AUDE

Together, for excellent university estates & facilities

ASSOCIATION OF UNIVERSITY DIRECTORS OF ESTATES

Legacy Buildings Guide

Intended to help you navigate your way through transforming your existing buildings.

Image:
The Learning and Teaching Building – University of Strathclyde
©BDP

Contents and layout

Image:
George Green Library
University of Nottingham
©Arup

Legacy Buildings Guide

Foreword

As leaders in the academic sector, universities have a unique opportunity - and indeed a responsibility - to set the standard for sustainable practices. By prioritising the reuse and retrofitting of legacy buildings, universities not only conserve resources but also demonstrate a commitment to leading the charge toward a more sustainable future. The choices we make today will resonate for decades, influencing both the built environment and the broader societal approach to sustainability.

Innovation lies at the heart of successful retrofitting projects. The process requires creative thinking and a willingness to adopt new technologies and methods that respect the past while preparing for the future. This guide is as much about inspiring innovative solutions as it is about providing practical advice. The case studies included showcase how challenges are being met with ingenuity, turning potential obstacles into opportunities.

In today's financially constrained environment, where universities face tighter budgets and increasing pressures, retrofitting presents an attractive, cost-effective alternative to new construction. Investing in the enhancement and repurposing of existing structures not only reduces upfront costs but also lowers ongoing maintenance expenses, providing long-term financial benefits. This guide underscores how retrofitting can be a prudent financial decision, enabling institutions to stretch their budgets further while still achieving significant improvements in infrastructure and sustainability. By making informed, strategic choices, universities can balance the need for fiscal responsibility with the imperative to improve and modernise their estates.

Beyond the environmental and financial benefits, retrofitting existing buildings also has profound social implications. These projects often preserve the cultural and historical fabric of campuses, maintaining a connection to the past while creating spaces that meet modern needs. Moreover, the process of retrofitting can engage and inspire the academic community, fostering a culture of sustainability that extends beyond the campus walls.

Retrofitting, while beneficial, is not without its challenges. This guide does not shy away from discussing the potential difficulties that may arise, such as dealing with unexpected structural issues or aligning modern standards with older frameworks. However, by providing clear guidance and real-world examples, it offers the confidence that these challenges can be overcome with thoughtful planning and expert execution. The success of retrofitting projects often hinges on collaboration - between architects, engineers, sustainability experts, and the wider university community. This guide encourages a collaborative approach, where diverse perspectives come together to create spaces that are not only functional and sustainable but also reflective of the values and needs of the community they serve.

Future-proofing the campus estate means more than just updating buildings; it's about creating adaptable spaces that can evolve with changing needs and new technologies. This guide offers strategies for ensuring that today's retrofitting projects remain relevant and functional in the decades to come, providing lasting value for both the university and the wider community.

As you embark on your own journey of retrofitting and sustainable building management, consider this guide a roadmap. It provides the tools and insights needed to make informed decisions that will positively impact the environment, the financial health of your institution, and the experience of future generations of students and faculty. The time to act is now - let's make the most of the buildings we have and lead the way towards a sustainable future.

I'd like to thank Arup for authoring this guide and sharing their knowledge and experience from successfully delivering transformational retrofit projects for decades in higher education as well as other non-educational buildings. I'd also like to thank the project steering group and the many contributors to the case studies that really help showcase the 'art of the possible'. The intention is that the case studies are a live part of the document that continue to share the amazing retrofit projects being undertaken.

Syd Cottle

Syd Cottle
Chair, AUDE – Director of Estates Management, University of Liverpool

Legacy Building Guide
Acknowledgements

This guide has been written under contract to AUDE by Arup.

As a firm committed to sustainable development, Arup continues to push boundaries on all built environment projects, whether retrofit, re-build or new build.

Where possible, we always strive for tailored retrofit solutions that balance environmental, social, economic and investment value with building health and usage requirements – without using more carbon than we must.

Drawing on over 75 years of experience and thousands of university new build and reuse projects, we know that every building is unique. To determine the best course of action, Arup pursues a Whole Life Carbon approach, using a combination of data and the latest industry standards to achieve the right outcomes.

Supporting critical decision making - This complex area requires a broad range of multi-disciplinary technical specialists that are continuously innovating, so our university clients, and industry collaborators can deliver buildings fit for the future. Since 2021, we have committed to evidence based Whole Life Carbon studies (embodied and operational) to assess multiple scenarios, which enable the right decisions to be made. Our data and insights are shared with the industry to help progress decarbonisation.

Driving down carbon together - Our clients benefit from our global expertise and capacity – from our research, understanding of policy and regulation, new technologies, benchmarking data, design and technical innovations, social and market trends.

Together, we help our university clients to anticipate the future by designing and delivering world-class solutions.

Valuable insight and experience was fed into this guide via the AUDE project steering group that included:

- Jane Harrison-White, Executive Director, AUDE
- Syd Cottle, Director of Estates Management, University of Liverpool, AUDE Chair
- Andrew Nolan, Director of Property, Space & Development inc. PMO and Sustainability, University of Nottingham, Chair of AUDE Sustainability Group
- Mike Clark, Director of Campus Infrastructure, Trinity College Dublin, Chair of AUDE Ireland
- Stephen Wells, Director of Estates and Facilities, University of East Anglia, Immediate Past Chair of AUDE and Chair of AUDE ED&I Group

Key Authors :

Rick Lee (Lead Author) is the Arup retrofit leader for the Northwest and Yorkshire (NW&Y) region and a recognised retrofit expert. He is responsible for ensuring the regional teams have the skills and offer the services required to deliver complex retrofit projects now and in the future. Rick's passion for retrofit was ignited years ago in the transformation of university legacy buildings through the forensic and considered approach required to ensure the project outcomes were achieved and the buildings lives extended.

Rick.Lee@arup.com

James Thorneycroft is passionate about sustainable development and is at the forefront of the push towards net zero within the industry. Building on a master's degree in sustainable construction, his award-winning research on sustainable concrete, and his IStructE published guidance on embodied carbon in structural steel, James has applied his knowledge to achieve significant embodied carbon reductions on several large projects over his 8 years in industry. James has worked across a variety of sectors including higher education, and campus redevelopment projects, as well as refurb and retrofit buildings.

James.Thorneycroft@arup.com

Andy Sheppard has been professionally dedicated to the issues of sustainability in the built environment for over 15 years. He leads the Sustainable Buildings team of specialists across the Northwest and Yorkshire of the UK, primarily serving clients in that area. Andy has led many sustainability focused projects both within the higher education sector and wider as well as broader university sustainability strategies.

Andy.Sheppard@arup.com

Philip Egan is a Senior Architect with experience in large scale, multi-disciplinary projects, particularly commercial and Science & Industry projects. Philip was the façade lead for 1 Triton Square where the re-use and refurbishment of existing façade elements played a key role in the building achieving BREEAM Outstanding status. Philip has presented widely on the project illustrating how existing fabric can be worked with to maximise the value of the built environment using a circular economy approach. Philip was lead author for the CIRIA C806 guide for the repurposing and reconfiguring of Buildings.

Philip.Egan@arup.com

Image:
CLASP Surveys
University of York
©Arup

Image:
George Green Library,
University of Nottingham
©Arup

Executive summary

The urgency for environmentally-driven development is evident, especially in the context of concerning weather patterns and temperature rises. In the UK's Higher Education sector, there are additional pressures stemming from post-pandemic shifts in student expectations, financial challenges, and the ever-increasing need for estate maintenance. A boom in higher education development occurred in the second half of the last century resulting in a significant number of legacy buildings now at the end of their design life. These buildings were designed for teaching styles and technologies that have long since become outdated and will continue to evolve.

Demolishing these legacy buildings and replacing them with new ones will continue to stress the finite natural resources of our planet. Institutions have made commitments towards positive change and reducing environmental damage. Retrofitting of legacy buildings can be a significant part of this positive change. Reusing existing buildings can cut embodied carbon by up to 70% compared with demolishing and reconstructing[1]. This, combined with the fact that the majority of the buildings we need are already built, highlights the potential embodied carbon savings available from future retrofit developments.

Additionally, as the grid continues to decarbonise, the operational carbon contributions will decrease substantially, meaning embodied carbon will become the main contributor to Whole Life Carbon from 2035 and will be pivotal in achieving our net zero trajectory. Retrofitting of legacy buildings to extend their lives and maximise the value realised from their already-spent embodied carbon is an obvious positive direction for the higher education sector.

