Campus of the Future

ARUP

This report is a product of collaboration between Arup Foresight, Research and Innovation, and experts in the higher education sector at Arup. We are grateful for the input and advice from a range of internal and external contributors.

Foresight, Research and Innovation is Arup's internal think-tank and consultancy which focuses on the future of the built environment and society at large. We help organisations understand trends, explore new ideas, and radically rethink the future of their businesses. We developed the concept of 'foresight by design', which uses innovative design tools and techniques in order to bring new ideas to life, and to engage all stakeholders in meaningful conversations about change.

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Cover Image: Scenario for a future campus by Benjamin Mackay, Eve Chokechalermwat, Jia-chi Wu, Rhiannon Williams, Annisa Lazuardini

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Executive summary

The higher education sector is undergoing significant change. Social, technological and economic trends are reshaping how, where and what university students learn. In the past decade, the emergence of digital learning has redefined and broadened access to education, making high quality resources available to a global audience, and enabling peer-to-peer feedback. However, despite its potential, the more insular experience that technology provides has clashed with the human instinct for inherently social experiences. As such, being part of a co-located student community still plays a key role in instilling a commitment to learn, establishing long-lasting relationships, developing soft social skills, building confidence and creating opportunities for innovation and economic growth.

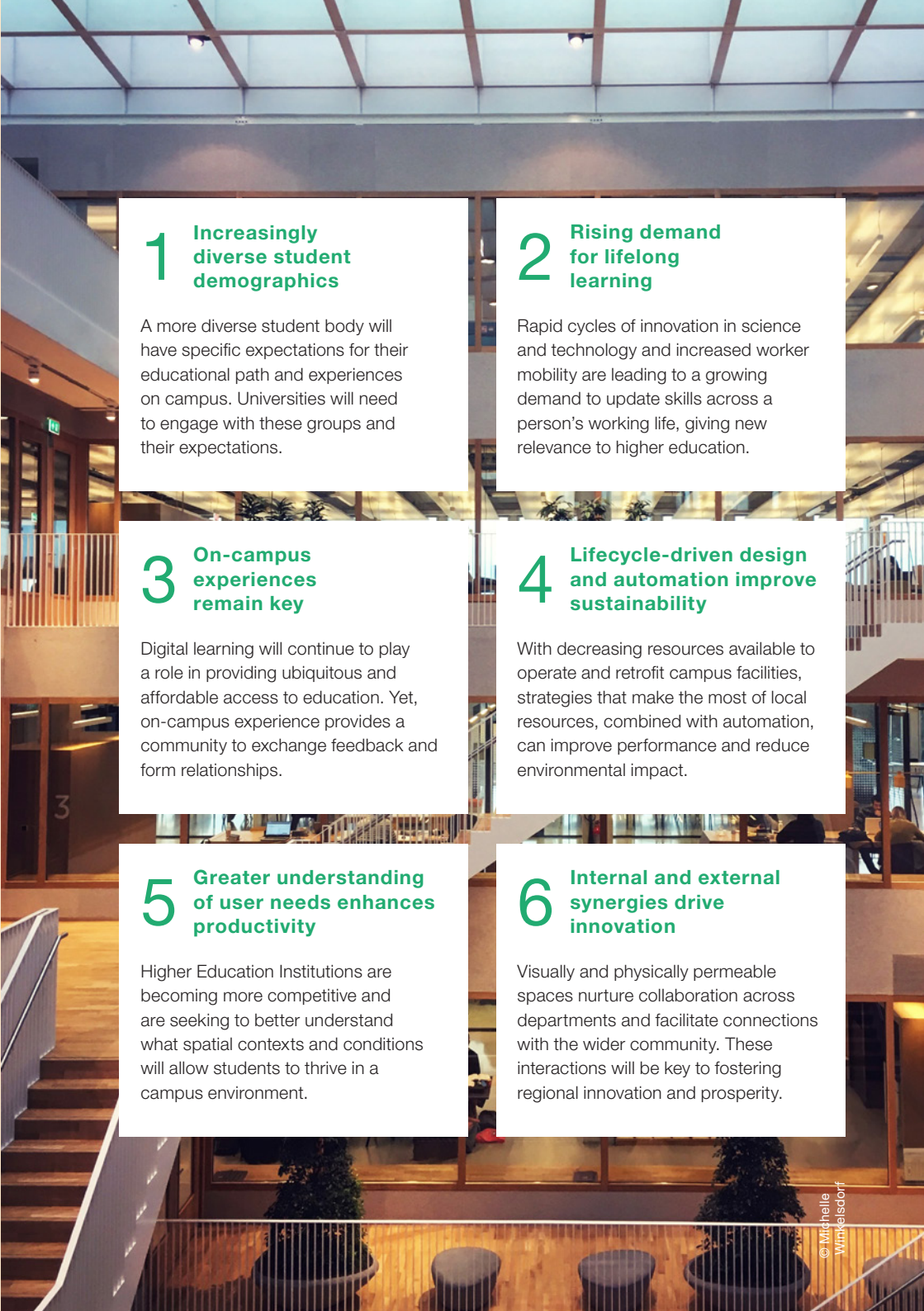
This trend, reinforced by an increasingly commercial relationship between students and education providers, brings a new relevance to the campus, in which the user is at the core of design practices and operation policies. In a context of decreasing financial resources, academic institutions are under pressure to deliver exceptional student experiences, while keeping costs down and resource consumption to a minimum.

Understanding students' needs and adopting virtuous approaches to resource management, sustained by automation, will be key to ensuring the sustainable long-term operation of facilities.

This report examines key trends that will impact the design, operation and experience of higher education spaces. It considers emerging best practice from the education sector, as well as useful lessons from commercial and urban environments, drawing out specific implications for designers, management and governance.

Complementing this research are three imaginative scenarios realised in collaboration with students from MA Narrative Environments at Central Saint Martins, London. These scenarios aim to visualise and narrate future spaces and services in the higher education sector.

Key findings influencing the design operation and utilisation of the campus identified in the report are highlighted on the next page.



1 Increasingly diverse student demographics

A more diverse student body will have specific expectations for their educational path and experiences on campus. Universities will need to engage with these groups and their expectations.

2 Rising demand for lifelong learning

Rapid cycles of innovation in science and technology and increased worker mobility are leading to a growing demand to update skills across a person's working life, giving new relevance to higher education.

3 On-campus experiences remain key

Digital learning will continue to play a role in providing ubiquitous and affordable access to education. Yet, on-campus experience provides a community to exchange feedback and form relationships.

4 Lifecycle-driven design and automation improve sustainability

With decreasing resources available to operate and retrofit campus facilities, strategies that make the most of local resources, combined with automation, can improve performance and reduce environmental impact.

5 Greater understanding of user needs enhances productivity

Higher Education Institutions are becoming more competitive and are seeking to better understand what spatial contexts and conditions will allow students to thrive in a campus environment.

6 Internal and external synergies drive innovation

Visually and physically permeable spaces nurture collaboration across departments and facilitate connections with the wider community. These interactions will be key to fostering regional innovation and prosperity.

Students and skills

A more diverse student body

The student body will increase in diversity over the coming decades. People from a broad range of age groups, cultural contexts and professional backgrounds will engage with higher education, each with their own specific motivations, needs and expectations. Underpinning this shift are demographic and socio-economic trends, which affect the higher education sector on a global scale.

Life expectancy is increasing, and most regions are experiencing an ageing population. A quarter of the world's population will be aged 60 or over by 2050,[1] with the exception of Africa. At the same time, older people are choosing to stay in work for longer to improve their quality of life. The proportion of workers aged over 60 shifted rapidly from 9% in 2000 to 15% in 2016.[2] In line with this, the proportion of students under 25 will also reduce.

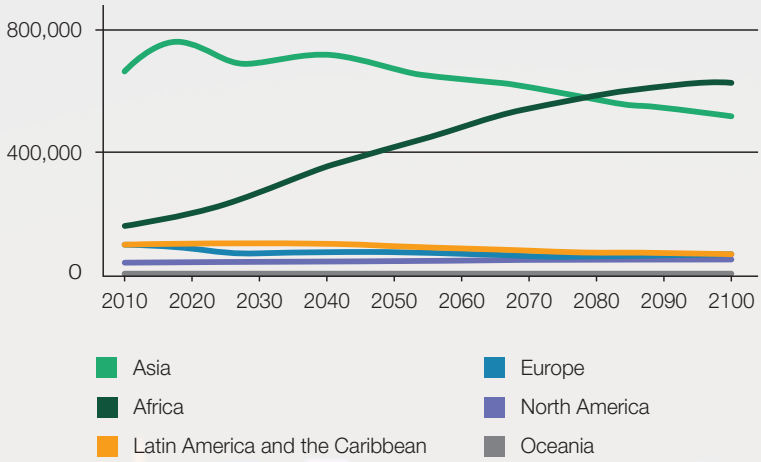
Diversity in age and background means that different student groups will have distinct expectations of their educational path and their experience on campus. Some will enter education for the first time, while others will need to update their skills while working, or invest in a change of career. This trend is calling for more flexibility in curricula, which will be reflected in a greater need for the continuous adaptation of learning facilities.

This is compounded in countries where tertiary education is not free. Students who have to pay for higher education will have greater expectations of the level and quality of service; they will expect to be treated as customers, and will look for personalisation and flexibility regarding the courses they choose and the ways in which they learn.

In response, Higher Education Institutions (HEIs) are striving to create world-class experiences as part of their campuses, and to better understand what conditions make a thriving environment for students to socialise and make connections. This is leading to a greater focus on student engagement, wellbeing and work-life amenities, with the aim of encouraging students to spend time on campus in a more meaningful and productive way.

