even more important in the building. These risks are exacerbated by the fact that institutions are experiencing a knowledge drain of employees with this expertise[18]. This development is visible across the entire umbrella of services provided by Big Tech companies – for example, it is also explicitly reflected in SURF's cloud strategy.

Application to the smart campus

The preceding trends briefly describe several relevant developments. It's important to take note of these and continue to do so, as these developments enable new applications. These applications sometimes also require the organization to take a position.

AI is a good example of this. The question that arises with AI is: do we want to use it for a particular application, or not? AI offers a world of possibilities for the smart campus in terms of analysis, both in the platform and technology layers. With AI, the smart campus can become predictive and advisory, or even self-managing, instead of just providing insights based on collected data. It is expected that it can take over work from humans, but the question is how and to what extent. This raises many issues. Who is responsible for the analysis if it is generated by AI? Who checks the AI-generated analyses, and can this person understand how the analysis was generated? What data can AI use, and what data is off-limits? Do we want AI to learn from user behavior? Do we even want to use it given its environmental impact?

Ironically, a smart campus could even lead to us becoming more incompetent: our own analytical capacity likely diminishes when we let AI do the analysis for us[19]. Is this a desirable development? Perhaps the key question is: does a "smart campus" mean that the campus itself becomes smarter, or that users can use it more intelligently? Responsible AI is relevant in this context; it involves developing AI in an ethical and responsible manner[20].

Developments in edge computing and the Internet of Things primarily impact the technology layer, but can also extend to the platform layer. An interesting development in this area is the combination of multiple (existing) sensors in spaces and data that each provide information about space utilization. This so-called “sensor fusion” aims to acquire more accurate information through the combination of different data. The development of the necessary analysis techniques for this is also being enhanced by the use of “multisensors,” sensors that essentially consist of multiple sensors and thus measure different environmental variables.

Another interesting development to keep an eye on is data minimization. Under privacy legislation (GDPR, EU), data minimization is already a requirement – organizations may only collect data they need. However, there is also technological development in this area. Sensors are being programmed to collect and transmit data only at specific intervals or when status changes occur, and data is encoded as efficiently as possible to minimize packet size. The result is that the sensors consume less energy and have a longer lifespan, placing less strain on the network technology and therefore requiring smaller dimensions. The same applies to the data platform. These developments not only benefit privacy but also the sustainability, flexibility, and scalability of solutions. For network technology, this means that methods designed for small amounts of data, such as LoRaWAN, are becoming increasingly attractive. In the long term, this could even reduce the necessary investment and operating costs for new sensor and network technology[21].

This trend also means that it will become easier to integrate existing buildings into the smart campus. Currently, examples of “smart buildings” in the market are mostly new or renovated buildings, with large numbers of sensors installed on IP or electrical points. Because battery-powered sensors have increasingly longer lifespans and LoRaWAN requires few gateways, major interventions are no longer necessary to make existing buildings smarter. Installing network cabling in an existing building is, after all, a costly undertaking.

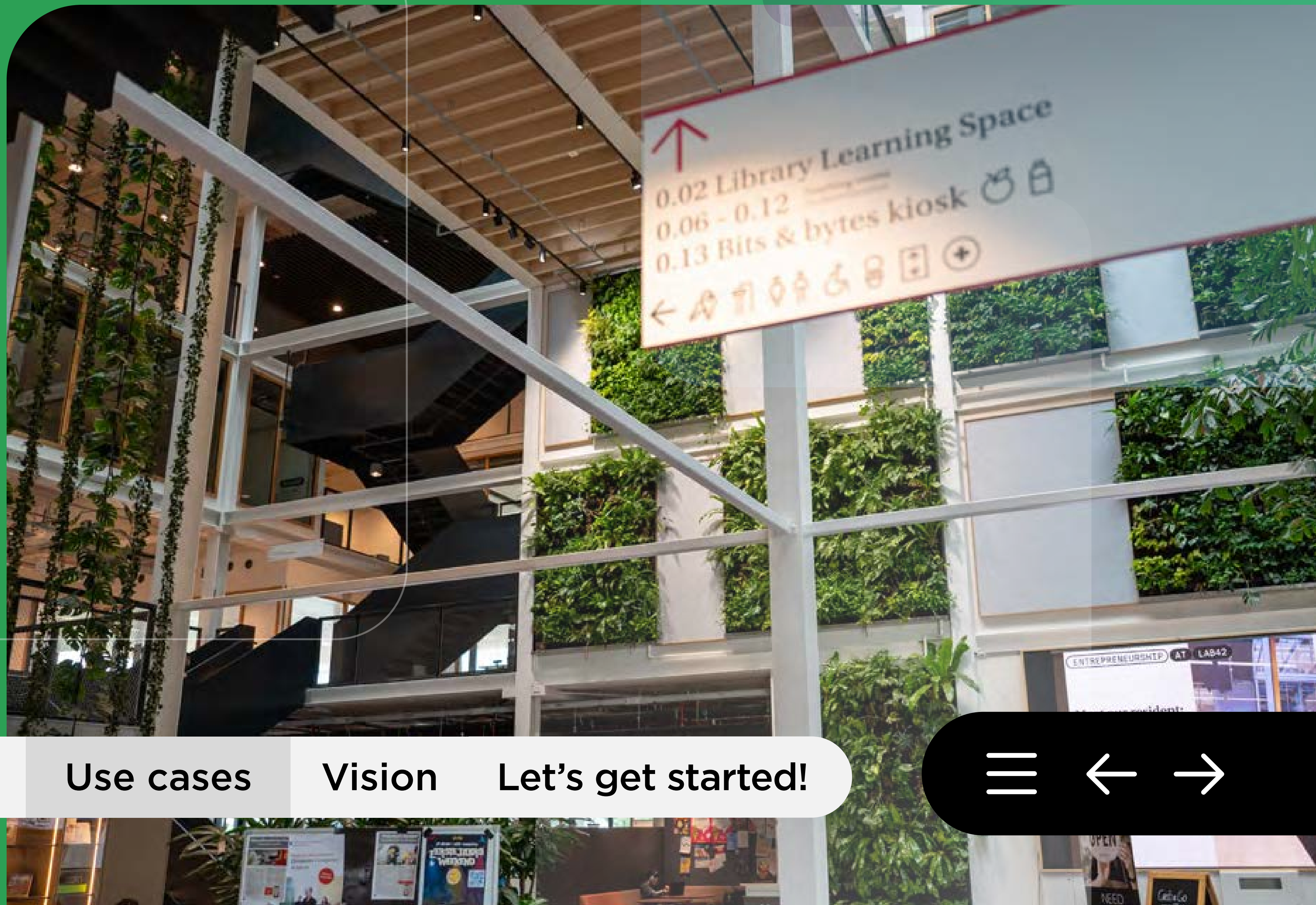
Finally, the relationship with Big Tech companies plays a significant role in both the application and technology layers. The question now and in the future is: do we want autonomy and data sovereignty, and how will we achieve this? Does this mean that institutions must create and operate their own platforms? Or is it sufficient to procure them from a company within the European Union? These questions will lead institutions to make different choices in 2025 than they did a year ago. While data autonomy and sovereignty sound appealing, they also require effort: significant knowledge, commitment, and infrastructure are required to develop, implement, and manage a data platform in-house, that also meets a similar or acceptable level of user-friendliness and security as the platforms already available.

CHAPTER 3

Use cases

The smart campus can add value for different types of users through various use cases. This chapter discusses eight examples.

1. Space optimization systems
2. Availability tools
3. Intelligent energy management
4. Productivity apps
5. Wayfinding
6. Comfort apps
7. Adaptive scheduling
8. Smart maintenance



SURF

SPACE OPTIMIZATION SYSTEMS

What?

Space optimization systems measure the frequency (usage in hours) and/or occupancy (usage in number of people) of workstations and spaces, and translate the collected data into management information. Space utilization data are collected via sensors, the Wi-Fi network, and/or access gates. This is translated into frequency and occupancy rates, which can be compared with historical data, benchmarks, and targets. This reveals whether there is sufficient space, or whether there is a shortage or surplus.