Building a deep understanding of our buildings is key to both unlocking the opportunities and gaining control of the issues. The earlier the understanding is captured, the more informed are the decisions being made. Policy is aware of this and moving in the direction of mandating documents that inform decisions, prioritising reuse of buildings over new build, referred to as 'Retrofit First'. An important part of this term is 'first'. It is deliberately not 'Retrofit Only', in cognisance that retrofitting is not always the right choice.

Defining the brief and priority outcomes helps ensure the transition of the legacy building into a space that meets today's need as well as the future's. This can be complex for Estate Departments to balance the needs of staff and students whilst working within budgets.

Decisions on retrofitting should be evidence-based and quality and consistency of data is an important part of this, especially when undertaking Whole Life Carbon-based assessments.

The value and benefits of retrofitting goes beyond the environmental, with numerous examples of great commercial and social returns. Given the recent uncertainty in construction material prices affecting many projects, keeping as much existing material as possible makes sense. Retrofit projects also offer faster projects simply as a proportion of the building is already built. Character is kept and often complimented with modern interventions.

We can't keep building at the rate we are and operate within planetary boundaries. Focusing on the repurposing and reconfiguration of legacy building will reduce the effect the construction industry (and their clients) has on the environment. This is a direction that Estate Departments can strongly influence and promote.

Setting the context

Image:
Old Gym
University of Birmingham
©Associated Architects

Setting the context

The purpose of the guide

Overview

This guide was developed by AUDE to help its members to find solutions for how to best utilise legacy buildings by showing the 'art of the possible' through case studies as well as discussing the key things that need to be considered throughout the retrofitting process.

The HE sector contributes to global carbon emissions through its buildings, from both an embodied and operational carbon perspective. Legacy buildings make up most of the HE sector's building stock.

This guide is intended for university management and estates teams. Universities have a great opportunity to drive decisions that can impact the overall emissions from their estate and therefore the HE sector.

This guide includes what needs to be considered in the decision-making process. Specific insight and guidance is provided on how legacy buildings can be reused as well as what the known problems and solutions are. Attention is given to how retrofitting can be achieved effectively with a focus on architectural and structural insights as well as guidance on asset management and finance considerations.

Key message points:

- Retrofit can offer a cost-effective and low carbon alternative to new builds.
- Focusing on the repurposing and reconfiguration of existing building will reduce the effect the construction industry has on the environment.
- We can't keep building at the rate we are and operate within planetary boundaries.
- In retaining building elements that are carbon intensive, such as the structural frames, emissions can be reduced early in the life of the building.

Image:
George Green Library
University of Nottingham
©Martine Hamilton Knight/Builtvision

Setting the context

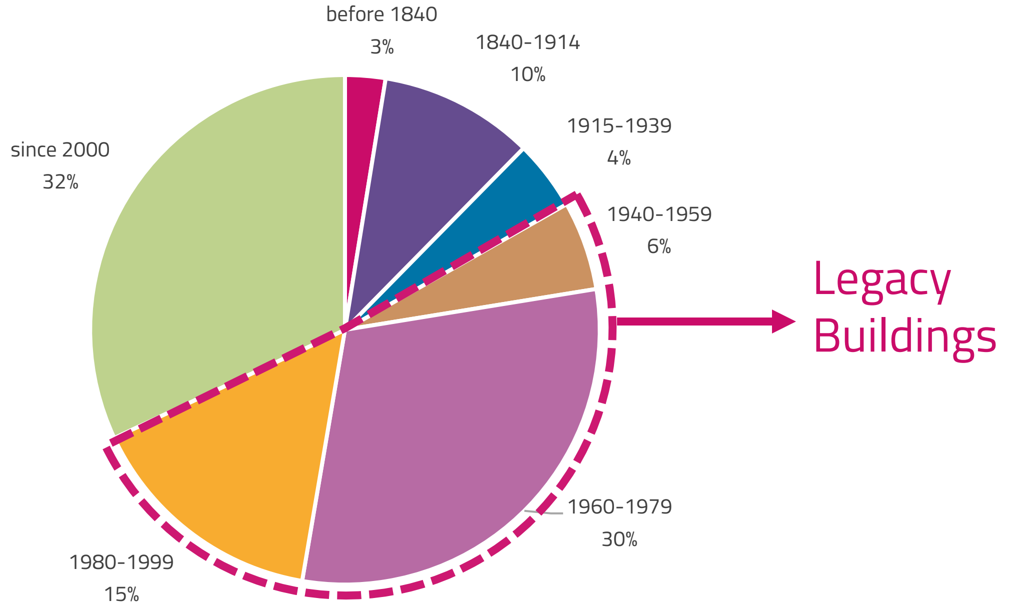
What are Higher Education Legacy Buildings?

Higher Education Building Stock

This guidance document is primarily focused on Higher Education 'legacy' buildings. After the Second World War there was a significant expansion of UK higher education establishments which led to a substantial amount of higher education building stock being constructed around this time. According to HMR data, of the 16,000,000m^2 of non-residential gross internal area across the UK's higher education institutes, 83% of it has been constructed since WW2. For the purposes of this guide a 'legacy' building is defined as one being constructed between the end of WW2 and 1999, this makes up approximately 51% of the UK's HE non-residential building stock.

Although the advice focuses on legacy buildings, it can be used for any building where retrofit is being considered.

Original Construction Date of HE Non-Residential Buildings



NMR Data

Legacy buildings typically have a number of issues, which result in many of these buildings being energy inefficient through their outdated design, having relatively high carbon intensities and are inflexible and underutilised, or no longer fit-for-purpose. Legacy buildings typically appear tired, dated and lower quality relative to heritage or new build stock.

It is possible to transform 'legacy' buildings to become modern, inspiring and flexible spaces with charm. There is intrinsic value (typically around 30-35% of a total new build project cost) in the structural bones of these buildings that produce carbon and financial value through their reuse. Retrofitting of buildings requires a different approach in terms of brief definition, end user expectations, design and construction methods, which this guide will highlight and discuss in detail.

Image:
Brynmor Jones Library
University of Hull
©Jonathan Davis –
Sheppard Robson

Legacy Buildings: These are buildings which were built between 1945 and 1999, that are becoming dated in their services and design and typically require maintenance. These buildings are ideal for retrofit as often they have structural integrity but could improve their operational efficiency.