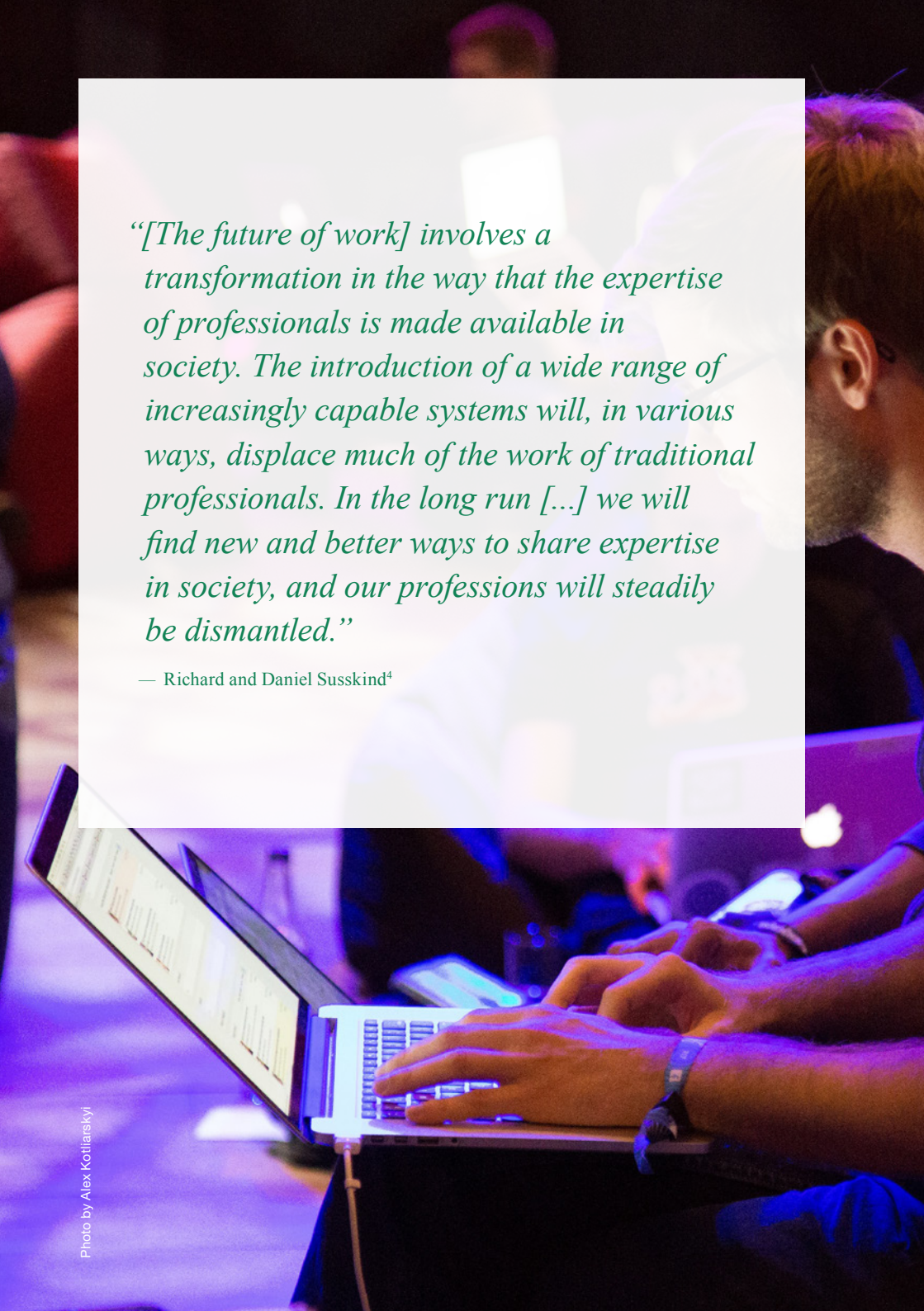
Changing demographics

Youth (aged 15–24) population projections per region, 2010–2100



Source: UN Population Division, adapted from the British Council[3]

Photo by Caleb Woods



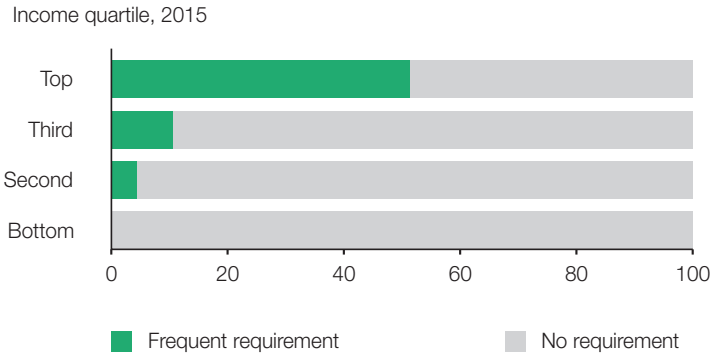
"[The future of work] involves a transformation in the way that the expertise of professionals is made available in society. The introduction of a wide range of increasingly capable systems will, in various ways, displace much of the work of traditional professionals. In the long run [...] we will find new and better ways to share expertise in society, and our professions will steadily be dismantled."

— Richard and Daniel Susskind[4]

Photo by Alex Kotliarskyi

Value of coding skills

Percentage of US online job postings requiring coding skills



Adapted from The Economist[5]

Market drivers for skills

Scientific and technological advances are fundamentally changing the way many industries and businesses operate. Artificial intelligence, robotics, digital fabrication and the fourth industrial revolution are some of the disruptive factors shaping multiple sectors and redefining the roles performed by humans. In many sectors, businesses and their human resources functions are looking for new capabilities that align with rapid cycles of technological innovation.

A range of studies estimate that between 10% and 47% of today's jobs in OECD countries are at a high risk of automation, including non-repetitive cognitive tasks.[6,7,8] Further to this, the World Economic Forum estimates that 65% of children entering primary school today will work in job types that don't yet exist.[9] In such a fast-moving context, the ability to teach skills that are relevant to the workplace is becoming more important than ever. In response, some universities are actively shaping their offering in collaboration with employers.

In this context of rapid change and uncertainty, lifelong learning is becoming a key requirement for employability and job retention, as well as a significant contributor to profitability and wider economic growth. Training and up-skilling

"Ironically, and thankfully, the glorious abundance of the virtual has created an even greater longing for the real."

— Mary Sue Coleman, president of the University of Michigan[10]

is increasingly fragmented, with the rise of micro qualifications or 'badges' that certify competence on a skill-by-skill basis. These can be flexibly stacked to personally curate professional profiles.

Blended and peer-to-peer learning

Digital learning or e-learning provides a quick, cheap and modular solution for learners of any age or background and will continue to play a significant role in the future of education. Today, self-motivated individuals can consult a body of curated knowledge and expertise that was unthinkable just a decade ago, with the explosion of digital learning enabled by MOOCs (massive open online courses) and other online offerings.

In 2016, the number of students who enrolled in MOOCs increased by almost two thirds from 2015, reaching 58 million students globally.[11] But despite the large number of enrolments, only 10% of Coursera and 20% of Open University online courses were completed by UK students in that same year.[12] Many attribute this to the lack of a shared social experience and the reinforcing motivation that comes from this. These are intrinsic characteristics of the on-campus experience.

In parallel to the diffusion of digital learning, new pedagogies and teaching methods are emerging that foster greater collaboration and encourage student and teacher autonomy. Many of these new approaches promote both networking and peer-to-peer (P2P) exchange. These are being promoted by established institutions, and are also emerging more informally through digital platforms. Blended learning seeks to combine the strengths of both digital and physical approaches to education by leveraging the accessibility, transparency and convenience of digital media, while also creating impactful learning experiences on campus.

Case study

General Assembly

Photo by Annie Spratt

General Assembly operates campuses in 20 global cities, including Seattle and Hong Kong, and has an alumni body of over 35,000 graduates. The company's curriculum is informed by an ongoing conversation with employers about the skills they believe they will need in the future. It holds "meet and hire" events where firms can meet students and engage with their work. Career advisors help students with their presentation and interview techniques. General Assembly measures its success by how many of its graduates obtain a paid, permanent full-time job in their desired field. Of its 2016 cohort, three-quarters used the firm's career-advisory services and 99% of those were hired within 180 days of graduation.[13]

Case study

P2P, Monash Business School

Photo by Annie Spratt

Monash University in Melbourne, Australia, run P2P sessions that are led by P2P leaders who have achieved high marks. P2P leaders offer weekly study sessions which are held on campus. These sessions provide students with guaranteed, effective study time. Each session sees students meet with their classmates and P2P leader to work on course material.[14]

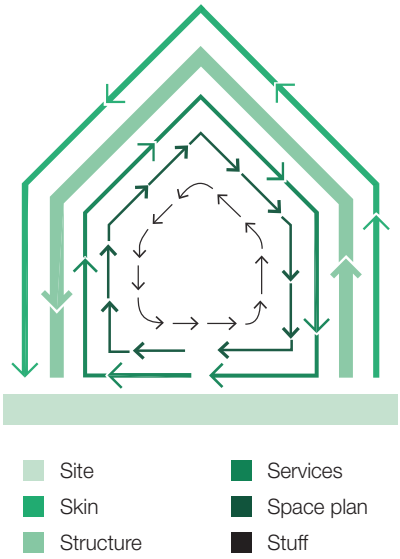
A future-proof campus

Lifecycle-driven flexibility

The spatial requirements for campus buildings are being redefined by the emergence of new, more varied learning methods. Less space is needed for traditional lecture theatres, while there is a growing demand for collaborative or trans-disciplinary workspaces, quiet spaces, labs and innovation hubs as well as other types of functional space. There is also a rising demand for spaces that can be transformed on a regular basis, according to ever-changing curricula and the individual requirements of students, departments and industry partners.

The demand for flexible spaces is reinforced by decreasing public expenditure in higher education in regions such as Europe[15] and the US.[16] Besides the negative impact on research funding, operational budgets have also been affected, resulting in a growing urgency to use space and resources more efficiently and effectively, and to safeguard the long-term viability of facilities. For these reasons, there is a greater acknowledgement of the need to design spaces that can be regularly adapted, at different speeds and scales. Design strategies should consider the lifecycle of buildings across the different lifespans of its interlinked

Layers of change



Adapted from Stuart Brand[17]

Photo: Designed by Aki Hamada, this community space in Kanagawa, Japan is characterised by reconfigurable partitions and exposed services that facilitate the adaptation of space over time.

Photo by LinkedIn

Photo: Light modular furniture can be appropriated by users to create layouts that meet their needs. Adding soft surfaces mitigates acoustic disruption.

layers: site, structure, skin, services, space and fit-out.[18] This results in a lean structure, complemented by adaptable layers, that is assembled to be easily separated, moved and adapted.

The way flexibility is achieved largely depends on context. However approaches such as off-site manufacturing and digital fabrication are proving well-suited to the creation of these types of spaces. Designs that include modular prefabricated elements as part of cladding, services and partitions, for example, allow buildings and their interior spaces to be easily reconfigured, extended or updated. Advanced fabrication techniques, such as digital fabrication and 3D printing, can also be used to manufacture modules, adding a further layer of adaptability, which can enhance both the efficiency and character of the place. Campus buildings can also be designed to be more easily deconstructed, thereby encouraging the reuse and recycling of materials and components at the end of their life.