For whom?

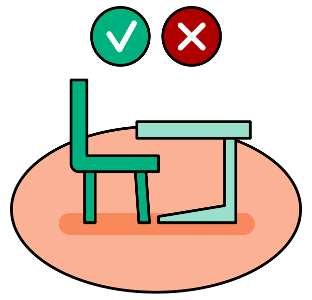
These systems are intended for real estate managers and consultants, so that they can make decisions together with the organization that lead to more effective and efficient use of existing buildings.

Benefits

- More effective and efficient space use
- Improved substantiation of investment decisions
- Reduced need for investment, if better use of existing buildings leads to less new construction

Challenges in the implementation

- The best choice for collecting the required data varies from case to case. This depends on (among other things) the presence of access gates that only permit individual access, the suitability of the Wi-Fi network for measuring the number of people, and the position of rooms within the buildings.
- User acceptance can be challenging for this type of application, especially among students. Combining it with applications that offer added value to them is an obvious solution, as they use the same types of data.
- The costs for this type of application are primarily related to the technology required to collect the data. However, this type of data can often be used for multiple use cases. In return, this use case translates into significant returns or cost savings from more efficient use of space.
- The scalability of the solution depends on the data collection method and, for existing sources, on the extent to which these sources are present in all buildings. For new sensors, the scalability depends on the ease with which they can be installed in the right location.
- Data collection for this use case can be done in ways that do not collect personal data. When using data from the Wi-Fi network or Bluetooth sensors, care must be taken to anonymize and process data in a way that prevents tracking of individuals, and to ensure further GDPR compliance.



AVAILABILITY TOOLS

What?

Availability tools provide users with (near) real-time information about the availability of study spaces, workspaces, and meeting rooms, helping them find a suitable place to work or study. This information can be provided at the location, room, floor, or building level. Data about space usage can be collected in various ways, such as using sensors, Wi-Fi network data, or access gates. For meeting rooms, combining data with reservation data and a booking functionality is an obvious solution. Displaying the characteristics of the spaces and the predicted occupancy level are also relevant.

For whom?

Availability tools are primarily intended for students and staff, but can also be used for visitors or students and staff from nearby institutions. These tools provide added value when user groups share facilities, especially at the building or campus level. The information generated by these tools is also very useful for real estate consultants – this use case is described in section 4.1.

Benefits

- Reduces stress and confusion for users who share facilities.
- Leads to significant time savings.
- Increases the effective use of spaces and areas and the distribution of users across the campus.
- Leads to the collection of occupancy data, which adds value to real estate investment decisions (see use case 1).

Challenges in the implementation

- The best choice for collecting the necessary data varies from case to case. This depends on (among other things) the presence of access gates that only permit individual access, the suitability of the Wi-Fi network for measuring the number of people, and the position of rooms within the buildings.
- Students generally have a demand for this type of solution. Employees may be more sensitive to acceptance when it involves a change in the office concept.
- The costs for this type of application are primarily related to the necessary technology for data collection, although the applications can also be expensive. These costs can be limited by deploying them for multiple use cases. Furthermore, the benefits of more efficient space utilization are enormous (see use case 1).
- The scalability of the solution depends on the type of data collection and, for existing sources, on the extent to which these sources are present in all buildings. For new sensors, the scalability depends on the ease of installation.
- Data collection for this use case can be done in ways that do not collect personal data. When using data from the Wi-Fi network or Bluetooth sensors, care must be taken to anonymize and process data in a way that prevents tracking of individuals, and to ensure further GDPR compliance.

CASE 3

INTELLIGENT ENERGY MANAGEMENT

What?

Intelligent energy management uses data on space or building usage, energy meters, and the building management system to save energy. Especially on campuses with heating and electricity networks, there are both variable demand (number of users and activities taking place on campus) and variable supply (solar energy generation). Intelligent energy management helps to optimize the match between these two. Supply is managed based on the actual or anticipated demand, but demand can also be adjusted if the situation requires it.

For whom?

Intelligent energy management is intended for managers of the campus energy system to help institutions make the best possible use of available energy.

Benefits

- More effective and efficient, and therefore more sustainable, energy use
- Cost savings through lower energy consumption

Challenges in the implementation

- Users will have little resistance to this type of use case, given its purpose. Acceptance depends primarily on the type of data source used to determine the use of buildings or spaces.
- The main costs associated with this type of solution are the connection of the data sources to the building management systems, and possibly even the adjustment of installations if more precise control is required. Not every building management system is equally open, making it sometimes difficult to extract relevant information.
- The scalability of the solution depends not only on the data collection method but also on the existing building management systems and energy networks. The control options of these systems and the effort required to allow new data sources to communicate with them determine scalability.
- Data collection for this use case can be done in ways that do not collect personal data. When using data from the Wi-Fi network or Bluetooth sensors, care must be taken to anonymize and process data in a way that prevents tracking of individuals, as well as to ensure further GDPR compliance.

CASE 4

PRODUCTIVITY APPS

What?

Productivity apps are applications designed to help students and staff increase their productivity. Just as there are apps that help users exercise more or learn a language, there are also apps that help them to study better. These apps show users how they score on certain indicators: e.g. time spent on campus, how much exercise and sleep they get, how often they were distracted by their phone, and so on.

N.B. These types of apps are, of course, only on a voluntary basis and on the condition that users have full control over their own information.

For whom?

Productivity apps are designed to provide students and employees with insights that can help them increase their own productivity.

Benefits

- Increase of productivity and study or work performance

Challenges in the implementation

- It is highly questionable whether users will appreciate these types of applications. Even if initiated by their representatives (such as a student council or works council), it could be seen as something that leads to increased performance pressure, or even an attempt at control.
- The costs of this type of use case are expected to be quite low, as they are relatively simple to develop. Fontys University of Applied Sciences has previously initiated a comparable initiative with students[22].
- The scalability of the solution is quite simple, as it requires little infrastructure and this use case would primarily utilize data that users voluntarily provide.
- This type of application is only feasible on an opt-in basis: users can choose to participate. Given its sensitivity, a structure could be considered in which an app is developed collaboratively and then offered solely as a service to users without further involvement of the institution.

WAYFINDING

What?

Wayfinding is the use of digital tools, such as a smartphone or interactive screen, to help users navigate on campus and within buildings. This navigation can be to a lecture hall, office, or even to amenities such as coffee machines, printers, lockers, accessible restrooms, service points, or activities within the building. Wayfinding can be passive or active: with passive wayfinding, you indicate where you are and where you want to go. With active wayfinding, positioning is automatic, and the route therefore adjusts based on your location.

For whom?

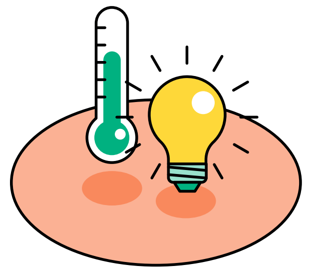
Wayfinding adds value as a use case for students, staff, and visitors. A student or staff member benefits from wayfinding when they need to find their way in an unfamiliar building, which might happen on campus for a meeting, or if their lecture or class is scheduled in a different building. This will become more common as education becomes more flexible (agile education). This is especially true for visitors, as they are likely unfamiliar with the campus and its buildings. Some wayfinding solutions offer the option of creating a digital tour, which can be used during orientation sessions.

Benefits

- Reduces stress and confusion for users
- Leads to significant time savings
- Reduces the need for personal assistance and staff time
- Contributes to inclusivity; with information for people with specific needs

Challenges in the implementation

- The data collection for this type of use case depends on the chosen wayfinding method. Passive wayfinding doesn't require data collection; active wayfinding requires positioning, which can be done using GPS, sensors in the buildings, or the user's own camera footage.
- Users will appreciate this type of application, especially if no additional data is collected.
- The costs for this type of application are primarily related to the application itself and its licensing costs. This could be limited by combining multiple use cases into the same application or by developing the application in-house.
- The solution is simple in terms of scalability.
- When using passive wayfinding, there are no relevant legal aspects. With active wayfinding, this depends on the method used for positioning.