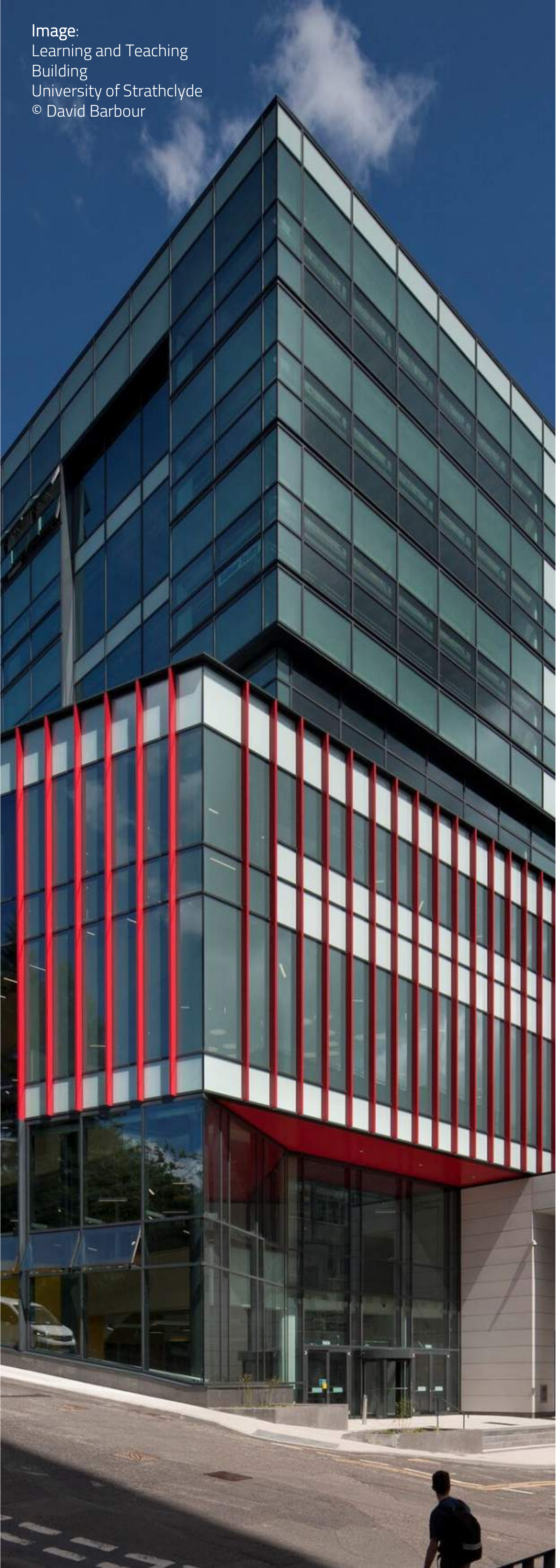


Image:
Learning and Teaching Building
University of Strathclyde

Setting the context

Retrofitting Building Stock

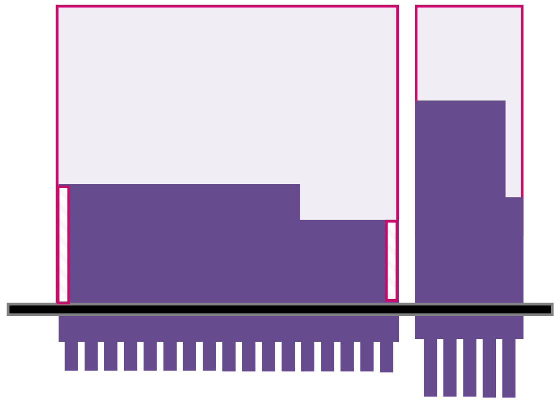
Retrofitting an existing building refers to the process of upgrading or modifying an already constructed structure to enhance its performance, energy efficiency, safety, appearance or functionality. As this is such a wide definition, it's no surprise there is often confusion around what this means, and the differences between terminology such as light vs deep retrofit, and major refurbishment vs minor revamp. There is also a general lack of consistency across the industry in these definitions, which can lead to misunderstandings. To add to any confusion, in university retrofit projects, it is fairly common that new build elements are incorporated into the project. The following definitions are used within this document and also widely used within the industry.

A **light retrofit** predominantly focuses on performance optimisation. This may include some basic remodelling, replacement, or adaptation of existing building elements, and tends to focus on only one or two upgrades at a time such as an upgrade to internal lighting. It typically can be done with limited disruption to the building occupants and can be carried out while areas of the building are still operational.

Includes one or several of these elements:

- Performance optimisation
- Basic remodelling, replacement or adaption
- Single existing building elements
- Flexible and limited disruption to occupants

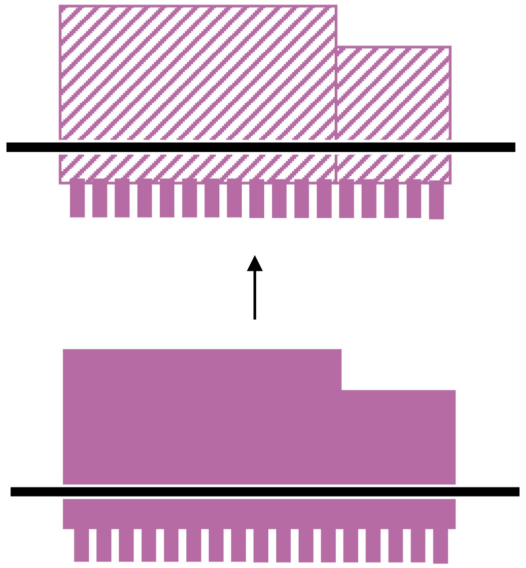
A **deep retrofit** typically involves significant works of size or scale that result in a fundamental change to the building structure, façade, or services. Work can be undertaken as one-off projects or part of a phased upgrade process, but often requires building occupants to temporarily vacate certain spaces.



Includes one or several of these elements:

- Substructure, superstructure and central MEP upgrades
- Some additional floors/basement levels
- Some infill of existing building
- Focus on large energy savings
- Vacating building by occupants

A **building repurpose** is often when a change of use is required to capitalise on changing staff and student needs.

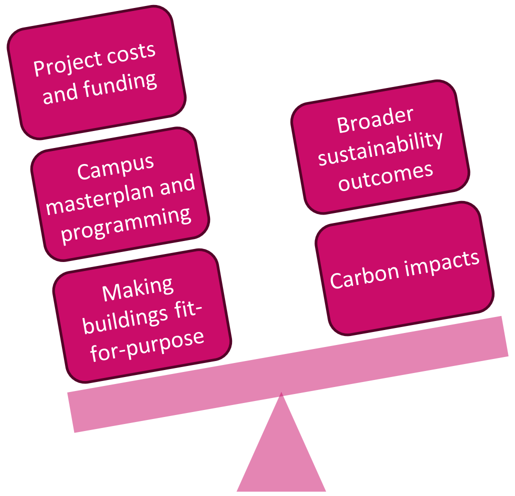


Includes one or several of these elements:

- Change of use for part / all of a building
- MEP / façade / architectural interventions

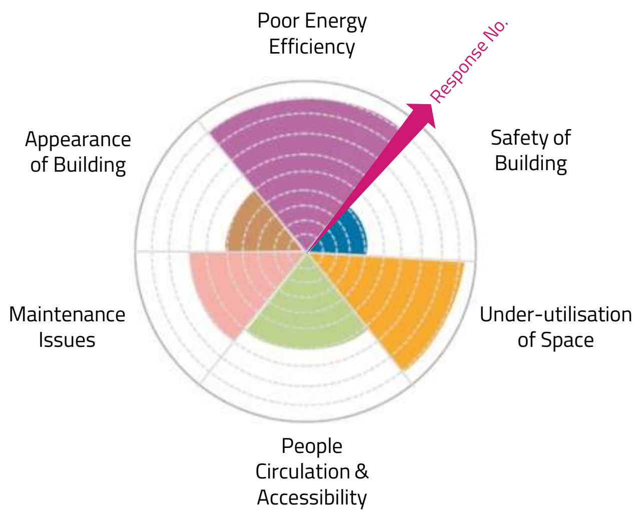
What can we do about legacy buildings?

Action needs to be taken to reduce the carbon impact of these legacy buildings whilst taking benefit of the embodied carbon being kept, and at the same time addressing the other major drawbacks of these outdated buildings. There are several factors that need to be balanced when considering what to do with the legacy buildings.



A questionnaire was sent out to AUDE members to ascertain what they deemed to be the main drivers and blockers for undertaking retrofit work. The survey showed that the poor energy efficiency and under-utilisation of the available space were the two main issues with legacy buildings whilst financial considerations such as costs and funding were the biggest blockers to retrofit.

Main drivers to retrofit



Main blockers to retrofit

Design Life and where retrofit fits in

Commercial buildings have a typical lifespan of only 30-60 years, despite being able to last for much longer through care and maintenance. Academic buildings are expected to last towards the upper limit at around 50 years.

The reasons for a building reaching its end-of-life tend to be more because of economic viability and an outdated fitness for purpose rather than because of structural reasons.

Retrofit offers an important opportunity to extend the life of a building and provides cost-effective solutions that enhance the longevity of our built environment and yield both commercial and social advantages.

There are generally three options with what to do with a building once it reaches its end of life:

New Build

- Demolish existing building and build a new, energy efficient, fit-for-purpose building
  - High embodied carbon
  - High capital cost
  - Low operational carbon

Retrofit

- Enhance existing building by adding features and systems to make it more efficient and fit for purpose
  - Low(er) embodied carbon than New Build
  - Low(er) capital cost
  - Low(er) operational carbon

Do nothing

- Continue with outdated design that is no longer fit-for-purpose and risk stranding the asset
  - No embodied carbon
  - Low capital cost but risk of stranded asset i.e., no longer fit-for-purpose
  - High operational carbon

The optimal solution often involves a combination of the above options, and making the correct redevelopment choice early is crucial. This decision should be well-considered and informed by data, prioritising circularity and the reuse of materials. More details on this topic will be provided in a subsequent chapter, and the various levels of retrofitting interventions are explored on the previous page.

Retrofit Drivers

Key Retrofit Drivers

Retrofitting existing buildings can offer cost-effective solutions that extend the life of buildings whilst utilising the previous building.

The drivers for retrofitting decision-making can be split broadly into value, risk management and environmental drivers. A summary of the key retrofit drivers are presented on the right. These drivers can be from a student, staff or estate's perspective.

Value Drivers

Retaining & attracting students and staff - Retrofitting can create, efficient and innovative places to work and study whilst minimising environmental impacts.

Project turnaround - Retrofitting can provide quicker turnaround of projects as the bones of the structure are already there.

Inherent value - Foundations and the structural frame are typically 35% of a projects total budget. Retrofit projects already have these in place. Allows a longer-term view on investments.