Despite a higher upfront cost compared to buildings designed for single use, these buildings can ensure their long-term relevance through an inherent ability to flex and morph over time. High ceilings, large floor slabs free from internal columns, and higher load-bearing properties are all general principles that can be adopted to enable easy transfer of use throughout the building.

Furniture and partitions — inside and outside buildings — are the elements that afford users more immediate and direct control to adapt space to their needs. In order to facilitate a greater share of informal learning spaces, there is an increasing tendency to choose furniture and fittings that can be re-arranged by students or teaching staff to define boundaries between different space uses. Diversity of layouts and furnishings allows for different teaching styles that support both collaboration and focused learning activities. For example, light, modular and reconfigurable tables can be rearranged to form different configurations, while pods can provide a private space for more focused study for individuals or small groups.

In recognition of the trend towards greater flexibility, the Finnish government has rolled out a country-wide programme to redesign the interiors of up to 100 schools.[19] Combined with new curricula that recognise the benefits of self-directed learning, the new layout of schools includes movable walls and replaces standard desks and chairs with a greater diversity of options. As students and teachers adapt their learning schedule and activities from week to week, they are able to create suitable spaces.

Crucial to the success of this initiative was the contribution of acousticians who helped mitigate noise, which is a major cause of frustration and distraction typical of flexible and open plan layouts. By carefully selecting sound absorbent materials for ceilings and soft, fabric-coated furnishings and flooring, sound designers created a calm ambience, further reinforced by encouraging noise reducing routines, such as a shoeless policy.

Case study

RMIT New Academic Street

A collection of university buildings from the 1960s and 1970s has been adapted into a vibrant, interconnected and flexible campus. Arup's structural knowledge was applied to determine which beams, slabs and columns could be removed from the existing buildings to facilitate their re-use. This helped to introduce more light and air into the buildings, while the campus as a whole has been opened up to the surrounding streets. The repurposed university 'precinct' includes three levels of flexible study space, featuring hive-like booths and diverse furniture that can accommodate different study modes, from independent working to collaborative study. New balconies extend from the library and are equipped with power points, deck chairs, desks and study booths, while former lecture theatres have also been transformed into informal study spaces with outward-looking windows.[20]

Permanent meanwhile

Emerging business models, which complement the more modular approach to construction explored previously, will reduce waste and support campus adaptation. Various manufacturers of interior fittings, façade elements and lighting are starting to provide components on a service or rental basis. Under this innovative model, refurbishment and maintenance can shift from building operators to contractors. For example, with their ‘Pay-per-Lux’ lighting as a service model, Philips maintains responsibility for the performance of their lighting infrastructure and ownership of the materials throughout the contract. This reduces the risk and cost to the client of replacing expensive fixtures. The ‘Pay-per-Lux’ service operates as a collaboration between the energy provider, Philips and the client, enabling real-time efficiency management, such as the autonomous dimming of lights in response to daylight levels. The design of the lighting system enables easy service and maintenance, supporting a 75% longer lifespan than conventional lighting and lower raw material consumption. Energy efficient LEDs reduce energy use by half, while remote online monitoring of system performance helps to reduce maintenance costs.

This approach can also be applied to other interior fittings, such as furnishing solutions. This means that different designs and layouts can be tested and adapted on a regular basis and with no additional cost to the operator, thereby enabling more granular feedback

loops between user, operator and supplier. The advantages of this approach are many: predictive maintenance saves resources and minimises service disruption and associated costs; components can be easily trialled and more economically adapted for improved effectiveness; and waste is significantly reduced.

Through this lens, the campus can be described as being in a ‘permanent meanwhile’ state, where change is part of the design and is constantly choreographed. As such, site adaptations no longer cause disruption and confusion, but become a display of permanently evolving activity. A plausible future is one where construction machinery doesn’t need to come and go but is an integral part of campus life, and an enabler of constant adaptation and experimentation.

Sustainable and resilient

Beyond the pressing need to improve the use of resources and save costs, Academic institutions are increasingly required to comply with ambitious environmental standards. Various organisations — whether public or private funding bodies — expect detailed building and operational strategies before new funding is made available for construction or the adaptation of facilities. As a consequence, there is a growing interest in design strategies that can future-proof the financial performance of the campus, while ensuring quality experiences for its users. This can go beyond established passive design principles that allow for

Case study

University of Melbourne temporary facilities

With major upcoming construction projects scheduled to begin across the site, University of Melbourne collaborated with Arup to understand how disruption could be mitigated. Stakeholder engagement activities established an understanding of the way the campus is used. These insights informed the design of a number of prototypes that sought to maintain a great student experience during the disruptive construction period. Examples include: digital wayfinding that responds to evolving construction activities as well as providing real-time event information; pop-up learning infrastructure; new food amenities; and construction hoardings reimagined with green walls, graphics and pop-out workspaces. These prototypes have been developed as a modular kit of parts, enabling them to be scaled, interchanged and adapted.

natural ventilation and interior natural lighting. Reducing resource consumption to a minimum, ensuring long-term resilience, and promoting sustainable lifestyles are some successful measures to achieve these goals.

With the diverse and potentially complementary activities that take place on campus sites, universities are ideal environments to turn waste into a resource. Emerging practices of resource use, underpinned by the circular economy, aim to enhance and preserve the natural environment. By breaking linear cycles of resource consumption, and instead keeping materials and energy in use for as long as possible, value and usability are extended.[21] Practices such as the sharing and reuse of materials, or remanufacturing of objects and components could allow the campus to retain value and minimise waste, reducing costs and environmental impact. In the context of a campus, for example, the by-products of some laboratories, such as heat, can contribute to the operation of other services, or be used by other laboratories or facilities.

A hyper-local and closed-loop approach can also be adopted throughout the lifecycle of other resources such as food or water. Solutions such as blue roofs can help harvest rainwater, whilst greywater recycling can help make the most of the water used on site. Such interventions improve the overall environmental impact of the site, and increase its resilience to both resource depletion and extreme weather events by retaining as much water as possible.

As climate change increasingly exacerbates the violence and intensity of weather phenomena, interventions that improve resilience to extreme weather and help mitigate other environmental issues — such as heat islands and air pollution — are becoming increasingly urgent. Spaces can combine their function of supporting social interaction and experimentation with complementary capabilities that increase the resilience of the site. Green infrastructure solutions such as green walls and biodiverse roofs, for example, can improve air quality and aid the cooling of the site resulting in up to 8% reductions in mean and peak energy consumption.[22]

Landscaping measures can also mitigate the consequence of extreme weather events. Introducing permeable surfaces and designing exterior amenities such as event space or playgrounds so that they can retain excess stormwater runoff can increase the resilience of the campus and broader neighbourhood. With this approach, these assets acquire a new dimension of strategic importance, which helps attract funds for the operation and maintenance of infrastructure. This is beneficial for the vibrancy of the campus and the wellbeing of its users.

Case study

Glasgow University district heating

The University of Glasgow is updating its heating and power network connecting 52 buildings. Historically the university's buildings have been heated by steam supplied by a central boiler, which has become inefficient in comparison to modern technologies. Using innovative combined heat and power (CHP) gas fired technologies the upgrade will help the university reach its environmental target of achieving a 20% reduction in CO^2 emissions.[23]

Case study

Enghave Park

Copenhagen's Enghave Park, designed by local architects Tredje Natur in collaboration with COWI and Platant, combines climate resilient city infrastructure with landscaped public space. The park's football and hockey pitches and a tiered amphitheatre are all built beneath ground level, transforming into surface water tanks in the event of heavy rain. Sunken flowerbeds also collect and hold rainwater when needed. The park is surrounded by a large dike to divert water, and subterranean stormwater tanks have been installed underneath the park. Combined, these measures help to accommodate 24,000m^3 of water when flooded.[24]

Efficient facilities and personalised services

Automation and efficiency

The past decade has seen the convergence of technological trends, such as the Internet of Things and the fourth industrial revolution, together with an exponential growth in data and computational power. This has created new opportunities to increase efficiency in campus resource management, enhance user experience and facilitate experimentation.

Successful strategies are underpinned by pervasive wireless connectivity and a high degree of integration between diverse data sources. These are sustained by resilient infrastructure that makes it easy to assimilate data flows from multiple sources — from real-time building usage data to social media and other urban data, such as transport schedules.

Combined, these technologies could contribute to the creation of an accurate 'Digital Twin' of spaces and services. This virtual, dynamic model of physical structures would act as a platform to allow every stakeholder to access all information from a single perspective.[25]

Today, the more pervasive and consolidated use of Building Information Modelling (BIM), is improving the ability to share data relating to all phases of an asset's lifecycle across stakeholders, whilst ensuring data inputs remain consistent over time.[26]

The use of sensors and connected devices is becoming more widespread thanks to miniaturisation and lower costs.[27] A campus-wide Internet of Things network can allow operators and facilities managers to gather real-time data from any asset and automate an increasing number of tasks. A wide range of parameters, such as air quality, noise, movement and energy consumption can be captured in real time. Integrated machine learning algorithms, fed with this unprecedented amount of data, enable building management systems to learn usage patterns over time and can signal targeted strategies for space occupancy and resource consumption.

An interesting example of how this type of system operates in a workplace environment is WeWork, a global provider of shared workspaces. By analysing data gathered from its 250 sites worldwide, WeWork achieve a granular understanding of how people are using their facilities and can adjust spaces based on continuous feedback. Anonymised