COMFORT APPS

What?

Comfort apps are smartphone applications that allow users to adjust certain aspects of their environment, such as temperature and lighting. Comfort apps use reservations or location data to determine which room the user sets the comfort level for. By interacting with the building management system, the user's preferences are translated into action.

For whom?

Comfort apps add value for students and staff. They find it convenient to adjust the comfort of the space they're in. For building managers, however, it can be challenging to find the balance between users adjusting comfort and optimizing energy consumption. AI is expected to add value in this regard.

Benefits

- Increases user satisfaction
- Increases user productivity through a higher comfort level

Challenges in the implementation

- The BMS's control options determine the possibilities for this type of use case. How to collect the required data also varies per building and what is already present.
- The acceptance of this type of solution depends on how well it works in practice. It could cause frustration, especially in large spaces, if, for example, users with different preferences give input to the system and as a result the room doesn't meet their individually desired preferences. However, it could be a good solution for individual rooms or meeting rooms. Furthermore, it could cause inequality across campus, as it is a use case primarily applicable to modern buildings.
- The costs for this use case are primarily related to the investment in the building management system during a new construction or renovation project.
- In principle, this use case primarily uses data on environmental variables and is therefore not privacy-sensitive. However, this could become a concern in the future if the collection of user data enables the creation of personalized settings.

CASE 7

ADAPTIVE SCHEDULING

What?

Adaptive scheduling uses information about classroom usage to improve the schedule. Scheduling based on the expected number of required hours and student numbers is enriched with information about actual usage. This data can be collected in various ways, using various types of sensors or the Wi-Fi network. This allows adjustments to be made during the current teaching period or in the next one.

For whom?

Adaptive scheduling is a feature intended for Education and Student Affairs staff, enabling them to improve the quality of their schedules and optimize the use of available space. Ultimately, this benefits both students and teaching staff.

Benefits

- Enhances the quality of education by better matching group size and room size.
- Frees up (large) rooms that can be used for other activities.
- Creates a feedback mechanism in the scheduling process, leading to insight and continuous improvement.

Challenges in the implementation

- This use case requires accurate data on the number of people in classrooms. If Wi-Fi data is chosen, this becomes more difficult as the room becomes smaller. If sensors are chosen at entrances, for example, this becomes more difficult as the room becomes larger.
- The acceptance of this type of solution depends on the communication about it and the extent to which everyone experiences the benefits. Students and staff want to see the added value for themselves in education, but also in how decisions about investments in new buildings are made.
- The costs for this use case are primarily related to the costs of reliable data on the number of people in the room.
- Data collection for this use case can be done in ways that do not collect personal data. When using data from the Wi-Fi network or Bluetooth sensors, care must be taken to anonymize and process data in a way that prevents individual tracking, and to ensure further GDPR compliance.

CASE 8

SMART MAINTENANCE

What?

Smart maintenance is a collection of applications that use sensors to measure the condition of building components, with the aim of determining when maintenance is required. Smart maintenance is relevant for preventing downtime or consequential damage, which is important in, for example, laboratory environments. However, it can also improve management of regular maintenance: instead of maintenance cycles based on expected lifespan or inspection rounds, maintenance scheduling is determined by current status and/or usage. As an example, consider the maintenance of revolving doors: not after x months, but after y rotations, because data has shown that this extends their lifespan. This development is most advanced in building services, but there are also sensors that monitor the condition of paintwork or roofing.

For whom?

Smart maintenance applications are intended for building managers and asset managers in real estate departments, so that they have more insight into the condition of building components and can plan maintenance better.

Benefits

- Reduced maintenance costs by performing maintenance at the right time
- Reduced costs for inspection rounds
- Reduced risk of (consequential damage due to) failure of research experiments

Challenges in the implementation

- This use case requires accurate sensor data that measures the properties of specific building elements. In many cases, this data is not yet available.
- Users will find this a compelling use case within the smart campus; no sensitive data is collected, and the results are positive (particularly a reduced risk of consequential damage to research).
- The costs for this use case are primarily related to the applications from vendors offering this as a service.
- This use case collects data on the properties of specific building elements and is therefore not privacy-sensitive.

Vision on smart campus

SURF

VISION

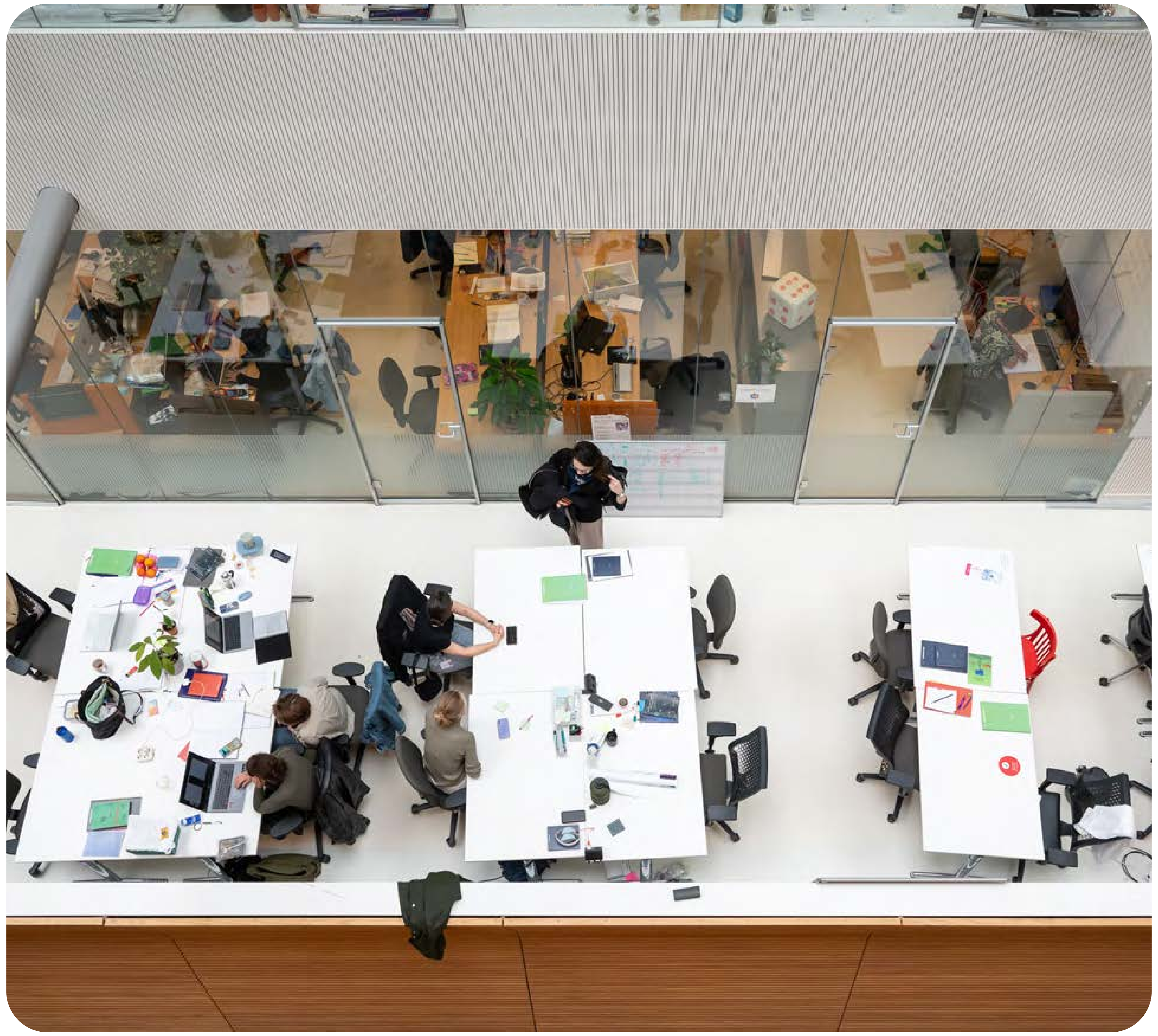
The smart campus is a campus where the combination of (existing) data sources, including sensors, is deployed for the benefit of students, staff, and visitors, enabling them to easily use and (digitally) interact with an efficiently designed and sustainable campus.