Adaptability / Change of use - Retrofitting existing buildings can transform externally and internally and offer flexibility to change use. They can also help to consolidate campuses.

Risk Management Drivers

Delivering upgrades in occupied buildings - Through careful planning, phasing and stakeholder engagement, the project can be undertaken with areas in occupation.

Reducing planning risk – Reusing the existing building can potentially provide a smoother planning approval process than a new build.

Managing existing building risks - Retrofitting allows inherent building risks to be addressed.

Building Safety - Safety implications can be addressed during retrofitting.

Environmental Drivers

Meeting climate targets / government mandates - Retrofitting provides a great opportunity for universities to meet their climate targets through both operational and embodied carbon.

Low carbon – Retrofitting utilises the inherent embodied carbon of the building whilst addressing operational efficiency.

Circularity - Retrofitting focuses on reuse of the structural frame and allows a focus on circularity of materials.

Reputation - Leagues tables for universities now include the 'sustainability'

Image:
Oxford Brookes University – Clerici & Sinclair replaced facades
© Fisher Studios

Benefits of retrofitting legacy buildings

The case for retrofit in legacy buildings

The carbon of existing buildings has largely already been ‘spent’ and therefore presents a great opportunity to save on Whole Life Carbon. Retrofitting legacy buildings offers a great opportunity to not only improve the energy efficiency of the building but also allows an opportunity to repurpose spaces and design for flexible spaces. Some of the main advantages of retrofit are summarised here.

	Better Whole Life Carbon performance to help meet net zero commitment	While the UK has committed to be Net Zero Carbon by 2050, many HE institutes have signed up for earlier dates. One of the most significant contributors to carbon emissions is new build construction. Retrofitting a building is often a lower carbon alternative.
	Lower capital costs of a retrofit vs new build	Retrofitting a building often has a significantly lower capital cost compared to an equivalent new build. Retrofit works also provide an opportunity to reduce long term operational costs such as water and energy use, as well as reduced maintenance.
	Protection of culture and heritage & ease of gaining planning approval	Many legacy buildings have some heritage significance associated with them. Retrofitting a building rather than demolishing it enables the most significant aspects to be retained as well as increasing the likelihood of achieving planning approval.
	Faster project turnaround & reduced operational impact	A retrofit project can typically be delivered quicker than a new build, particularly if major structural works are not being undertaken. A retrofit also provides the opportunity to phase the works, enabling part of the building to stay in operation and therefore minimising disruption.
	Improve sustainable reputation of institute	Recent research suggests the sustainability of a higher education institute is increasingly becoming a consideration when students are deciding where to study. Retrofitting and a sustainable approach can help with applications for grant funding and research in the same field.
	Align with potential future government policies	With the UK government committed to be Net Zero Carbon by 2050, many predict it is only a matter of time before policies are introduced to limit carbon emissions associated with new construction.

Image:
Engineering Building
©University of Leicester / Simon Kennedy

Image:
Oxford Brookes University –
Clerici Gateway construction

Setting the context

Benefits to retrofitting legacy buildings

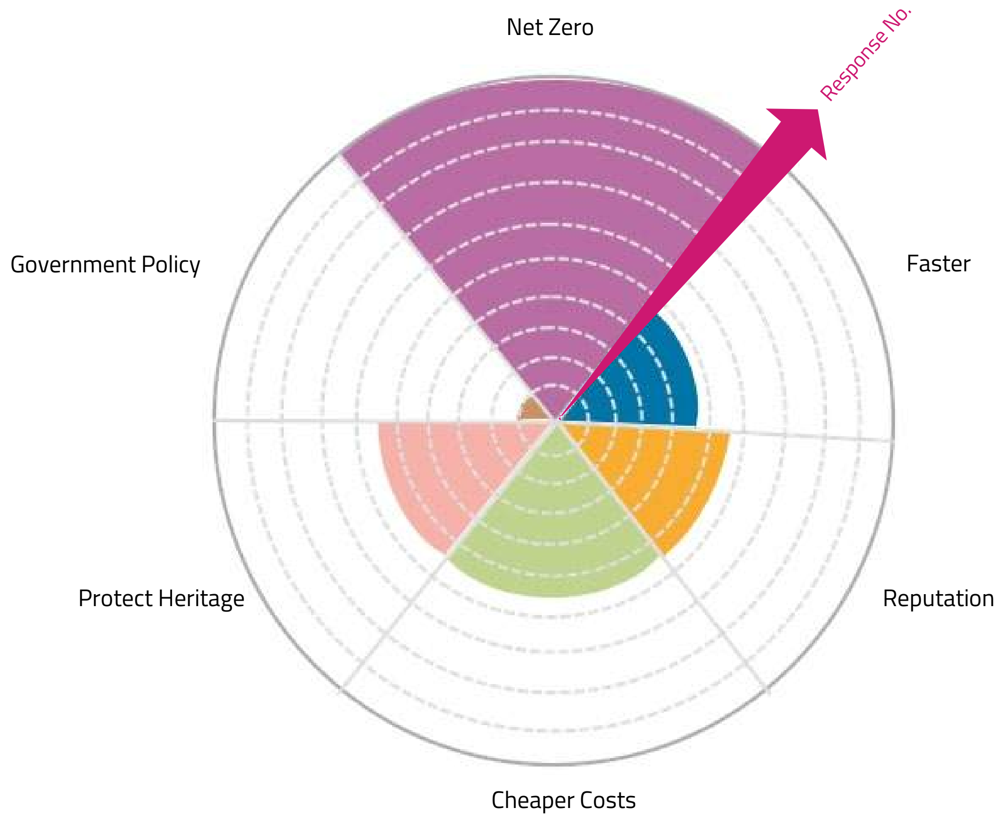
AUDE questionnaire response

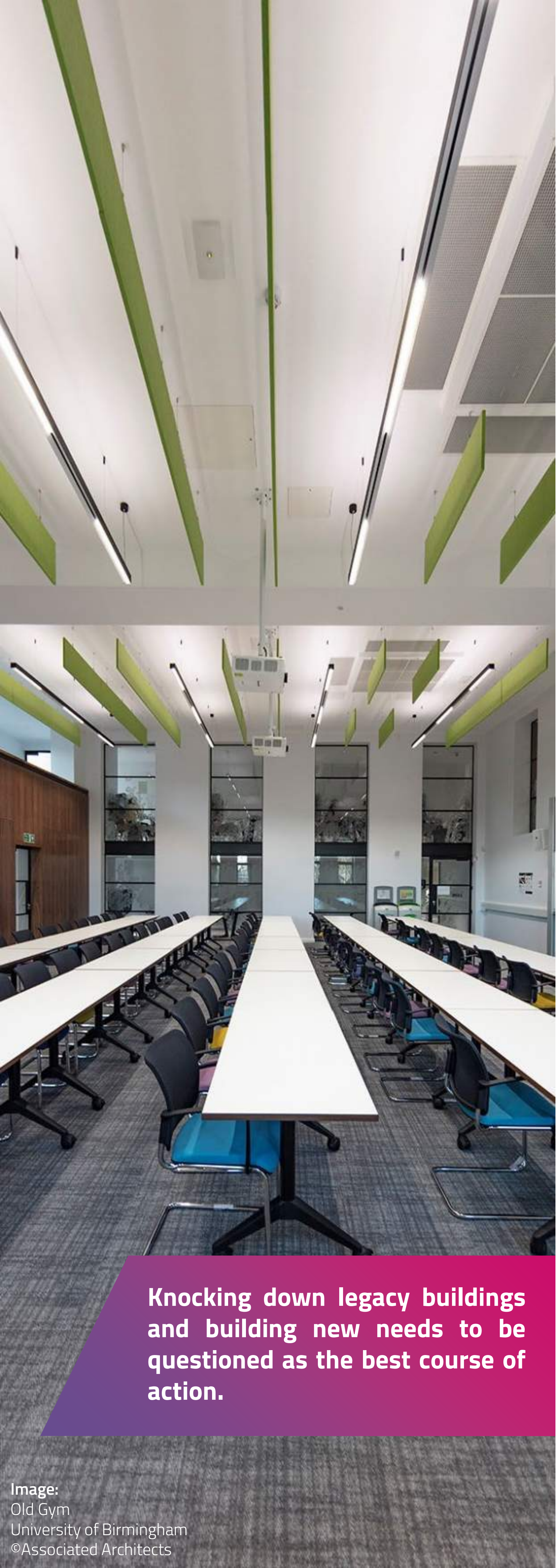
The questionnaire sent out to AUDE members looked to gauge what they deemed to be the main opportunities associated with retrofitting a higher education legacy building.