Data harvesting and utilisation

Data harvested from multiple sources enhances campus performance

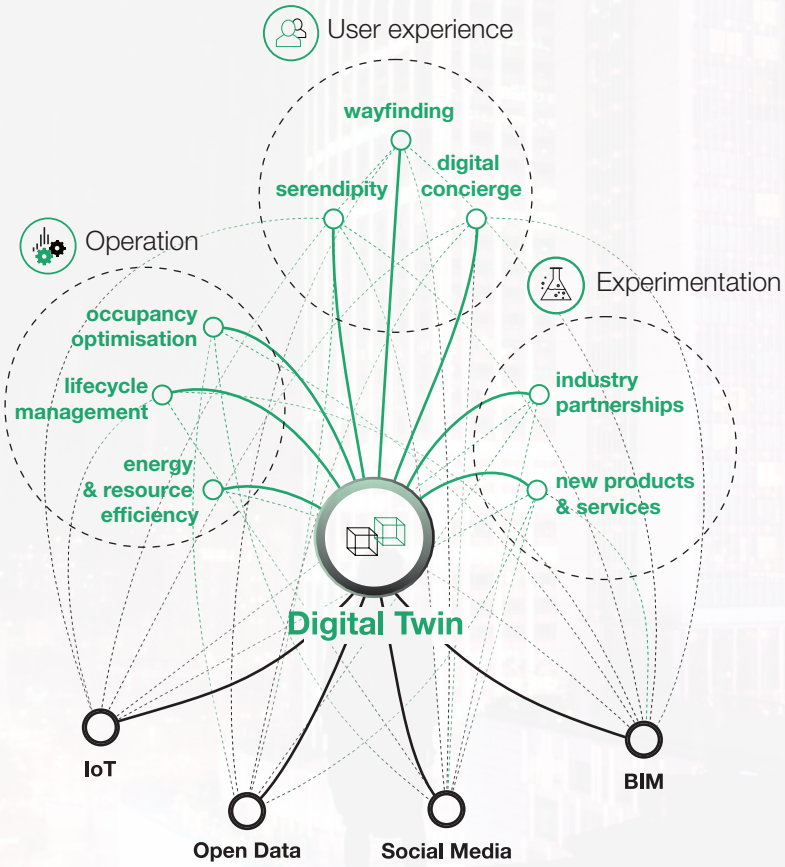
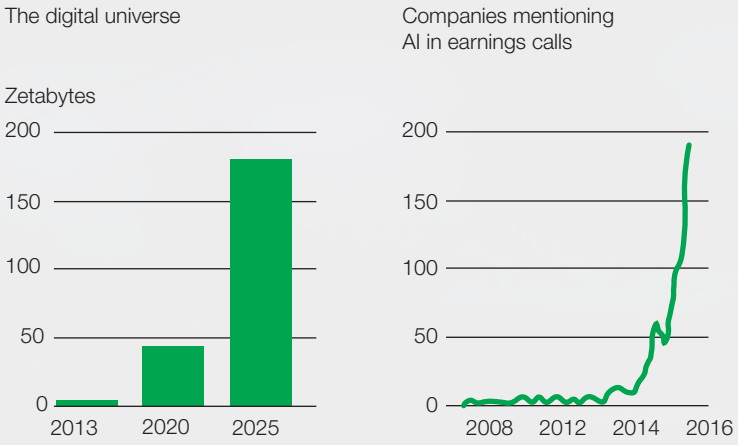


Photo by Jesusintaiwan

The rise of Artificial Intelligence



Adapted from The Economist[28]

Photo by Chris Liverani

data from various sensors and sources, including activity monitors on desks, presence sensors in conference rooms, and member preference data, can help to indicate patterns of activity and identify opportunities for optimisation. For example, changes to a floorplan can encourage people to mix and reduce isolated groups, while analysis of meeting attendance could indicate the need for more informal breakout spaces. For the individual, this can also support personalisation across multiple locations, for example automatically adjusting desk height or recommending a relevant workshop or event via the in-house app.[29,30]

Maintenance can also be improved as a result of enhanced data integration and sharing. Conventional systems and components are maintained on a fixed schedule, or when malfunctions occur. However, with sensor- and data-based systems, the deterioration of components can be flagged in advance. This enables predictive maintenance, which saves resources, minimises service disruption and cuts associated costs.

A similar predictive and responsive approach can be applied to energy consumption, taking advantage of smart meters and the emergence of decentralised utility networks of renewable sources. By exchanging data with energy suppliers, there is the potential to create smart contracts that are automatically activated to meet fluctuating consumption and production rates. Still not at a mature stage, blockchain technology is likely to deliver these types of enhanced services that allow for a more intensive use of local renewable sources.[31] They also promise a substantial reduction in transaction costs on account of having eliminated intermediaries.[32]

A persistent issue for HEIs is the low utilisation rate of spaces and facilities compared to their cost. In the UK, for example, expenses for university estates account for an average of 20% of total expenditure, making them the second largest cost area.[33] This paradox highlights the opportunity to extract social and financial value from under-utilised resources.

Informed by usage data, digital concierge services can allow all stakeholders, including asset operators and occupants, to know in advance which spaces or facilities are used

"Universities [...] are possibly the least intensively used space you can imagine."

— Paul Temple, reader emeritus at the UCL Institute of Education[34]

Workspace choice improves user experience

Users who have choice in when, where, and how to work have higher levels of satisfaction, innovation and performance

Adapted from Harvard Business Review[35]

across daily, weekly or monthly cycles. This empowers HEIs to set up collaborative partnerships or create membership programmes with external private and public organisations who can rent available facilities, such as desks, meeting rooms or workshops. This model has been adopted successfully in commercial offices by the likes of WeWork and other co-working business models. Besides the economic benefits, this model allows for a broader and more distributed presence of industry partners, and a higher degree of integration between students, academic staff and professionals.

Personal control and experimentation

There is now a greater understanding of the positive correlation between personal control over environmental conditions, and individual productivity and satisfaction.[36] This is leading to the adoption of solutions that enable people to create the environments they need.

Allowing for a more granular control over thermal and visual comfort doesn't mean compromising on energy performance. Buildings can be conditioned and lit to minimum requirements, while allowing users to further adjust environmental conditions according to their needs. Connected and intelligent building control systems that can enable this degree of personal control are becoming widespread, especially in workplace environments. In commercial spaces, tools such as Comfy — a subscription-based smartphone app — allow office workers to control the temperature around their individual workstations. The app has options to 'warm my space' or 'cool

Photo: Mobile apps enable students and staff to adjust thermal and visual comfort.

Photo by Marvin Meyer

Case study

NUS SDE4 net zero energy building

The new National University of Singapore (NUS) School of Design and Environment (SDE) building is designed to produce more energy than it consumes. This net-zero approach is achieved despite high temperatures and humidity levels, with building conditioning systems accounting for around 60% of total energy consumption. Roof-mounted photovoltaic panels provide renewable energy, while the building is positioned to maximise natural cross-ventilation. A decentralised cooling system conditions spaces to the minimum requirement, leaving the choice to the user to adjust airflow to their personal comfort through individually operated overhead ventilation units. The building's prominent roof canopy provides additional shade, further reducing demands on the cooling system.[37]

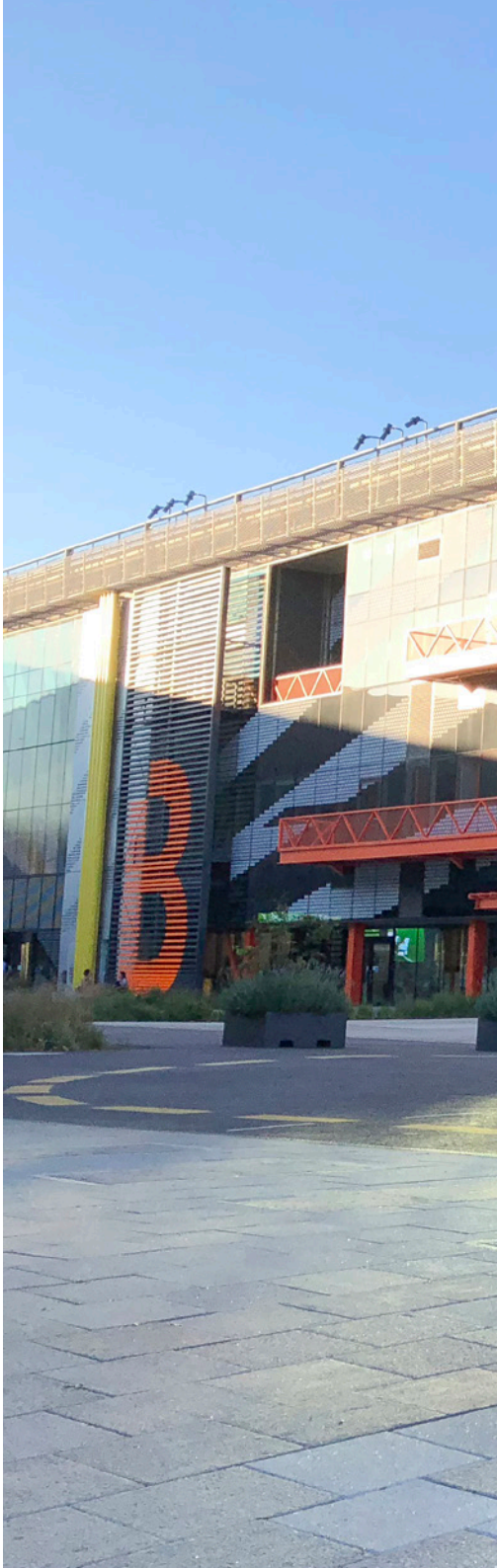
my space', as well as an 'I am comfy' option, and works by connecting users directly with the building's existing management systems. The approach essentially allows people to act as a network of sensors, and can function across the workplace, whether at workstations, meeting rooms or breakout areas. The app uses a machine learning algorithm that can identify trends and automatically adjust temperatures throughout the day and in alignment with the changing seasons. Comfy's developers claim that the system can help to reduce a building's energy consumption by up to 25%, as well as improving workplace satisfaction.

Abundant real-time data streams are also giving rise to new applications that facilitate better user engagement with life on campus. Data visualisation, improved wayfinding and user interfaces are being used to mediate people's experience of environments and services such as room booking, equipment hire and transport information. Through the use of machine learning algorithms, relevant information can be selectively communicated to individual users, based on their background, their academic or personal interests and their familiarity with campus spaces, services and activities.

This also adds a layer of serendipity to the campus experience. For example, wayfinding totems distributed across the campus can be fitted with digital elements that show ephemeral messages, such as upcoming events or temporary offers. Cloud-based platforms allow the coherent display of information across both personal devices and campus infrastructure, accommodating a high level of customisation and inclusivity.

Besides improving site management, an open approach to data harvesting and usage can be a source of opportunity for research and experimentation, both for HEIs and their partners and collaborators. Initiatives that encourage openness, transparency and sharing increase the potential for researchers to innovate and create new digital products and services. For example, the University of Southampton made its data accessible in 2011, creating an open data service. This allows anyone to use administrative data, including building usage, events and even the position and status of its vending machines.[38] The project is part of a wider plan facilitated by ODINE (Open Data Incubator Europe) looking to support data-powered entrepreneurship across Europe.[39]

Aspects of regulation and security are an increasingly important factor that influences infrastructure investment and data usage policies. As information infrastructure becomes more reliant on connected digital systems, preserving the integrity of networks becomes an urgent priority in order to protect intellectual property, personal data and other sensitive information. Universities are an attractive target for cyberattacks, as their security systems are perceived to be unsophisticated, while the data they hold is reasonably valuable.[40] Open policies around the harvesting and use of data shouldn't happen at the expense of protection of personal privacy. Recent General Data Protection Regulation (GDPR) in the EU has set stricter standards for data protection,[41] affecting the way data is collected and stored.