The smart campus has rules and a structure that guide its continuous development. These are designed not to be too restrictive, while simultaneously safeguarding the autonomy and security of the institutions and their users. Opportunities are recognized, stimulated, and taken.

This section formulates a vision for a smart campus. This is in line with the definition in Chapter 1, based on all the input from the previous chapters and coordinated with various institutions. It begins with a further specification of the general definition and is then specified for each layer of the ecosystem:

Users and services: deployment for the benefit of students, employees and visitors

The various services and applications within the smart campus are tailored to the users, their goals and needs, together with them. Therefore, every smart campus is unique. The institution continues to engage with users on this topic, as both these goals and needs, as well as the technology itself, evolve. Existing technology is being further developed, and pilot projects are underway to explore the added value of new technology.

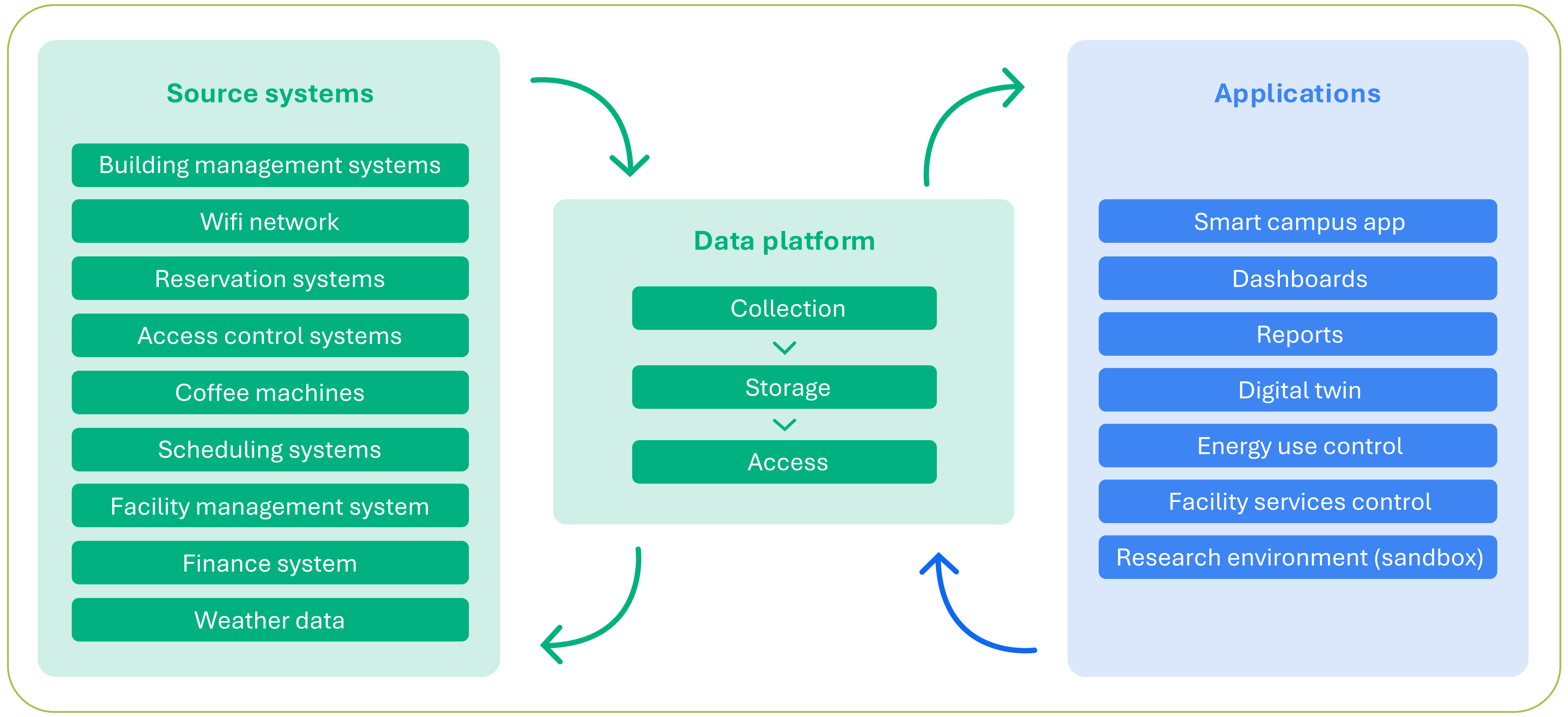


Organization and processes: rules and structure that guide development

Services and applications are embedded in the organization and processes based on the institution's goals for the smart campus. This allows relevant processes to run faster and/or more efficiently, or they are even replaced by new processes. The organization and users have jointly shaped this change and play an active role in its implementation. Organizational checks and balances have also been established to guide the development of the smart campus: for example, a committee that assesses planning from an ethical perspective and by reviewing privacy (GDPR) and information security. Innovation is thus realized responsibly[23].

Applications and information: continuous development with various partners in an open ecosystem

A smart campus operates various applications, tailored to different user groups and embedded in the organization and processes. A vendor is selected for each use case or set of related use cases, or the application is developed in-house. Applications are always part of an open ecosystem. It is also recommended to determine the architecture within the institution, as this helps inform decisions about what to develop in-house or outsource, and how. An example is shown in the figure below.



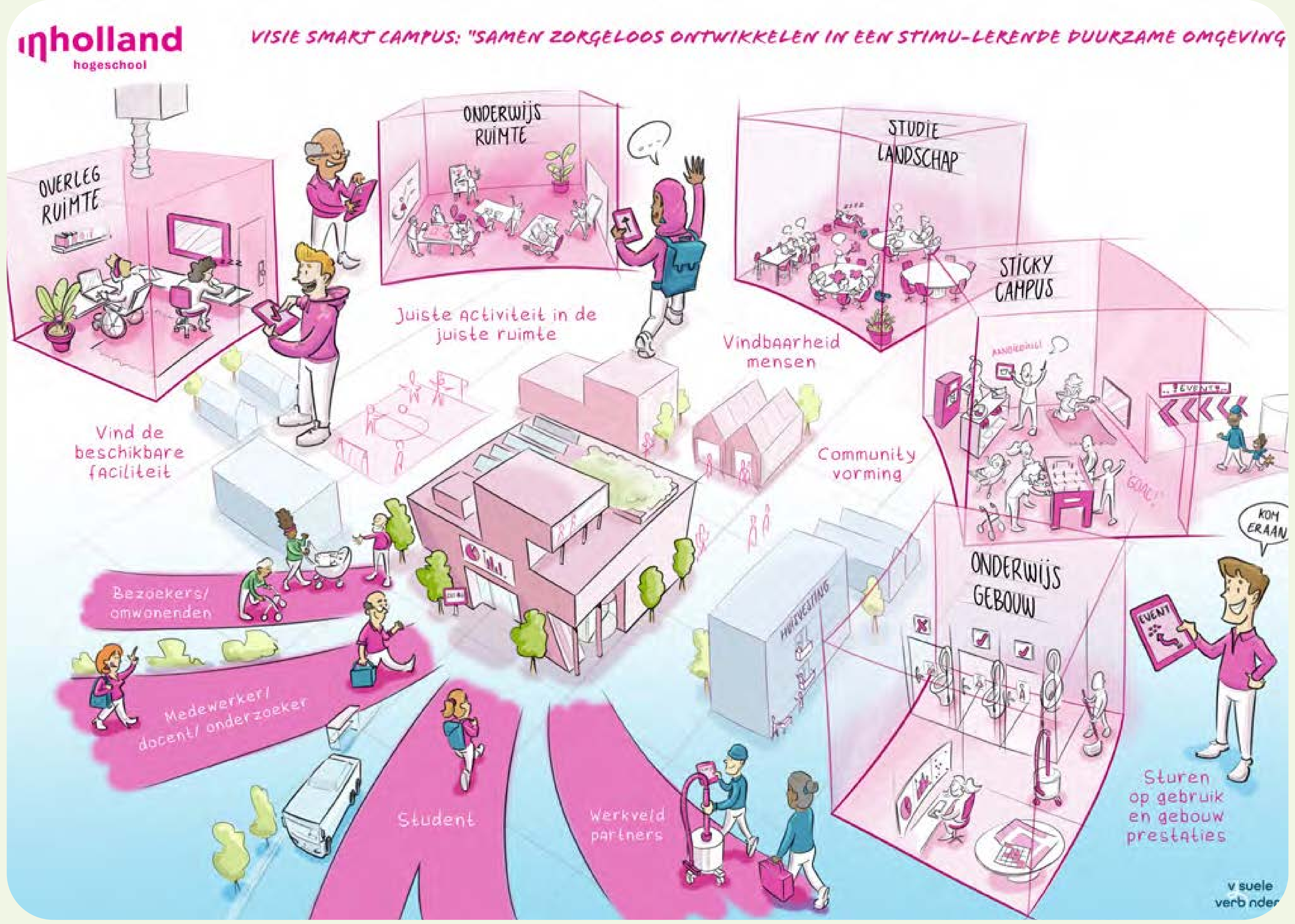
Technology:
direction with one data platform as a foundation