The survey showed that the opportunity to achieve better Whole Life Carbon performance to help meet net zero commitment was by far considered the main reason why retrofitting a building would be done ahead of demolishing and re-building.

Other reasons that scored favourably were a faster project turnaround, and lower cost than a new build, as well as the ability to protect the heritage of the existing building.

Main opportunities with retrofit





Knocking down legacy buildings and building new needs to be questioned as the best course of action.

Image:
Old Gym
University of Birmingham
©Associated Architects

Typical issues faced by HE legacy buildings

Typical Issues with Legacy Buildings

There are often many issues associated with these legacy buildings compared to some of the more recently constructed building stock. Often these are associated with changes to how buildings are used, and developments in the performance of materials and systems. The below list highlights some of the most prevalent issues and these are covered in greater detail in a subsequent chapter:

	Under-utilisation of space / improved functionality	The way higher education buildings are being used has changed significantly over the last 80 years, particularly post-Covid. This has led to many buildings becoming under-utilised, containing spaces that are no longer required or that people no longer want to use.
	Tired aesthetics / appearance both internally and externally	Internal fixtures and fittings can quickly become worn and tired, particularly when heavily used. Public perception of what is aesthetically pleasing also changes over time and can be a significant consideration for students when applying to HE institutes.
	Poor natural lighting and thermal comfort of building	Lots of natural lighting and a stable, comfortable, internal temperature make a space much more enjoyable to spend time in. Improvements in heating and ventilation systems and the performance of insulation materials have meant this is much easier to achieve now compared to when many of these buildings were constructed.
	Poor accessibility and circulation of people around building	How people circulate around a building is a significant factor in their user-experience. Wide, easily navigable routes offering direct links between the most heavily trafficked areas are preferred. Disability discrimination laws have also been introduced since many of these buildings were constructed.
	Poor energy efficiency and sustainability of building	Since many of these buildings were originally constructed, there have been significant developments in the way energy can be provided to buildings as well as improvements in the energy efficiency of heating and ventilation systems. Developments in insulation materials reducing heat loss have also meant it's now much easier to achieve low energy buildings.
	Safety issues with building	Common construction materials in use when some of these buildings were built, such as asbestos and high alumina cements, and construction systems such as RAAC and panel cladding systems have since shown to have significant safety issues. Legislation around fire, electrical and water safety has also changed since many of these buildings were constructed.
	Maintenance issues with building	Over time, buildings often require maintenance when the installed systems approach the end of their life span. The most common issues relate to water ingress from leaking roofs and windows, issues with the building services including plumbing, heating and mechanical ventilation as well as the deterioration of materials such as timber, concrete and paint systems.

Given the number of issues associated with legacy buildings, there is a tendency to demolish and build a new, more energy efficient, better fit for purpose building. However, this course of action needs to be questioned when we consider the broader implications that this could have on the environment as well as the social and financial benefits retrofitting can offer. Both policy and perceptions are encouraging a different, more sustainable approach to be taken.

Ensuring adequate funding for maintenance is not just a matter of preserving the physical integrity of legacy buildings; it is a critical financial strategy that safeguards the long-term economic viability of a university's estate.

Image:
Oxford Brookes University – Sinclair Facade

Setting the context

Looking after buildings

How did we get here?

Approximately 50% of the current university stock was built between WW2 and the end of the 20th century. The majority of these buildings will now be beyond their intended design life (typically 50 years during this period). A key factor in their current condition and state of repair is the historical maintenance and repair activities that have been undertaken, or not.

Across all sectors, maintenance to ensure maximum life spans has not been a priority, with many tired buildings simply being knocked down and replaced to solve the problem. A change in thinking and priorities is required to focus efforts on getting the most out of the buildings we have and maximising lifespans of materials. This puts a greater focus on maintenance than might have been considered historically. Maintenance requires funding which can put strain on available resource, with often limited notable, obvious or valued outcomes.

Ensuring adequate funding for maintenance is not just a matter of preserving the physical integrity of legacy buildings; it is a critical financial strategy that safeguards the long-term economic viability of a university's estate. In financially challenging times, there may be a temptation to reduce or defer 'influenceable' maintenance budgets in an effort to cut costs. However, this approach is myopic and will lead to significantly higher expenses in the future. This is the situation that many universities find themselves now due to decisions made in the past.

Underfunding maintenance leads to the accelerated deterioration of building components, resulting in more frequent and severe failures that are both costly and disruptive and is arguably why the sector has so many legacy buildings. Minor issues that could have been addressed with routine maintenance can escalate into major problems requiring extensive and expensive repairs. This not only increases direct costs but also impacts operational efficiency, leading to further financial losses through downtime and the potential disruption of university activities, and quite often unfair criticism of reactive maintenance services.

Moreover, the value of a university's estate is intrinsically linked to the condition of its buildings. Poorly maintained facilities can decrease the attractiveness of the university to prospective students and faculty, potentially leading to reduced enrolment and a decline in revenue. On the other hand, well-maintained buildings contribute to a positive campus environment, enhancing the university's reputation and supporting its strategic objectives.

In the context of legacy buildings, where the structures are often older and more prone to wear and tear, the importance of consistent maintenance cannot be overstated. The economic and commercial sense of maintaining these buildings lies in the fact that it preserves the substantial investment already made in these assets.

By protecting and extending the life of legacy buildings through regular and appropriately funded maintenance, universities can avoid the far greater costs associated with premature building failure or the need for extensive retrofitting or even complete replacement. This requires support and understanding from all levels of university department, namely those in control of finance, decisions and delivery.

Setting the context

What is the problem and what role does the HE buildings sector play?

Climate Crisis

In 2021, the Intergovernmental Panel on Climate Change (IPCC) laid out the 'unequivocal' link between human-induced climate change and the effects on weather and climate extremes already being felt. To meet the ambitions of the Paris Agreement and avoid the most catastrophic effects of climate change, the global economy needs to significantly reduce greenhouse gas emissions by 2030 and reach net zero emissions by 2050.

The UK government legislation to meet net zero by 2050 applies to higher education and its property portfolio. In 2008, the UK Government became the first country to legally mandate reductions in greenhouse gas emissions when the Climate Change Act was passed. Since then, targets have become even more ambitious, with the latest commitment to be net zero carbon by 2050, and to achieve a 78% reduction by 2035 compared to a 1990 baseline[2]. It is critical that future decisions aid in mitigating the climate crisis and ensuring global warming is kept within 2 °C.

Higher Education sector context

In response to climate change, the HE sector has set targets on how to reduce its carbon footprint. These targets are often aligned regionally and are often more ambitious than the national targets.

However, traditionally, the higher education sector has a poor track record of honouring their net zero commitments. In 2010, a sector-level carbon reduction target was set to reduce scope 1 and 2 emissions by 43%, between 2005/06 and 2020/21, 59% of UK universities failed to meet this target[3].

While carbon reduction targets have been established, considerable gaps remain on how these targets can be achieved. It is essential to recognise that this is not a failing of the sector; rather, the decisions and strategies required to meet these targets are complex and affected by the economic and political climate. This guide positions itself as a valuable tool to assist in reaching the ambitious goals that have been set whilst creating functional, attractive and efficient buildings.

Key message points:

- Carbon pollution is causing a climate crisis.
- 59% of universities have failed to hit their emission reduction targets established in 2010.[3]
- This guide will aid the HE sector to meet future targets.