Case study

Here East wayfinding

Here East is using an innovative wayfinding system for its 336,000m^2 digital and creative campus in the Queen Elizabeth Olympic Park in east London. Large black angular monoliths embedded with interactive displays have been erected outside the building. These show details of events and other live information, and can be updated as the campus evolves and changes around them. Inside, lines of orange paint stretch along the floor and up the walls making visible the routes and connections between different departments and services. This site-specific signage system is inspired by electronic circuit diagrams and other symbols familiar to Here East's community.[42]

A living campus

Holistic user-centred experiences

The boundaries between everyday life and learning are continuously blurring, aided by the growing availability of remote services. This trend, combined with the increased autonomy of students and academic staff to choose where and how they want to research or study, is leading to a new requirement for a holistic work-life experience on campus. For HEIs, this means offering an attractive destination for students to spend time beyond formal learning activities.

Design practices that put human needs and desires at the core of decision-making have strongly influenced product and service design in the past few decades. Similar expectations are now changing the way spaces are designed. The human-centred approach acknowledges the diverse nature of human desires and focuses on understanding user profiles to deliver context-specific solutions. These aim to enhance the quality of experiences and extend productive time by facilitating ancillary aspects of daily lives.

Personal development, leisure and physical health can be nurtured by including dedicated facilities as part of learning and common spaces. Placed close to transition spaces, these facilities provide an opportunity to meet new people and exchange experiences. To cut operational costs, some of these facilities such as canteens and gyms can be run by students themselves as part of their curricular or extracurricular activities. Boundaries between learning and social spaces should be minimal to encourage accessibility and visibility of activities.

As working, studying and playing amalgamate in the campus, it is important to make sure that students and staff can access facilities for extended hours in order to support flexible schedules. If operational cost has historically been a barrier to extending opening hours, technology is making it more achievable. In terms of security, for example, remote cameras and sensor technology can reduce the need for human supervision, making the 24/7 operation of campus spaces more financially sustainable.

To truly become a focal place for people's everyday activities, the campus should integrate with the broader fabric of touchpoints of student and staff life. Integrating lockers for online shopping, grocery deliveries,

Photo: Green spaces promote health and wellbeing across the campus

Photo by Benjamin Schneider

Case study

Convene

© Convene

Convene improves user-experiences in offices, with human-centred design and community programmes helping companies to attract talent, and landlords to increase asset value. Under their workplace-as-a-service model, they manage various building amenities, suggesting that at least 12% of a commercial building should be dedicated amenity space, compared to 3% for a conventional Class-A office building. This user-focused "all inclusive" approach is intended to improves workers' day-to-day experience. Amenities typically include catering services and an in-house chef, gyms and fitness studios, and a dedicated Community Manager to arrange events and encourage interaction.[43]

Case study

Mcity driverless shuttles

© Michaël Gounon, Navya

The University of Michigan is using autonomous vehicles (AVs) to transport students and faculty members around its campus. The electric shuttle buses can accommodate up to 15 passengers, and travel at a maximum speed of 20km per hour along a 3.2km route. The shuttle service aims to reduce congestion and better connect the campus with the city of Ann Arbor, with stopping points including a car park and local bus stops. The project is a partnership with Mcity, a 32-acre research facility working on the development of AVs, and Navya, a French AV start-up. Navya shuttles are also operating at Charles de Gaulle airport in Paris, and in downtown Las Vegas.[44]

Case study

Farmer's Fridge

Farmer's Fridge kiosks provide a healthy alternative to conventional vending machines, selling sustainably produced, fresh and nutritious meals. The units are restocked at 5am every day with freshly made organic salads, snacks and yoghurts, all sourced locally and packaged in BPA- and phthalate-free reusable, recyclable plastic jars. The recycled-wood kiosks are equipped with touchscreens that allow customers to browse produce and make their selection, with receipts emailed to registered accounts. Salads are discounted after 6pm, and any unsold food is removed at night and donated to local food banks.[45]

childcare or laundry services can facilitate the more mundane aspects of daily life for both students and staff, and increase the time they spend engaging in meaningful activities on campus.

Easy access to local transport and attractive pedestrian routes will support this, with tactics including strategically placed entrances and on-site shuttles helping to connect the campus with its wider context.

Health and wellbeing

As students and staff are encouraged to spend a large proportion of their day within the campus, there is the opportunity to positively impact their health and wellbeing. This will help students to perform better, as well as helping to differentiate the HEIs' offer. This ambition can be met by designing interior and exterior spaces that have human wellbeing at their core. For example, placing staircases in a prominent position can encourage more healthy and active lifestyles. In some cases they can also become a feature of the building's interior, with the steps used as seats for events or as gathering spaces that promote informal interaction. Opportunities for physical activity can likewise be woven in to any part of the campus, for example by integrating sport facilities in rooftops or transitional spaces.

Lighting also has a significant influence on wellbeing. An improved understanding of the effect that specific parts of the light spectrum have on human alertness is leading to fine-tuned solutions that allow users to

actively influence their performance. Building designs that maximise the use of daylight not only reduce energy consumption but also provide more comfortable learning conditions. Where artificial lighting is used, diversity of conditions and personal control can enhance perceived comfort and productivity. Like lighting, the right sound levels can also influence wellbeing. Specific areas of 'acoustic refuge' for example can enable creative thinking and concentration away from the noise of an open-plan environment.

Recent research links the presence of greenery within and outside learning spaces with increased wellbeing and productivity, as they improve air quality and increase visual and acoustic comfort.[46] If costs are a barrier to the introduction of more greenery into building designs and spaces, champions across academic staff, students and the broader community can be engaged in bottom-up participatory programmes — including planting, feeding and watering — to ensure the long-term operational sustainability of green pockets.

Following these principles, Milan's Polytechnic University has successfully delivered 'Coltivando', a community allotment owned and operated by the university, and open to residents in the local neighbourhood. A collaboration between the university's service design and spatial design practices engaged the community in shaping the allotment, maintenance models and continuously evolving services. This convivial space is used both as a living lab by students, and as a space for the university to connect and share experiences with its neighbours.

An anchor for local innovation

Retaining local students and attracting international talent continues to be a priority for national and city authorities, which rely on innovation to sustain economic growth and prosperity.

Academic institutions have a key role in facilitating the creation and diffusion of knowledge, not only within their premises but also across the wider urban context. University campuses placed strategically within urban environments help to activate districts, and create a socio-economic anchor for the sharing of ideas, skills and resources. Close proximity to the local business community can establish a collaborative space for testing innovative ideas and give life to new enterprises. For entrepreneurs, higher education is critical in nurturing talent and ideas. For students to try and test their ideas, the campus should provide accessible equipment and infrastructure, from more tangible laboratories to data. Management should be open to allow students to test new services or operation models. The benefit of this virtuous exchange can be significant for regional economies. For example, almost 50% of private sector jobs available in UK cities are SME based.[48]

The way research is funded and enterprises are incubated is changing. From established sources, identifiable in government and key

Selected international student recruitment targets

Australia
720,000
onshore enrolments
by 2025

Canada
450,000
international
students by 2022

China
500,000
international
students by 2020

Germany
350,000 inbound
internationally mobile
students by 2020

Japan
300,000
international
students by 2020

South Korea
200,000 foreign
students by 2023

Malaysia
250,000
international
students by 2025

Ireland
44,000 foreign
students by 2019/20

Adapted from The British Council[47]

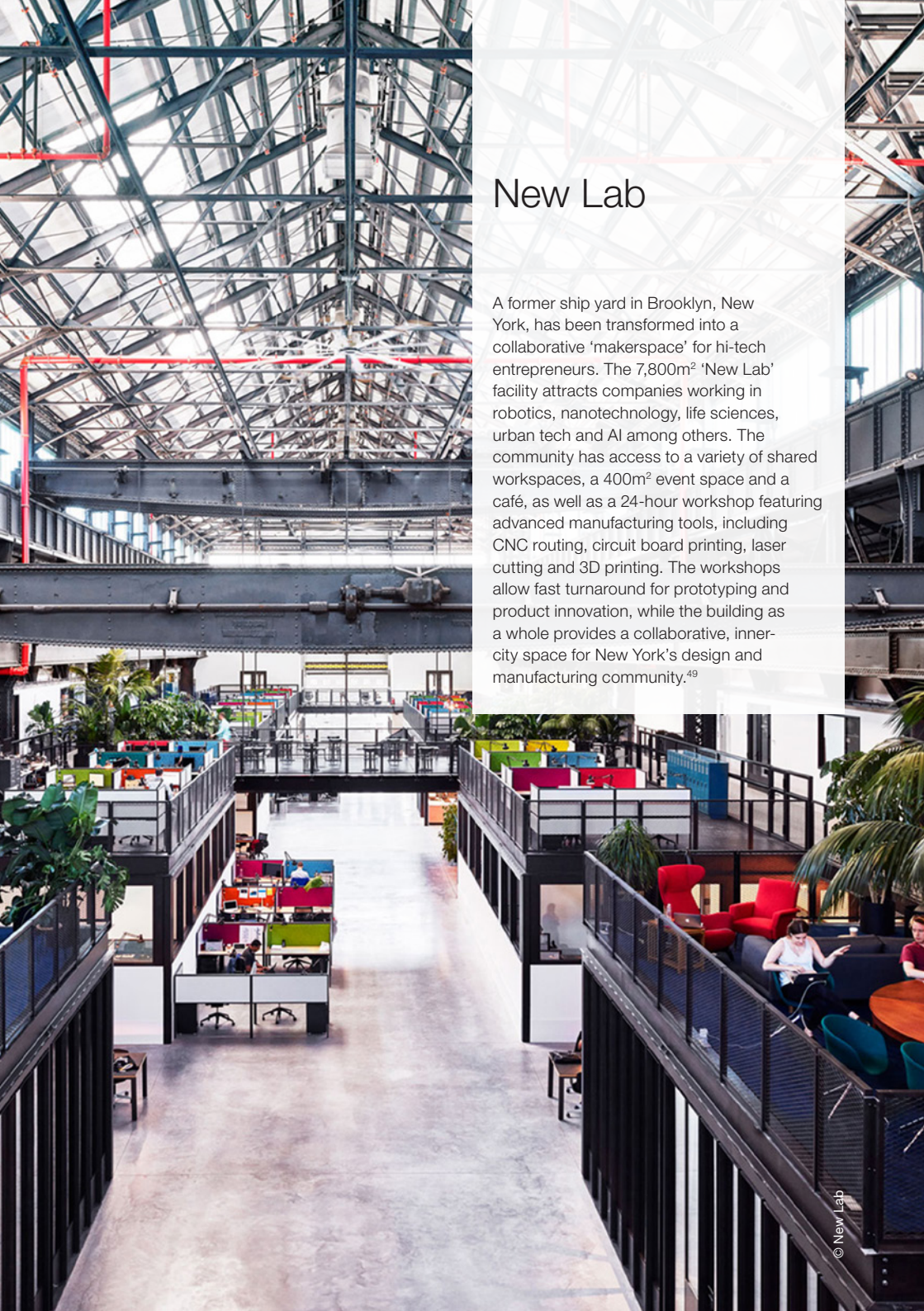
industry partners, the funding landscape has become more fragmented and dispersed with the rise of venture capital and crowdfunding platforms. Understanding and exploiting these diverse sources is becoming a key differentiator for universities to sustain innovation. Students and staff need the space to interact across departments and with partners, who are now local and global, which means that campus facilities need to provide the means to connect and promote research both on site and online.