Institutions have a single data platform as the foundation for all smart campus applications within an institution, giving them control over the data. The data platform can be developed in-house, by SURF, or by a supplier. If the data platform is purchased through a supplier, data sovereignty risks are managed through a data processing agreement, including agreements on data portability and technical measures such as data encryption.

Sensor technologies are selected based on the intended applications, the required measurements, and the costs. Institutions therefore make their own choices in this regard, and collective knowledge and experience have been built up to make smart choices in this area. Flexibility is desirable for the network infrastructure, but very challenging in terms of management and security. Wired and wireless IP networks will remain part of the campus in the future and often form the foundation. SURF is therefore focusing on networks based on IP and LoRaWAN for the smart campus[24]. In doing so, it also closely monitors developments in other technologies.

Co-creation in the smart campus

At Inholland University of Applied Sciences, co-creation is a key component of the institution's smart campus vision and approach. The vision itself was developed through various sessions with users about the "why" of the smart Campus and by defining what it is and isn't. This resulted in this (interactive) visual. Users are continuously consulted in the development of use cases: for example, various dashboards for course scheduling have been created in collaboration with and reviewed by users.



DESIGN PRINCIPLES

The smart campus is being developed step by step through collaboration. The smart campus is user-focused, and its various components are interoperable, modular, and scalable. Privacy and security are taken into account, and the use of open standards limits the risk of vendor lock-in.

Collaboration within the education and research community plays a crucial role in realizing the smart campus. This is because the smart campus is an innovation process. The smart campus is not a product you can buy from a supplier, but an interplay of new applications, changing processes, and collaborations with a highly dynamic market in terms of suppliers and technology. It also means more uncertainty, unforeseen circumstances, and the occasional step back before you can take two steps forward. The following principles are applied:

User centered design	The needs of students, teachers and staff are central.
Interoperability	Systems must be able to communicate with each other seamlessly.
Avoiding vendor lock in	Open standards ensure freedom of choice and flexibility.
Modular architecture	Technology must be easy to extend and adapt.
Security and privacy	Security and privacy are integrated into the design from the start.

The principles mean the following for the different layers of the ecosystem:

Users and services: user-centric design

User-centered design ensures that applications in the smart campus ultimately benefit users, their goals, and their needs, directly or indirectly. The smart campus doesn’t aim to be a market leader and experiment with all sorts of technologies. Instead, it should focus on technology where it truly adds value; that’s where innovation takes place. It is and will be a means to an end, not an end in itself.

It seems self-evident that applications are user-centered, but that is not always the case. For example, use cases that are a good fit for one organization don’t necessarily align with another. Take Schiphol Airport, for example: they focus on using smart technology to reduce wait times and ensure the restrooms are as clean as possible. The reason for this is that these are the two defining factors of the user experience in an airport. At an educational or research institution, these relationships are different, and there's a much greater urgency for different use cases. Use cases can also differ within institutions, for example, due to culture, ambition, or direction.

Organization and processes: user-centric design and security and privacy

User-centered design also plays a key role in the organization and processes layer. The true added value of the smart campus is only achieved through process changes. If these changes don't occur, the only result is an investment in technology. Some examples:

- Educational activities can be rescheduled up to 24 hours in advance to best align the room with group size and needs; previously, scheduled rooms were scheduled on a biannual or annual basis.
- Meeting rooms can be booked directly by staff via an app; previously, this could only be done through the secretariat.
- Study spaces must be reserved via an app; previously, study spaces were freely available.
- Buildings are not opened or only partially opened on quiet days; previously, all buildings opened and closed at the same time.

The institutions themselves must have a vision of which processes the smart campus will influence and/or impact, and how these will change. First, there must be an understanding of what exactly will change and how (in terms of processes), and a willingness to implement that change, both within the organization's management and the users.

Furthermore, security and privacy by design are crucial. When organizations are viewed from the perspective of processes and what could be done more effectively and efficiently, it's important to consider the restrictions that apply regarding these aspects. This can lead to certain solutions being unfeasible or unworkable in this context. Users of educational and research institutions are also acutely aware of this, and there can even be a difference between how privacy and security are addressed and how users perceive this. By identifying these principles early on, it's possible to be transparent with users and prevent misperception.

Applications and information: modular, interoperable and open standards

The application and information layer comprises various applications, focused on the diverse goals and needs of user groups, supporting processes. They are a collection of modules within the modular architecture of the smart campus. For each module, consideration is given to who supplies the application(s) within that module, how to purchase or build them ourselves, and so on. This gives institutions flexibility in implementing the smart campus: if they want to modify a specific functionality or switch suppliers, they only need to look at the relevant module. Another reason for this could be the acquisition of an existing supplier by a larger company.

Interoperability is crucial within the modular architecture. The various applications use data from one or more sources to provide users with information. In turn, these applications likely also receive information from users that needs to be processed and/or sent to other applications. For this to happen, the applications must be able to communicate effectively with each other and with the underlying infrastructure. Applying open standards and requiring this from suppliers is the most effective way to achieve interoperability, both now and in the future.

Technology: modular, interoperable and open standards

The same principles apply to the development of the technology layer as to the applications and information layer. Interoperability is crucial for the data platform because it connects to the numerous applications and data sources. It must be scalable so it can grow with the development of the smart campus. And the most important aspect for the data platform is that it uses open standards, facilitating vendor switching and reducing the risk of vendor lock-in. All of this takes place within the bounds of the expected consensus on requirements regarding data autonomy. Institutions ultimately make their own choices in this regard; at the time of writing (June 2025), SURF is investigating whether and how services can be offered in this area. Integration with other existing initiatives, such as EU Data Spaces, is also being explored.

For sensors and networks, the focus is on modular and scalable technology – how it can be rolled out gradually across the campus. Here too, interoperability is required through open communication standards. The risk of vendor lock-in is lower due to the rapid development of the technology and the potential deployment of various types of sensors and connectivity.

With building management systems, preventing vendor lock-in is very difficult. During construction, the measurement and control technology from a specific vendor is installed, and replacing it during the operational phase is very expensive. For new buildings, there is the option of an “open BMS,” where open standards create possibilities for reading out and controlling the BMS. However, in older buildings, the BMS often has limited options for reading out its data and controlling it, making this much more difficult.

CHAPTER 5

Let's get started!

WHAT DOES SURF DO?

SURF provides services and expertise to support the smart campus in various ways. Based on its expertise, the focus in terms of activities is on the technology layer. SURF facilitates community building, collaborates on various pilot projects with institutions, and develops services such as iotroam and, in the future, possibly an IoT network and/or an IoT data platform. Work is also underway to establish a procurement platform.