40% of global energy-related carbon emissions is attributed to the built environment

Setting the context

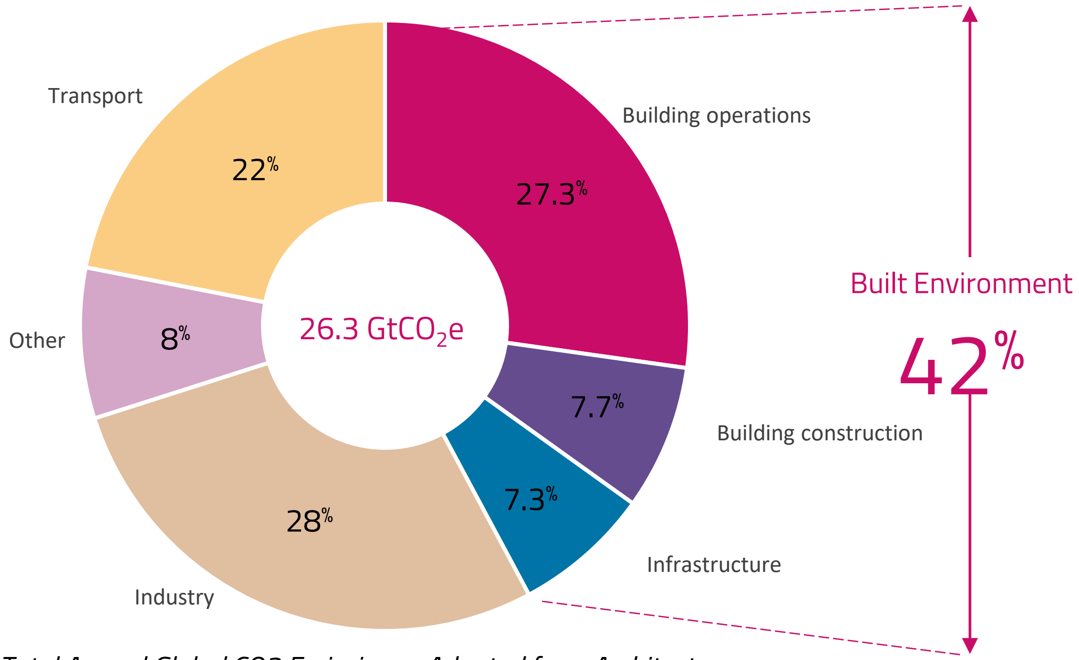
Carbon in buildings

The legacy buildings and the materials they are constructed from contain huge amounts of embodied carbon. For context, let's say the average amount of embodied carbon in a typical higher education legacy building is 500 $kgCO_2e/m^2$ and that legacy buildings account for 52% of the 16,000,000m^2 of non-residential gross internal area across the UK's higher education institutes. There is therefore approximately 4.16 billion kg of carbon equivalent embodied in the current legacy building stock. This is a huge amount of carbon that would, in effect, be lost if the buildings were demolished and rebuilt.

Operational carbon savings can also be achieved through retrofitting by upgrading plant and façade elements as well as energy optimisation through data-led smart buildings. It can take decades of operational carbon to equal the embodied carbon to construct it and this gap will only increase as operational carbon reduces.

There is a significant amount of carbon associated with the end-of-life stage through the demolition, transport, waste processing and disposal. In fact, the construction industry accounts for around 60% of the UK's total waste. Not all waste needs to go to landfill and there is an increasing awareness and use of circular economy, which is discussed in a subsequent chapter.

All the stages of a building's life and its associated carbon at each stage is considered when looking at Whole Life Carbon.



Total Annual Global CO2 Emissions - Adapted from Architecture 2030 from IEA and Statista

35%-50% of total carbon emissions of a building over its lifecycle happen just to build it

Between 2018 and 2022 embodied carbon emissions have reduced by just 4%, less than ¼ of the amount that was needed

62% of total UK waste was from construction and demolition in 2018

Image:
Oxford Brookes University – Sinclair replaced facades
© Fisher Studios

Setting the context

Embodied Carbon Savings

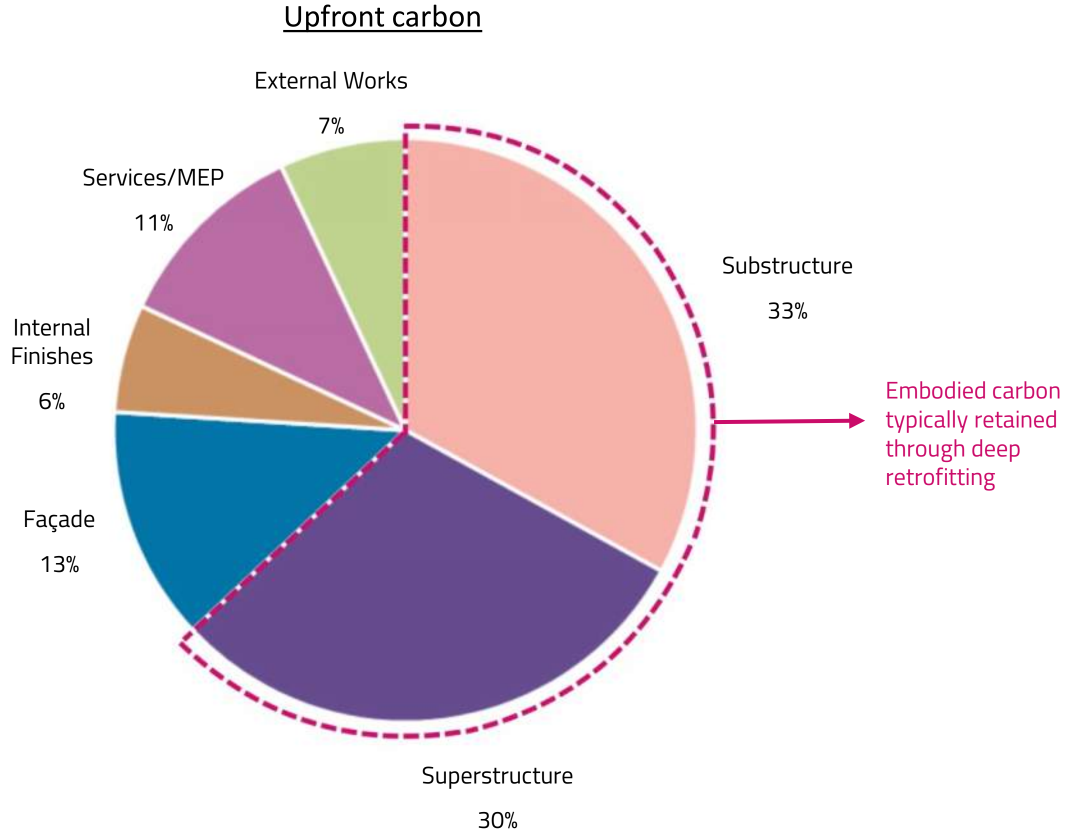
How much carbon can retrofitting save?

Retrofitting projects typically reuse all, or the majority, of the substructure (structure below ground) and superstructure (structure above ground). This is one of the key environmental benefits of retrofitting, it is all about getting the most out of the carbon we use. Carbon use is only going to grow as a consideration in decisions, and may even overtake other historical key considerations such as cost for some institutions and projects. However, given that the sub and superstructure typically account for around 35% of total project costs for new builds then retrofitting can be win-win.

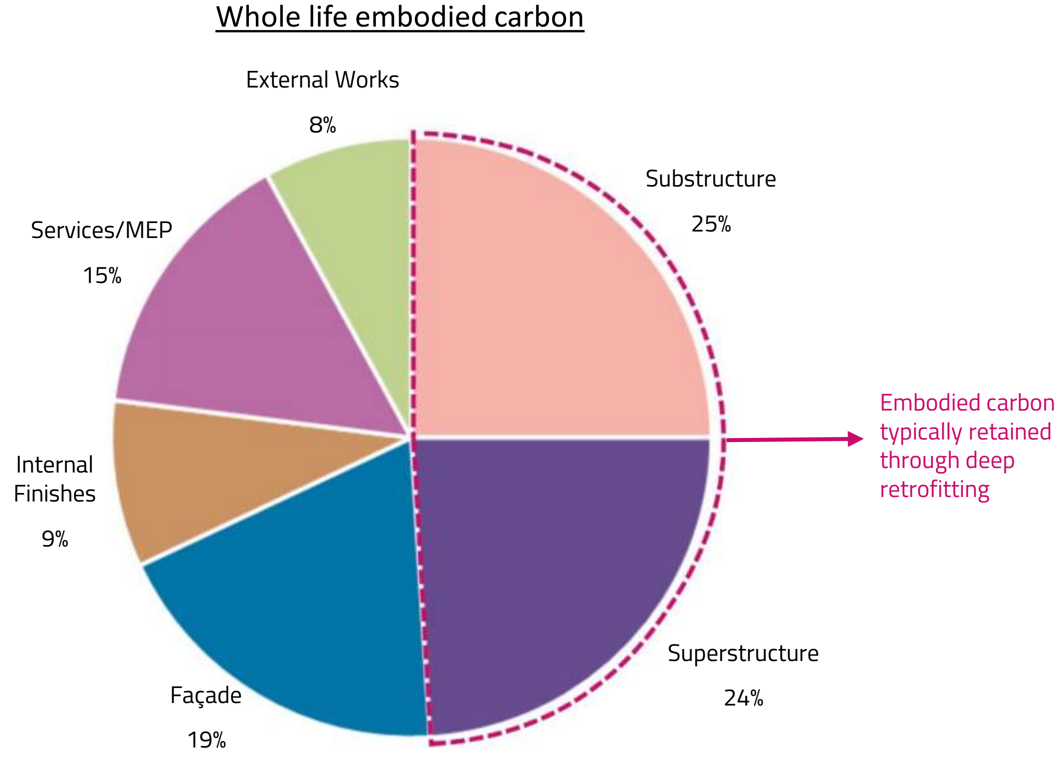
To demonstrate the potential savings retrofitting can offer in terms of carbon the charts on this page are taken from GLA whole building embodied carbon benchmarks for new builds for education typologies.