The benefits of cross-departmental synergies are becoming increasingly tangible. Indeed, the body of unconventional and inter-disciplinary research that aims to tackle 'wicked problems' or complex global threats continues to grow. To facilitate this process, spaces should become more fluid and their boundaries less defined. Spaces such as laboratories for example can be shared across departments and, where health and safety allows, barriers to access reduced.

To encourage the participation of external partners on-site, the campus should become physically and visually permeable to create a sense of welcome, and show activity to the broader community. Ground floor spaces and façades are particularly strategic locations to showcase vibrant research activity. Multi-functional and adaptable spaces can be used to host exhibitions, events, or simply as communal working spaces. Media façades can also be used to display students' creations through interactive installations.

New Lab

A former ship yard in Brooklyn, New York, has been transformed into a collaborative 'makerspace' for hi-tech entrepreneurs. The 7,800m^2 'New Lab' facility attracts companies working in robotics, nanotechnology, life sciences, urban tech and AI among others. The community has access to a variety of shared workspaces, a 400m^2 event space and a café, as well as a 24-hour workshop featuring advanced manufacturing tools, including CNC routing, circuit board printing, laser cutting and 3D printing. The workshops allow fast turnaround for prototyping and product innovation, while the building as a whole provides a collaborative, inner-city space for New York's design and manufacturing community.[49]



© New Lab

Case study

The Why Factory

The Why Factory is a think tank and research institute run by Delft University of Technology and architecture practice MVRDV. The centre is housed in a striking, three-storey structure, which contains meeting rooms, lecture halls and research facilities. Stairs and seating on top of the structure allow the surrounding atrium to become an auditorium, while the adjacent furniture is designed to be highly flexible, adapting the floor for research uses, exhibitions or lectures. A large glass façade makes the atrium visible at street level, providing a public display of the vibrant activities within.[50]

Beyond the opportunities provided by the emerging 'servitisation' of spaces to weave industry partners into campus life, some universities are creating ad-hoc facilities for this purpose. For example, joint partnerships between multinationals and vocational schools in China are creating opportunities for students to acquire specialised skills while providing employers with a direct pipeline for talent. At Nanjing Technical College, a partnership with Siemens Bosch has funded a new training centre for students and Siemens employees to work side by side. Students are part of a programme that combines theoretical studies and apprenticeships. The dual education system is an approach that is already extensively used in Germany, and promises to produce a large number of skilled professionals to fuel the rapidly growing Chinese economy.

Interacting with potential online backers alongside conventional venture capital investors has become increasingly important for the academic community. The volume of the global crowdfunding market grew from of US$2.7bn in 2012 to US$34.4bn in 2015.[51] A new breed of philanthropists is investing in emerging ideas through websites such as Kiva, Zopa and Kickstarter. Students of any background will need the right skills to market their ideas to this increasingly influential audience. The campus should therefore provide facilities and training for students to succeed in promoting their work and raise funding. These include video recording and editing resources and marketing skills.

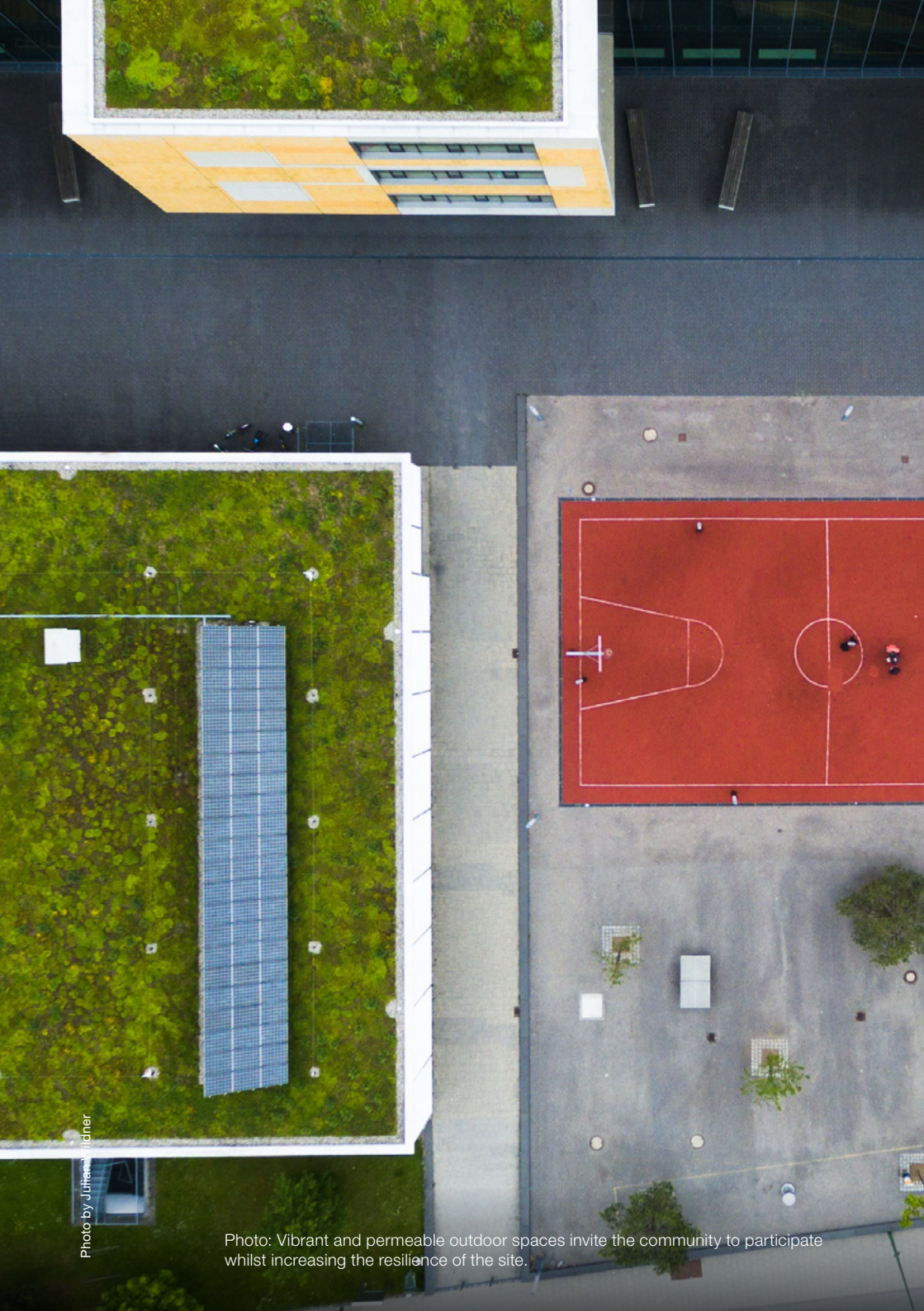


Photo by Julian Weidner

Photo: Vibrant and permeable outdoor spaces invite the community to participate whilst increasing the resilience of the site.

Future scenarios

Arup Foresight, Research and Innovation collaborated with 20 students from MA Narrative Environments at Central Saint Martins, London to explore and visualise the future campus. Students approached the subject from the point of view of different personas, each identifying a specific group of actors in future cities. The three groups used foresight techniques to investigate three possible worlds. Each future world presents its own opportunities and constraints, and delivers a unique viewpoint on the future of universities.

This exercise provides provocative and holistic visualisations of future higher education environments. These help to challenge conventional thinking and inspire debate, highlighting relevant issues for the design and planning of future buildings and infrastructure.

The following pages present these scenarios, developed for three sites in London that are undergoing major change:

- Imperial West
- London College of Communication
- London College of Fashion

Imperial West

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This scenario imagines a fictional 2037 campus as a sleek, intensive facility. Its prime purpose is to encourage peer-to-peer interaction, multidisciplinary work and student exposure to partners and audiences from outside the university, however, a series of unintended consequences emerge.

The campus combines these ideas in a design that embodies student 'cross-pollination'. However, site barriers impose a prominent barrier to the desire for permeability, including a wide, busy motorway and a railway line.

This scenario also aims to inspire reflection on the potential tensions that could manifest in an attempt to manage people's performance and space utilisation.

The efforts of HEIs to promote competition across students could in turn create a sense of anxiety and control. In this scenario, students are encouraged to become rivals for public attention in the 'Project Market' where the industry selects projects to invest in. Research and prototyping take place in adjacent and transparent rooms that inadvertently reinforce rivalry, an accidental by-product of the designers' intention to promote knowledge exchange.

With the need to protect IP and maintain health and safety standards, ensuring selective access to facilities is a key concern of the university's management. Certain areas are inaccessible to particular students, undermining the vision of a collaborative campus. How can the two be reconciled?


LAB ZONE

London College of Communication

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With industry partnerships and technological innovation as key themes, this scenario highlights underlying tensions in data management, and comments on the evolution of commercial relationships in the academic sector.

Connected devices and robots are a discreet presence that complements and enhances learning activities on and off campus. Available through wearable devices and on-site screens, a campus-wide digital platform is used by students and faculty to access information and convenient targeted services, including a personalised productivity plan matching individual performance, as well as concierge services to book spaces, services and amenities. Personal data analysis and digital recommendations are closely intertwined.

Yet this system, driven by optimisation goals, clashes with the human components of the reality it is attempting to capture. This leads to mistrust and disengagement.

Facing intense pressure on resources, the university adopts multiple strategies to conserve resources and increase revenue. For example, the building façade features algae harvesters to generate biofuel. Industry partnerships are incentives on many levels, from renting available facilities to on-campus advertising and intensive recruitment strategies.

How does the financial sustainability of the institution influence the vibrancy of student experience and their personal development?