SURF possesses expertise in networking for the smart campus, but the service domains of Flexible education, Security, Identity and access management, Procurement and delivery, and Storage and data management also possess highly relevant expertise.

SURF provides services and expertise in various ways to support the development of the smart campus at institutions, in collaboration with them. SURF, from its Network and connectivity service domain, primarily focuses on the Technology layer, but can also contribute to other layers of the ecosystem. The network services (in development) will be included in the CNaaS proposition, in which all campus network services will be seamlessly connected. In terms of expertise, collaborations with various service domains within SURF are conceivable.

Users and services and Organization and processes

In the first two layers of the ecosystem, the goal is to determine where and how the smart campus will add value and what changes are needed to achieve this. The institutions themselves are primarily responsible for engaging with users, mapping their organization and processes, and analyzing how these will change. SURF facilitates knowledge sharing between institutions through community building. SURF also has some practical experience in this area through various pilot projects.

When considering the service domains, a relationship with the Flexible education service domain may develop in the future, if a flexible education system becomes more prevalent within the institutions. They could then advise on how to adapt student services accordingly. The Security and Identity and access management service domains can play a key role in safeguarding privacy and data security within the smart campus. Applying existing principles and services from these domains to the smart campus will foster recognition and trust in discussions with stakeholders within the institutions.

Applications and information

In this layer of the ecosystem, the goal is to develop applications that support the concepts developed in the Users & Services and Organization & Processes layers. SURF primarily focuses on the Technology layer, but has collaborated with the institutions on various pilot projects. A wayfinding pilot project was conducted with NHL Stenden University of Applied Sciences, and RUG Maps was developed with the

University of Groningen. A report on Wayfinding has been written, outlining the use case for various user groups, the available solutions, and the factors for success or failure[25]. As an example of what can be done with sensor data, SURF has developed the showcase app Plekkie. This app displays available (free) spaces based on user preferences. Furthermore, within the SURFwireless service, work is underway to develop a congestion indicator based on privacy-friendly Wi-Fi data (the number of devices per access point at a given time, without any additional user data).

Several SURF service domains can play a role in this layer of the ecosystem:

- Identity and access management offers solutions to manage access and authorization in various smart campus applications;
- Security offers solutions to ensure privacy and data security in smart campus applications;
- Procurement and delivery can organize joint procurement and implementation processes.

Technology

At the bottom of the ecosystem, the goal is to create a flexible and future-proof infrastructure for applications and information. This is the layer SURF focuses most on, based on its position and expertise.

Due to the strategic role of the data platform, SURF is currently conducting research (June 2025) into developing an Internet of Things (IoT) data platform with the institutions. SURF's cloud sourcing strategy is also highly relevant in this context and can serve as a guideline when purchasing a data platform[26].

Several SURF service domains can play a role in the development of the data platform:

- Identity and access management offers solutions for managing access and authorization for the data platform;
- Network connectivity offers solutions for connecting data sources and systems within institutions to the data platform;
- Security offers solutions to ensure privacy and data security in smart campus technology;
- Storage and data management has expertise that can be leveraged for the use of the data platform. They can advise, together with the Publishing domain, on how to make data from the smart campus available to education and research.
- Purchasing and delivery can organize collective purchasing and implementation processes.

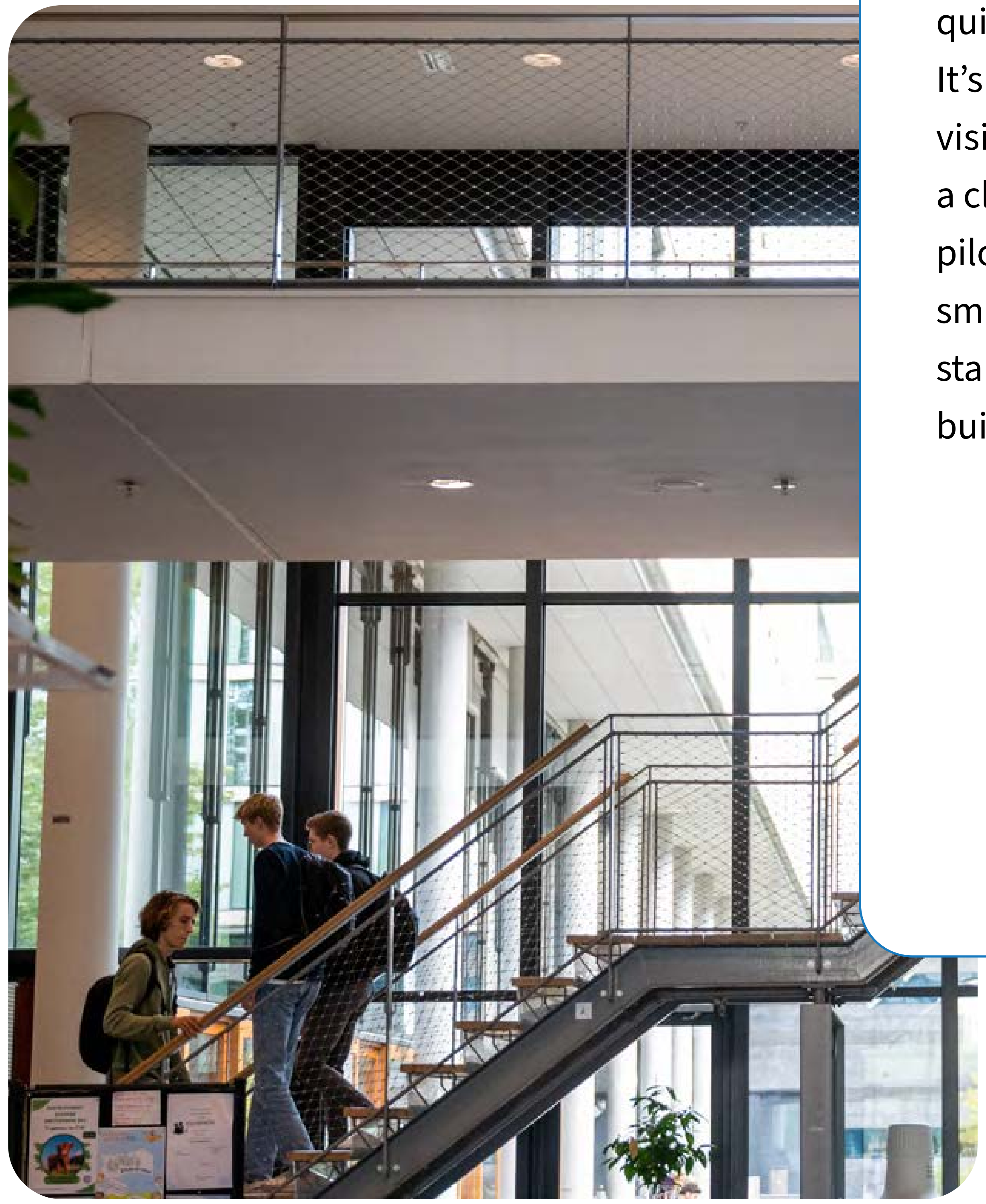
The following services have been developed or are being developed for the infrastructure consisting of sensors and network connectivity:

- iotroam, a network service that allows institutions to securely and traceably connect IoT devices to the IP network;
- A dynamic purchasing system (DAS) for purchasing sensors and services. This is an example of a service provided by procurement and distribution;
- A LoRaWAN network service development for the sector is also underway. (IoTnet)

RECOMMENDATIONS

Based on experiences to date, the recommendations are: start small and with a clear vision; establish a sound governance structure; design the smart campus from the top down; When designing the smart campus, also carefully consider its management; utilize internal expertise and innovation; learn from the experiences of other institutions and collaborate where possible; monitor privacy and ethical compliance before, during, and after implementation; and improve your source data.