The figures demonstrate that the carbon associated with the structural frame is significant. Approximately 63% of upfront carbon and 49% of Whole Life Carbon. Across the higher education building stock this accumulates to a huge amount of carbon, if the buildings frames are reused rather than knocked down and rebuilt then less total carbon is required.

The benefits of retrofitting are obvious, a change of mindset is required to swing from the constraints, unknowns and risks associated with retrofit to opportunities and savings that retrofitting offers. The case studies in this guide demonstrate the benefits as well as quality that can be achieved – 'second hand, not second class'.



<750 $kgCO_2e/m^2$ GIA - WLC benchmark
<500 $kgCO_2e/m^2$ GIA – Aspirational WLC benchmark



<1000 $kgCO_2e/m^2$ GIA - WLC benchmark
<675 $kgCO_2e/m^2$ GIA – Aspirational WLC benchmark

GLA WLC benchmarks for new build education[4]

Image:
Engineering Building
©University of Leicester / Simon Kennedy

Setting the context
How can we reduce carbon in buildings?

Reducing Carbon in Buildings

Historically, operational carbon tended to account for most of a building's carbon emissions. However, through industry wide efforts to improve the efficiency of heating and cooling equipment, this balance has shifted. The largest contributor to a modern and future building's emissions will be during its construction including the carbon associated with the materials used - its embodied carbon.

There are two types of action that can be used to reduce embodied carbon of buildings:

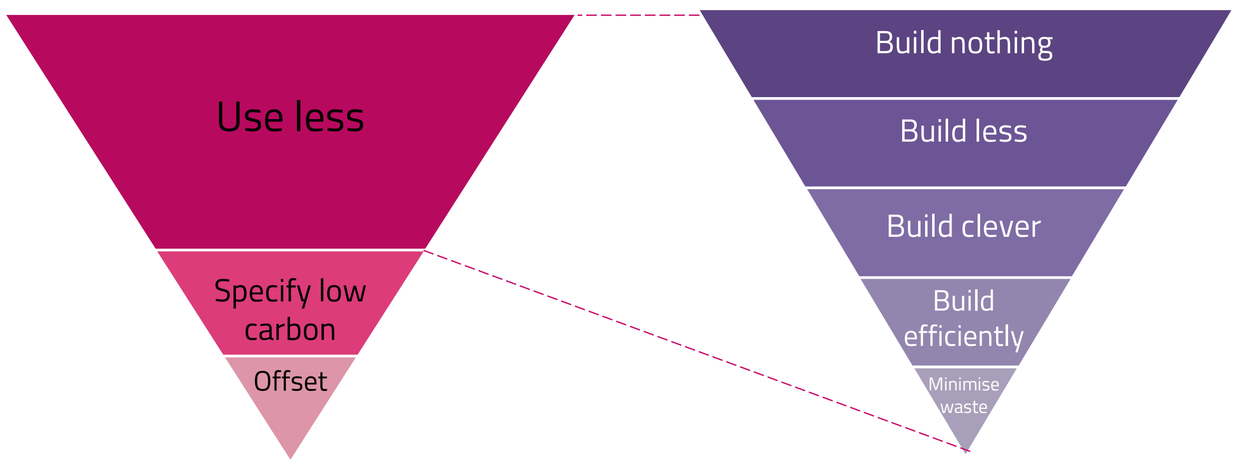
- **Minimise the amount of carbon released in the material used** – this is about selecting low carbon materials in the construction of new buildings and the retrofitting of existing ones.

- **Use less** – ideally nothing by building nothing. There is a hierarchy of net zero design (see below) associated with challenging decisions.

  To have the greatest impact on the carbon of a building, the brief needs to be challenged from the project onset. We need to ask some questions:
    - Are we providing the best solution? Do we need to build?
    - Could we retrofit and build nothing new?
    - Do we need to build this size, or could we build less?

  Once answers to these questions have been fixed, we need to ask ourselves:
    - Are we building clever, using the smartest scheme?
    - Can our designs be more efficient?
    - Can we adopt a circular approach?
    - How can we minimise waste further?

In order to maximise carbon reductions in design, the client, architect, engineers and contractors need to collaborate and share collective goals.



Adapted from IStructE (Circular economy and reuse: guidance for designers, 2023)

Why a Whole Life Carbon approach is important?

Whole Life Carbon (WLC)

Working within a whole lifecycle framework allows accurate and informed decisions to be made on how to balance savings in operation and embodied carbon. Without a whole life perspective, achieving the right objectives isn't always possible. It is recommended that the assessment be as robust as possible and continues to be developed through the project stages. If the project is within Greater London Authority (GLA) this will form part of the planning submission. Local authorities have sustainability high on agendas and therefore this may become mandatory elsewhere soon.

Key message points:

- Whole Life Carbon (WLC) needs to be assessed.
- Policy is moving towards WLC based decisions.
- 'Retrofit First' based decision mindset.
- Embodied carbon will become the most significant factor as we move towards net zero.

New-Build vs Retrofit: WLC

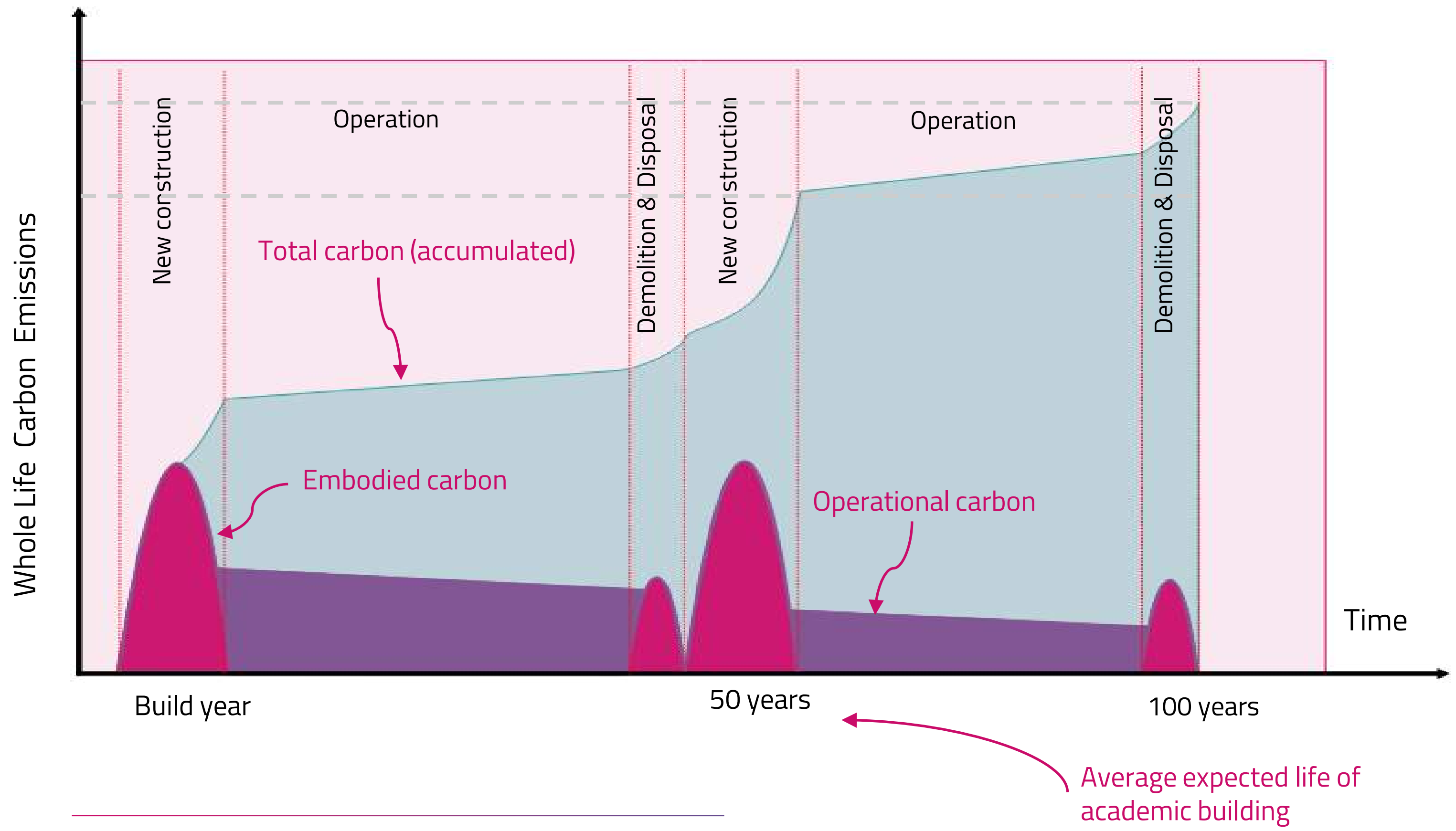
When considering whether to demolish and rebuild, or retrofit, it is important to consider the Whole Life Carbon impact of these decisions.