IKEA
RENT AT LCC
ATM

London College of Fashion

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This scenario imagines a new campus for the London College of Fashion, combining its six former locations into a consolidated landmark. The architecture of the building is a statement for the brand of the institution. The glass walls and curves bring daylight into the structure and eliminate the border between the outside world and the learning spaces within.

The campus is imagined as a destination for both Londoners and tourists, equal in appeal to neighbouring cultural and entertainment institutions.

The vast use of campus spaces to display students' excellence in their craft is balanced by policies that encourage ubiquitous learning. Dedicated learning spaces are considerably reduced to make space for event venues, exhibition and social spaces. The profusion of co-working spaces in the city provides a valid alternative for students to learn collaboratively and be exposed to other complementary disciplines.

With the increasing need to communicate a strong identity to an international audience, can HEIs use their buildings and resources to showcase their brand, while still providing a meaningful and valuable learning environment?

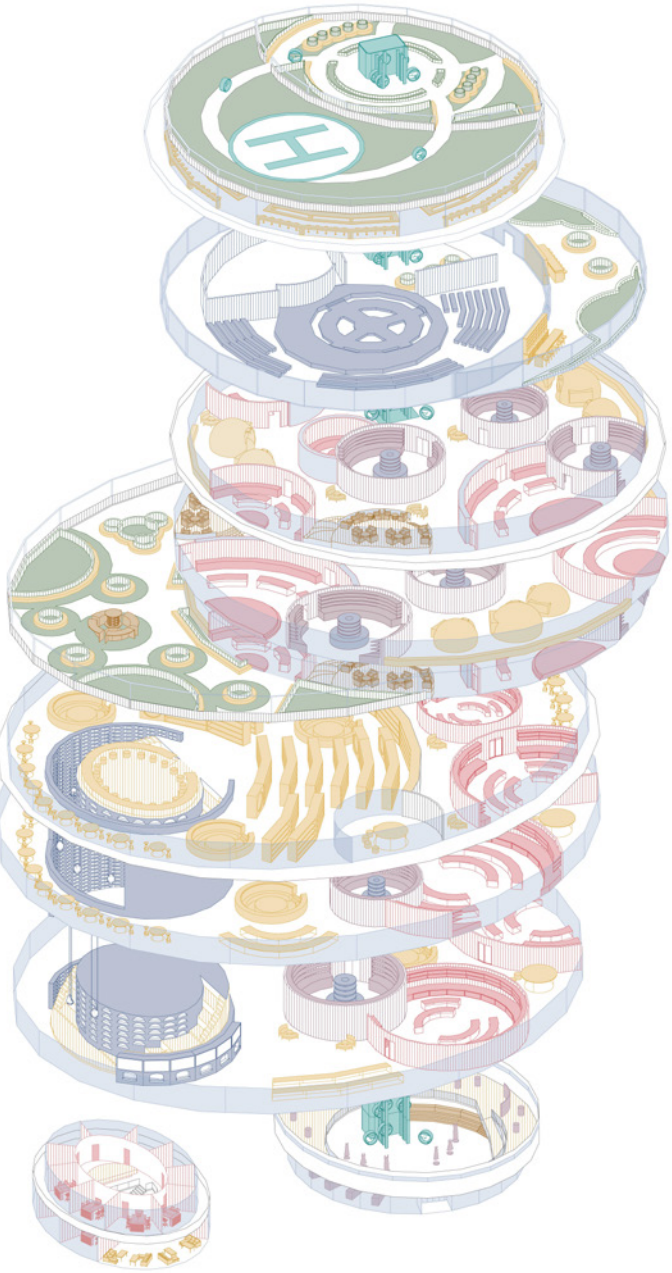

Photo: Blended learning combines the convenience of digital tools with the collective engagement of face-to-face exchange.

Conclusions

Academic institutions are the backbone of innovation for regional economies. On-campus activity is what largely facilitates the exchange of knowledge and networking that in turn creates new opportunities. Given this, the seemingly disruptive impact of digital learning can in fact be woven into new learning styles that redefine the function of campus spaces.

Focusing on people's needs will be key to providing spaces and experiences where students and staff want to spend time engaging in meaningful and productive activities.

To do so within sustainable financial schemes, campus facilities will need to become more flexible and adaptable. Harnessing the potential of technology to improve efficiency through automation will also contribute towards this goal and help to create more inclusive experiences.

Delivering a future campus is an ambitious endeavour that requires the integrated efforts of governance, management and designers. The following pages provide a summary of implications for each of these stakeholder groups.

Designers

Evaluate opportunities to embed flexibility and adaptability in building design. Prioritise designs that allow for high floor-to-ceiling space, and large floor slabs. Consider leaving services exposed and including moveable partitions, while also ensuring maintainability and acoustic comfort.

Target health and wellbeing with designs that encourage physical movement, improve air quality, embed natural lighting and feature plants and green spaces.

Make the most of natural resources, with services designed to operate in closed loops and buildings that take advantage of shading and natural ventilation, alongside landscaping measures that increase environmental resilience.

Design adjacencies and thresholds to encourage cross-disciplinary interaction and improve spatial utilisation. Use available data to enhance students' experience and building management.

Create exterior-facing spaces that can act as a platform for students to display their work, host events and devise new experimental activities.

Campus managers

Develop adaptable and efficient building systems. Ensure that systems and sensors communicate data openly and seamlessly to a consolidated repository where they can be accessed.

Prioritise open data standards that maximise the usability of data for research and innovation purposes. Combine data with ethnographic studies and observation to better understand the needs and expectations of students and staff.

Use artificial intelligence with machine learning to predict building usage patterns in the short and long-term and establish occupancy strategies that adapt resource consumption accordingly, and new business models that create revenue from under-utilised space.

Overcome the maintenance cost of interior and exterior green spaces by engaging with student and staff champions to establish schemes to maintain plants across the campus and provide access to fresh healthy food.

Encourage the use of the campus as a living laboratory, providing student access to building systems to test innovative ideas.

Governance

Maintain the long-term value of assets by investing in technology and designs that facilitate traceability and material reuse, and establish partnerships with hardware suppliers to test new equipment at lower cost.

Encourage employability-focused learning, with spaces that create engagement between students and local businesses to maximise high value employment and innovation opportunities.

Work with local authorities to establish last mile transport solutions that reduce congestion at peak hours and encourage shared mobility and physical activity.

Invest in data harvesting infrastructure (sensors and connectivity) across interior and exterior spaces, using data to dynamically assess usage patterns and inform layout adaptations, alongside curricular requirements.

Provide everyday amenities that make the campus an attractive and convenient destination and that enhance the holistic development of the individual.

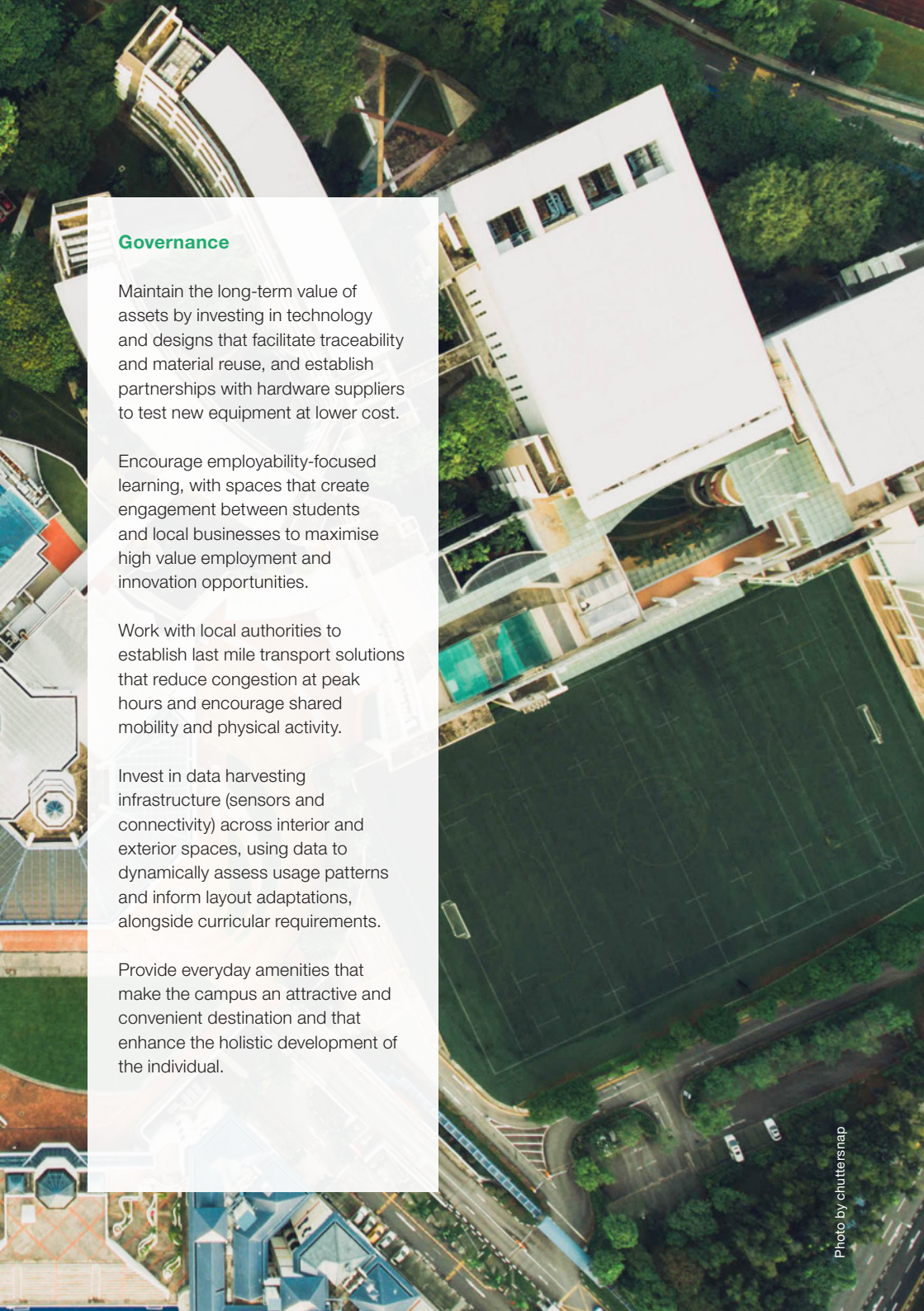

Photo by chuttersnap

Photo: The interior of RMIT's New Academic Street building provides diverse spaces and uses digital media to engage with students and staff.