The institutions have been working on the smart campus for some time now. Here is an overview of the key recommendations they have made, which can help in realizing the smart campus:



1. Start small and with a clear vision

When considering the entire set of use cases, the stakeholder landscape, and the interplay between the various components of the ecosystem, a smart campus can quickly become very large and complex. It's important to take steps based on a vision for the future. The vision provides a clear goal, but conducting small-scale pilots demonstrates the value of the smart campus to the organization, allows stakeholders to gain experience, and helps build support.

2. Establish a sound governance structure

The governance of the smart campus is a crucial issue. Many stakeholders are involved: the departments and their users represent a key target group, but Real Estate, Facilities Management, and Education and Student Affairs are also important stakeholders. It's crucial that all these stakeholders are involved in the governance structure in some way. IT has the expertise in the applications, the data platform, and the technology. Real Estate, Facilities Management, and Education and Student Affairs are key stakeholders in several of the use cases linked to their own processes and services. And departments and their users are the ones who, with the help of the smart campus, can make better use of existing spaces.

3. Design the smart campus from the top down

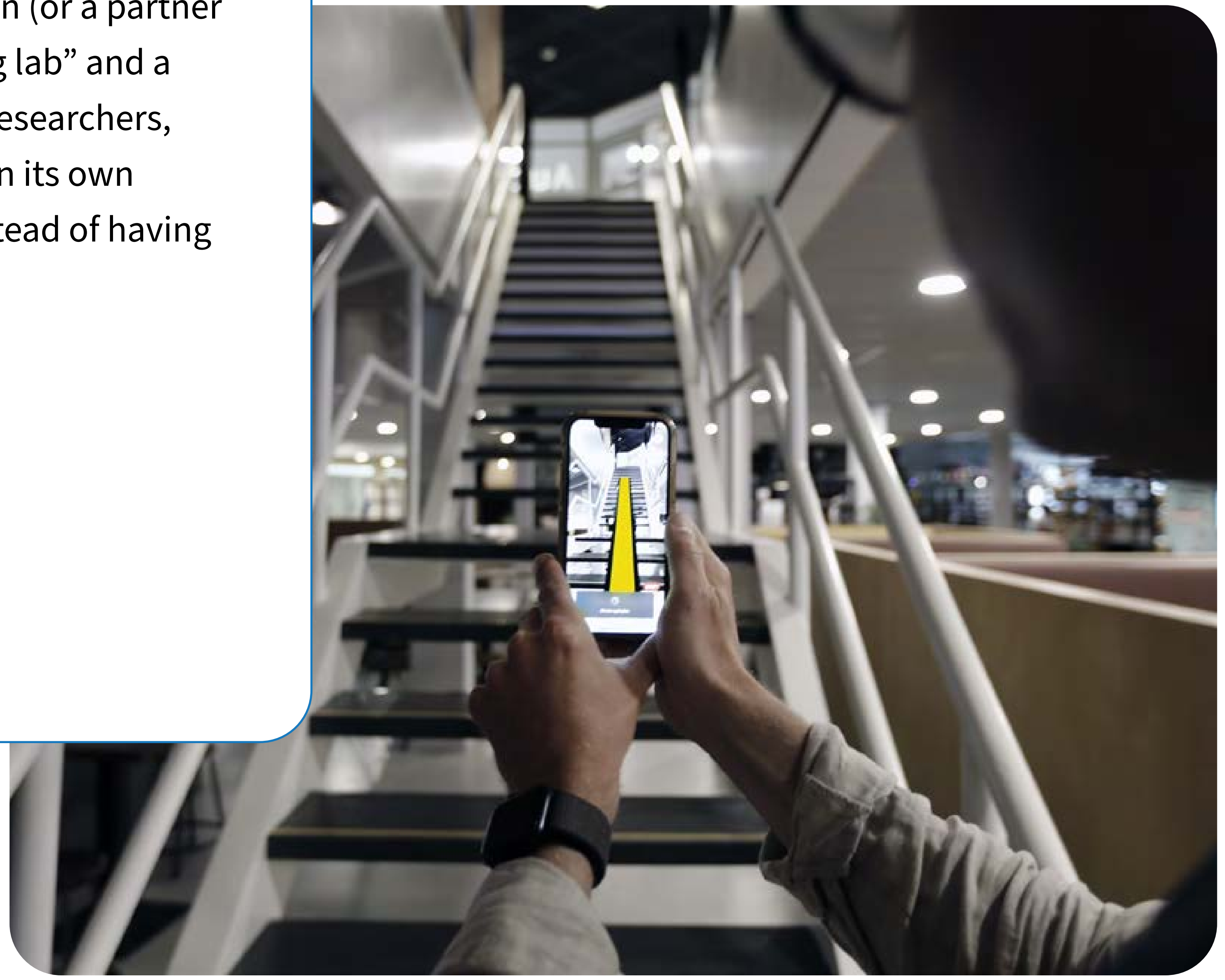
When designing the smart campus, or a use case within it, many different aspects play a role. The smart campus ecosystem, explained in Chapter 2, can help you develop use cases step by step. This begins at the top of the ecosystem, designing from the perspective of users and their needs, and then considering how this fits within existing or new organizational units and/or processes. Only then is it considered whether and, if so, which applications and information are needed, and what requirements apply to them. Finally, the question arises as to what technology is needed to support and inform the application layer.

4. When designing the Smart campus, also carefully consider its management

Smart campus management is also an important aspect to consider during the design phase. For example, adding extra sensors to the campus or using multiple different types of network connectivity leads to increasing complexity of functional and technical management. As with the investment, the question is: how much of the management will you handle yourself as an institution, and what will external partners do? What costs and/or staffing are involved?

5. Utilize internal expertise and innovation

Within the institutions, there are plenty of students and researchers who can contribute to the smart campus. They can help research the application of sensor technologies, collaborate on data analyses, evaluate AI applications, develop new ones, and so on. This represents a huge win-win situation: your own institution (or a partner institution) serves as a “living lab” and a case study for students and researchers, and the institution can rely on its own knowledge and expertise instead of having to source it externally.



6. Learn from the experiences of other institutions

Many other institutions are also working on the smart campus, and they often deal with similar stakeholders, use cases, and technologies. Institutions starting with the smart campus can learn a lot from what's possible and how others have approached it. Why did an application work or not? How have other institutions structured their governance? What assessment criteria were used in tenders? Institutions share their knowledge with each other within the Smart Buildings knowledge network, and the smart campus community platform is expected to facilitate this.

7. Monitor compliance on privacy and ethics before, during and after implementation

In an innovation process like the smart campus, it's crucial to constantly address privacy and ethical aspects. The smart campus has enormous potential, but it's equally important to realize it in an ethical, respectful, and useful way. SURF offers various resources to help you achieve this[27]. In addition, there are plans to deepen this topic for smart campus in the future.

An additional recommendation here is to continuously monitor these aspects after implementation. It's possible that vendors continue to develop the technical side of their products while the institution is using a service, which can lead to the technologies gradually becoming non-compliant with privacy and security agreements. If the institution doesn't properly monitor compliance, a risky situation arises. It is recommended to incorporate checkpoints with the data protection officer (DPO) when a platform performs updates.

8. Improve your source data

Smart campus (and business intelligence in general) relies heavily on high-quality source data, which often requires a great deal of human effort: for example, floor plans, information about room capacity, or the operating costs of buildings. The need for clean data in the source systems is (rightly) secondary to the proper functioning of the process. However, for the smart campus, improving data quality can be essential. The organization must ensure this is sufficiently prioritized; otherwise, there is a risk that, for the sake of speed and getting the application up and running, a new dataset will be created in collaboration with the vendor.

GLOSSARY

Artificial intelligence: A collection of technologies (including machine learning, deep learning, and generative AI) that enables computers and other machines to simulate human learning, understanding, problem-solving, creativity, and autonomy.

Applications: The collective name for applications in the smart campus, which can take the form of apps, dashboards and reports, for example.

Apps: The applications that are mainly aimed at students, employees and visitors in general.

BIM: A Building Information Model. This is a digital 3D model of a building, in which the building is constructed from various objects containing information.