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References

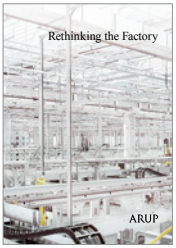
1. United Nations (2017). World Population Prospects The 2017 Revision. Available at: esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf
2. OECD (2017). Labour Force Participation Rate. Available at: https://data.oecd.org/emp/labour-force-participation-rate.htm
3. British Council (2017). 10 Trends, Transformative Changes in Higher Education. Available at: ei.britishcouncil.org/educationintelligence/10-trends-transformative-changes-higher-education
4. Susskind, R., Susskind D. (2015) The Future of the Professions. Oxford University Press.
5. The Economist (2017). Lifelong Learning is Becoming an Economic Imperative. Available at: economist.com/special-report/2017/01/12/lifelong-learning-is-becoming-an-economic-imperative
6. OECD (2017) The Risk of Automation for Jobs in OECD Countries. A Comparative Analysis. Available at: oecd-ilibrary.org/social-issues-migration-health/the-risk-of-automation-for-jobs-in-oecd-countries_5jlz9h56dvq7-en
7. Arntz, M., Gregory, T., Zierahn, U.(2017). Revisiting the risk of automation.Economics Letters Volume: 159 Pages: 157-160
8. Frey, C.B., Osborne, M.A., (2017). The Future of Employment: How Susceptible Are Jobs to Computerisation? Technological Forecasting and Social Change 114, 254–280.
9. World Economic Forum (2016). The Future of Jobs. Available at: reports.weforum.org/future-of-jobs-2016/chapter-1-the-future-of-jobs-and-skills/#
10. Christensen, C.M., Eyring, H.J. (2011). The Innovative University: Changing the DNA of Higher Education from the Inside Out. Jossey Bass, Wiley.
11. ICEF Monitor (2017). Global MOOC Enrolment Jumped Again Last Year.
12. Taylor, I. (2016). Future Campus. RIBA Publishing
13. General Asssembly (N/A). Available at: generalassemb.ly
14. Monash University (N/A). Accounting Peer-to Peer Learning (P2P) Program. Available at: monash.edu/business/accounting/student-experience/peer-to-peer-learning
15. European University Association (2016). EUA Public Funding Observatory 2016. Available at: eua.be/Libraries/governance-autonomy-funding/public-funding-observatory-2016.pdf
16. Tugend, A. (2016). How Public Universities Are Addressing Declines in State Funding. The New York Times. Available at: nytimes.com/2016/06/23/education/how-public-universities-are-addressing-declines-in-state-funding.html
17. Brand, S. (1994) How Buildings Learn. Viking Press.
18. Ibid. 17.
19. O'Sullivan, F. (2017). Why Finland Is Embracing Open-Plan School Design.
20. Architecture Design. (2017). A Bold Example of Adaptive Re-use": Unpacking RMIT New Academic Street. Available at: architectureanddesign.com.au/projects/education-research/a-bold-example-of-adaptive-re-use-unpacking-rmit-n
21. Webster, K. (2017). The Circular Economy, a Wealth of Flows. Ellen MacArthur Foundation.
22. Arup (2016). Cities Alive: Green Building envelope. Available at: arup.com/publications/research/section/cities-alive-green-building-envelope
23. Sweco (N/A). Glasgow Univesitu Heat Network. Available at: sweco.co.uk/our-offer/case-study-container/glasgow-university-heat-network/
24. Grodzanic, L. (2016) Copenhagen's Enghaveparken Public Park is Designed to Be Flooded. Inhabitat. Available at: inhabitat.com/copenhagens-enghaveparken-public-park-is-designed-to-be-flooded/
25. IBM (2017). Creating a building's 'digital twin'. Available at: dezeen.com/2017/05/22/substrate-factory-ayase-community-space-japan-kanagawa-aki-hamada-architects/ ibm.com/blogs/internet-of-things/creating-buildings-digital-twin/
26. Arcadis (2017). Building Information Modelling (BIM). Available at: arcadis.com/en/united-kingdom/what-we-do/our-capabilities/design-and-consultancy/engineering/building-information-modellingbim-/
27. Cisco (2017). Cisco Visual Networking Index: Forecast and Methodology, 2016–2021. Available at: cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/complete-white-paper-c11-481360.pdf
28. The Economist (2017). Data is giving rise to a new economy. Available at: economist.com/news/briefing/21721634-how-it-shaping-up-data-giving-rise-new-economy

29. Orbach, M. (2018). WeWork's Shiva Rajaraman on Using User Data to Optimize Buildings. Calcalist. Available at: calcalistech.com/ctech/articles/0,7340,L-3738916,00.html
30. Rajaraman, S. (2018). How AI is shaping how we Think About Space. CognitionX. Available at: youtube.com/watch?v=lBRayL2BmSs&list=PLMU7XLs-Lrl_24VKMCR-DM4FRYlAHsooc&index=29
31. Mengelkamp, E. Notheisen, B., Beer, C. et al. (2018). A blockchain-based Smart Grid: Towards Sustainable Local Energy Markets. Computer Science - Research and Development. 33: 207.
32. PWC (2017). Use Cases for Blockchain Technology in Energy and Commodity Trading. Available at: pwc.com/gx/en/industries/assets/blockchain-technology-in-energy.pdf
33. Pick, C. (2017). 5 Reasons Why Universities Should Continuously Monitor Their Space Use. AUDE. Available at: aude.ac.uk/Resources/News/View?g=4f49266a-f33f-470a-940e-1805c2e4151c&m=10&y=2017
34. Parr, C. (2014). Six trends in Campus Design. Times Higher Education. Available at: timeshighereducation.com/features/six-trends-in-campus-design/2017412.article
35. Hoskins, D. (2014). Employees Perform Better When they Can Control their Space.
36. Ibid 35.
37. Frearson, A. (2016). National University of Singapore Starts Building Zero-Energy Design School. Dezeen. Available at: dezeen.com/2016/11/07/national-university-singapore-building-zero-energy-design-school/
38. Powling, I. (2014). Open Data Opportunities in Higher Education. Efficiency Exchange. Available at: efficiencyexchange.ac.uk/5607/open-data-opportunities-in-higher-education/
39. Lewis, J. (2014). Opening Doors to Open Data at the University of Southampton
40. Kuchler, A. (2015). Universities Steel Themselves for Wave of Cyber Attacks. Financial Times. Available at: ft.com/content/ad07fc52-93c7-11e5-bd82-c1fb87bef7af
41. The EU General Data Protection Regulation. Available at: eugdpr.org
42. Domus (2016). Find Your Way. Domus Web. Available at: domusweb.it/en/news/2016/11/23/here_east_dn_and_co.html
43. Griffth, E. (2017). Exclusive: Convene Raises $68 Million to "Starwood-ify" Offices. Fortune. Availale at: fortune.com/2017/05/01/convene-funding-brookfield/
44. Arbor, A. (2018). Mcity Driverless Shuttle Launches on U-M's North Campus. Mcity. Available at: https://mcity.umich.edu/mcity-driverless-shuttle-launches-on-u-ms-north-campus/
45. Stone, M. (2014). This Vending Machine Dishes Out Fresh Fruits And Veggies Instead Of Junk Food. Business Insider. Available at: techcrunch.com/2016/10/07/new-lab/businessinsider.com/farmers-fridge-vending-machine-2014-2?IR=T
46. Nieuwenhuis, M., Knight, C., Postmes, T., & Haslam, S. A. (2014). The Relative Benefits of Green Versus Lean Office Space: Three Field Experiments. Journal of Experimental Psychology: Applied, 20(3), 199-214.
47. Ibid 3.
48. XLN Telecom (N/A). New Report Highlights the Importance of SMEs to UK Cities. http://bit.ly/1M1PbEV
49. Ha, H. (2016). New Lab is a New Home for Hardware Startups in Brooklyn's Navy Yard. Techcrunch. Available at:
50. MVRDV (N/A). The Why Factory. Available at: mvrdv.nl/en/about/the-why-factory
51. Hobey, E. (2015). 2015 Massolution Report Released: Crowdfunding Market Grows 167% in 2014, Crowdfunding Platforms Raise $16.2 Billion. NCFA.

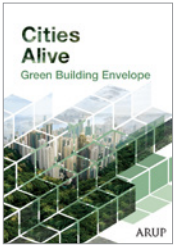
Publications

Living workplace considers a broad spectrum of research and trends relevant to this transforming typology, including digital services, emerging business models and workforce wellbeing. By analysing what aspects need immediate attention and action, the report aims to help developers, tenants and designers better understand the forces shaping the workplace of the future.

The circular economy in the built environment identifies how the circular economy can benefit Arup, our clients, and the built environment sector. We reflect on the economic, social and environmental advantages of employing circular principles. We propose strategies to progress our offering, deliver new services, engage a wider network of stakeholders and unlock opportunities for all parties in the value chain.



Rethinking the factory describes the emerging trends, processes and technologies that will transform the manufacturing landscape. The inevitable shift to leaner, smarter and more flexible forms of production will have a range of impacts on how the factory is designed, how supply chains operate, how people experience changing operational environments and how the future spaces of production will be organised.



Green building envelopes can help to reduce the urban up-heating (heat island effects), filter fine dust on the streets and reduce noise levels. Within this edition of *Cities Alive* report, experts from eight Arup skill networks across the globe cross-examine these questions with a view to shape better cities. The comprehensive research considers whether green building envelopes can have a special role to play in improving our cities for their inhabitants.

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About Arup

Arup is the creative force at the heart of many of the world's most prominent projects in the built environment and across industry. We offer a broad range of professional services that combine to make a real difference to our clients and the communities in which we work.

We are truly global. From 80 offices in 35 countries our 14,000 planners, designers, engineers and consultants deliver innovative projects across the world with creativity and passion.

Founded in 1946 with an enduring set of values, our unique trust ownership fosters a distinctive culture and an intellectual independence that encourages collaborative working. This is reflected in everything we do, allowing us to develop meaningful ideas, help shape agendas and deliver results that frequently surpass the expectations of our clients.

The people at Arup are driven to find a better way and to deliver better solutions for our clients.

We shape a better world.

Digital learning, automation and the expectations of an increasingly diverse student body are affecting how, what and where we learn. At the same time, the growing demand for life-long learning and a renewed interest in face-to-face experiences, are giving higher education environments a new relevance.

In the face of shifting financial resources, the campus of the future will need to navigate constantly changing international and local contexts, whilst reducing environmental impact and fulfilling commercial responsibilities.

This report examines the key trends affecting the design, operation and experience of higher education campuses, highlighting global best practices from the education sector and beyond. It aims to help higher education designers, developers and facilities managers better understand the forces shaping these evolving spaces.

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