BMS: A Building Management System (BMS) is a system that provides automated, central control of the building services such as heating, ventilation, air conditioning, lighting, access, security, sun blinds, etc.

Cloud computing: A model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

Dashboards: Visualizations aimed at displaying data from various sources in a comprehensible and clear manner.

Data platform: A combination of hardware and software that enables an organization to collect, store, process, and use data for various applications.

Digital twin: Virtual model of something in the real world, such as a power plant, using data from sensors, simulations, and historical performance data.

FMIS system: Facility management information system. This system supports the entire range of facility management, including creating and handling calls and notifications, managing information about space usage, resources, contracts, and more.

Internet of Things: The interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications.

Living lab: A user-centric open innovation system that brings together education, research, and innovation through co-creation within an existing physical environment.

LoRaWAN: Type of network technology suitable for long-distance communication with little power (and thus transferring small amounts of data)

LPWAN: Low Power Wide Area Network. A network type designed for long-distance communication and small data volumes. LoRaWAN is a subtype of LPWAN.

Sensor : A device that measures a property of its environment, or a change in that property.

Use case: A description of a system that specifies which stakeholder does what to achieve which goal.

Vendor lock-in: The phenomenon that an organization becomes so dependent on a supplier that leaving or switching is not possible without major (financial) consequences.

REFERENCE LIST

[1] Gartner (2019). Gartner Identifies the Top 10 Strategic Technologies Impacting Higher Education in 2019. https://www.gartner.com/en/newsroom/press-releases/2019-03-26-gartner-identifies-the-top-10-strategic-technologies-

[2] Malkus, M., van Grinsven, E. (2024). Visiedocument smart campus. Erasmus University Rotterdam.

[3] Visie op Smart Buildings, Amsterdam University of Applied Sciences.

[4] Gil-Garcia, J. R., Pardo, T. A., & Nam, T. (2015). What makes a city smart? Identifying core components and proposing an integrative and comprehensive conceptualization. Information Polity, 20(1). doi: https://doi.org/10.3233/IP-150354

[5] From multiple sources, the added value of a smart campus can be derived: both from scientific publications and from visions, strategies and program plans of SURF partners. See for example:

- Valks (2021). Smart campus tools: Technologies to support campus users and campus managers. Delft: TU Delft. doi: https://doi.org/10.7480/abe.2021.18.6146
- Polin, K. et al. (2024). Smart Campus Performance Assessment: Framework Consolidation and Validation Through a Delphi Study. Buildings, 14(12), 2024. 10.3390/buildings14124057
- Malkus, M., van Grinsven, E. (2024). Visiedocument smart campus. Erasmus University Rotterdam.

[6] Bakker, N., Janse, D., Renders, E.A., (2024). Interoperabiliteit in het onderwijs. Utrecht: Npuls.

[7] Valks (2021). Smart campus tools: Technologies to support campus users and campus managers. Delft: TU Delft. doi: https://doi.org/10.7480/abe.2021.18.6146

Den Heijer, A.C., Arkesteijn, M.H., Pelosi, C., Bacani, J. (2024). Campus NL: Knowledge sharing and hybrid working, Annual report 2023-2024. Delft: TU Delft. https://research.tudelft.nl/en/publications/campus-nl-knowledge-sharing-and-hybrid-working-annual-report-2023

[8] Valks (2021). Smart campus tools: Technologies to support campus users and campus managers. Delft: TU Delft. doi: https://doi.org/10.7480/abe.2021.18.6146

[9] SURF, (2024). Cloud Sourcing strategy. https://www.surf.nl/files/2024-10/surf-cloud-sourcing-strategie.pdf

[10] SURF (2023). Future campus –Scenarios for the campus in 2040. https://www.surf.nl/files/2023-12/surf-rapport-eindrapport-future-campus-futuring-webversie.pdf

[11] Universities of the Netherlands (2023). Kiezen voor kwaliteit in 2040. The Hague: UNL. https://www.universiteitenvannederland.nl/files/publications/UNL%20Kiezen%20voor%20Kwaliteit%20in%202040_FIN.pdf

[12] SURF (2025). Report Disruptive Education Scenarios. https://www.surf.nl/files/2025-03/2025-surf-disruptieve-onderwijsscenarios.pdf

[13] den Heijer, A., Arkesteijn, M., de Jong, P., & de Bruyne, E. (2016). Campus NL: Investeren in de toekomst. Delft: TU Delft, pp.48-49. https://pure.tudelft.nl/ws/portalfiles/portal/37614992/Campus_NL_digital_version_for_websites_.pdf

SOURCES

[14] SURF (2023). Responsible Tech: On Public Values And Emerging Technologies. https://www.surf.nl/files/2024-03/responsible-tech_over-publieke-waarden-en-nieuwe-technologieen_nl_1.pdf

[15] SURF (2023). SURF Tech trends 2023. https://www.surf.nl/files/2023-02/sf_trendrapport_v10_compressed.pdf

[16] IBM (2024). What is artificial intelligence (AI)? https://www.ibm.com/think/topics/artificial-intelligence

[17] Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. Future generation computer systems, 29(7), 1645-1660. doi: https://doi.org/10.1016/j.future.2013.01.010

[18] SURF (2023). SURF Tech trends 2023. https://www.surf.nl/files/2023-02/sf_trendrapport_v10_compressed.pdf

[19] Van Belkom, R. (2020) Prangende ethische vraagstukken. https://detoekomstvanai.nl/artikelen/ai-heeft-geen-stekker-meer/ai-ethiek/prangende-ethische-vraagstukken/ The danger that users become less adept at analyzing data, because AI does it for them, parallels what van Belkom writes about self-driving cars. If you never have to drive a car, how can you become a skilled driver? And will you be able to take appropriate action in the situations where you are required to intervene as a driver?

[20] See also the SURF theme Responsible AI: https://www.surf.nl/themas/artificial-intelligence/responsible-ai

[21] Sustainability directory (2025). Sustainable Data Practices in IoT Ecosystems Future. https://prism.sustainability-directory.com/scenario/sustainable-data-practices-in-iot-ecosystems-future/ Read the “Ascend” scenario in particular for a picture of how the development of data minimization can continue towards the future.

[22] Quantified Student. https://quantifiedstudent.nl/

[23] SURF (2023). Responsible tech: On Public Values And Emerging Technologies. https://www.surf.nl/files/2024-03/responsible-tech_over-publieke-waarden-en-nieuwe-technologieen_nl_1.pdf

SURF (2021). Value Compass for digital transformation of education. https://www.surf.nl/themas/publieke-waarden/waardenwijzer

[24] Stratix, SURF (2019) Position paper Internet of Things. https://www.stratix.nl/wp-content/uploads/2020/01/SURF_Stratix_iot-on-campus_2020.pdf

[25] Esman, T. (2023) Wayfinding. Stand van zaken 2023. SURF: Utrecht. https://www.surf.nl/files/2023-07/wayfinding-stand-van-zaken-2023.pdf

[26] SURF, (2024). Cloud Sourcing strategy. https://www.surf.nl/files/2024-10/surf-cloud-sourcing-strategie.pdf

[27] SURF (2021). Waardenwijzer voor digitalisering in het onderwijs. https://www.surf.nl/themas/publieke-waarden/waardenwijzer

Images

Image of the dashboard en BIM-viewer: (p. 14 ,19): University of Groningen

Images of the Ecosystem (p. 12, 13, 15, 18, 20): nPuls, design Dirma Janse

Image of dashboard (p. 16): Inholland University of Applied Sciences

Image of sensors (p. 20): Bart Valks / Thomas Esman

Image of keyboard with AI-button (p. 28): BoliviaInteligente - Unsplash.com

Image of smart campus architectuur (p. 41): Bart Valks, bsed on example Erasmus University Rotterdam

Image of smart campus vision (p. 42): Inholland University of Applied Sciences

Image of Wayfinding app (p. 13,50): NHL Stenden

images onderwijs (p. 15, 46): Future Campus, SURF

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