Decisions on whether to retrofit, build new or do nothing need to be made on a case-by-case basis. The 'Retrofit First', rather than 'Retrofit Only' approach is recommended as some scenarios may dictate that a new build may offer the most sustainable outcome when considering whole life timeframes.

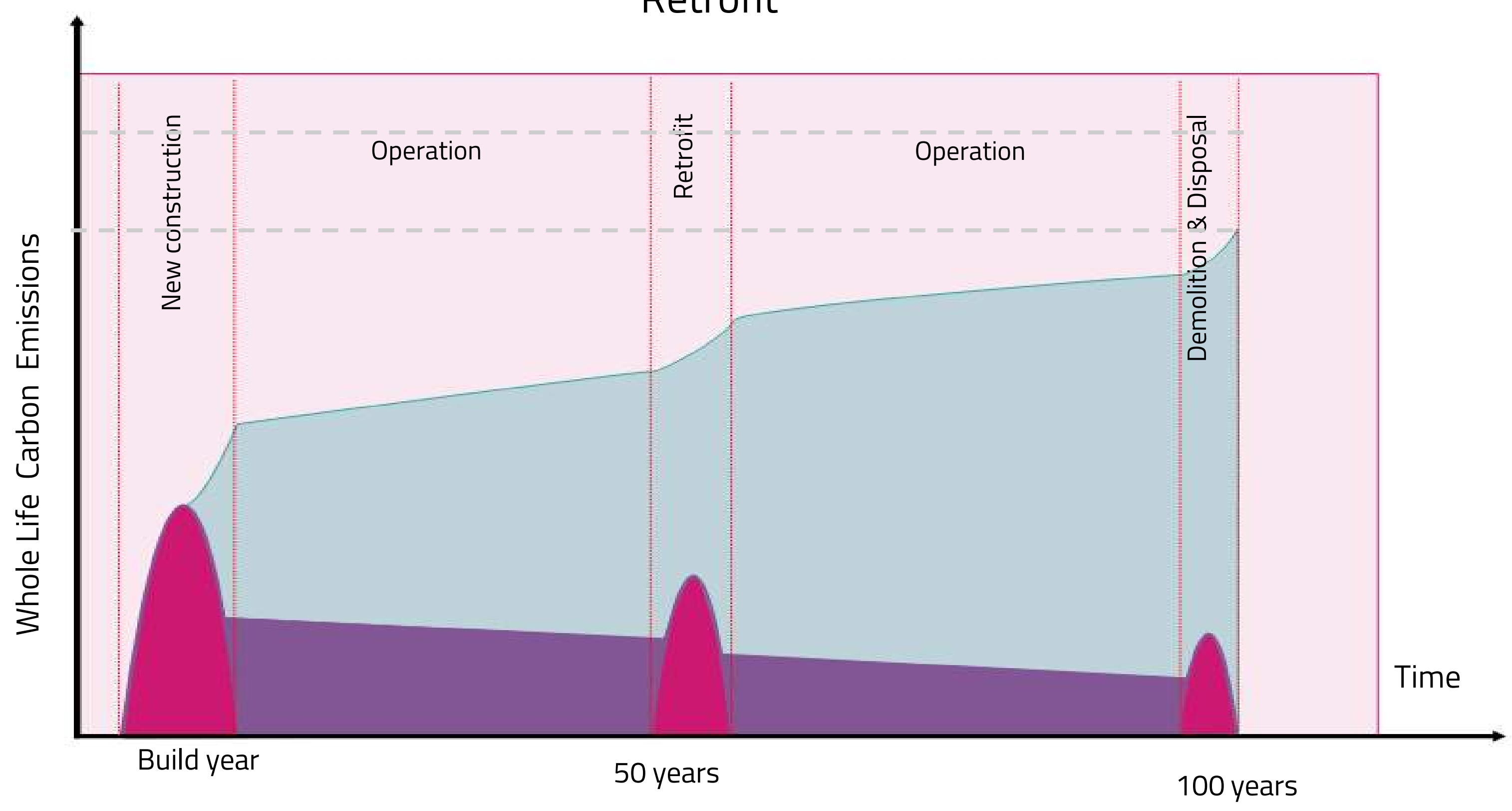
The Net Zero WLC Progress report[5] states that whilst operational carbon is on track for meeting overall net zero targets, emissions from embodied carbon are way behind the targets . Retrofitting can play a role in getting these targets on track. As operational carbon and supply improves on the journey to net zero, embodied carbon becomes the biggest differentiator.

The graphs to the right demonstrate two scenarios: the top one demonstrates the WLC story where a legacy building is demolished and replaced and the end of the buildings design life, whereas the lower graphs shows the building's design life being extended through retrofitting. This removes the carbon associated with the demolition, disposal and new build elements and maximises the embodied carbon of the original construction whilst improving operational carbon.

New Build



Retrofit



**Example scenario Illustrative & not to scale*

MEP Embodied Carbon

What is the impact of embodied carbon in MEP equipment?

MEP equipment embodied carbon is notoriously difficult to measure and the scopes of measurement are not always consistent, but often for appropriate and good reasons. MEP equipment is an assembly of many raw materials, often sourced from and manufactured in different parts of the world creating a complex supply chain that is difficult to account for.

Furthermore, MEP equipment is usually measured according to two different scopes.
- Upfront Embodied Carbon and
- Whole Life Embodied Carbon

The embodied carbon of MEP equipment is estimated to contribute between 4-40% of the whole life cycle embodied carbon of a new construction, depending on building use and complexity. In education and office buildings, it is estimated to be between 15-21%.

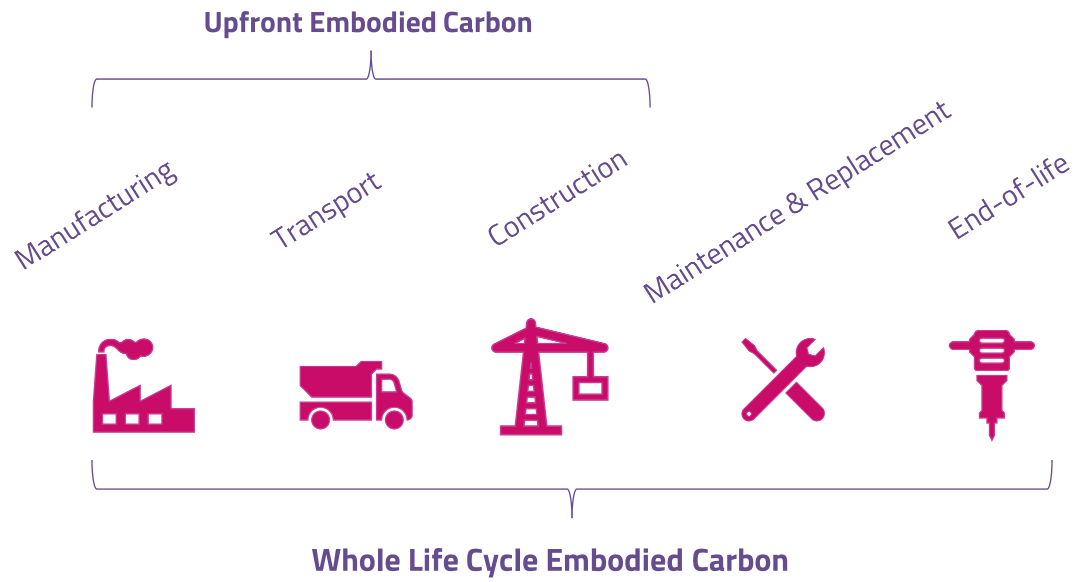
As the operational carbon of services becomes less significant due to grid decarbonisation, the embodied carbon becomes more significant and more important to address.

The following issues are identified as hot spots for contributing and therefore present opportunities for reducing the embodied carbon of MEP equipment.

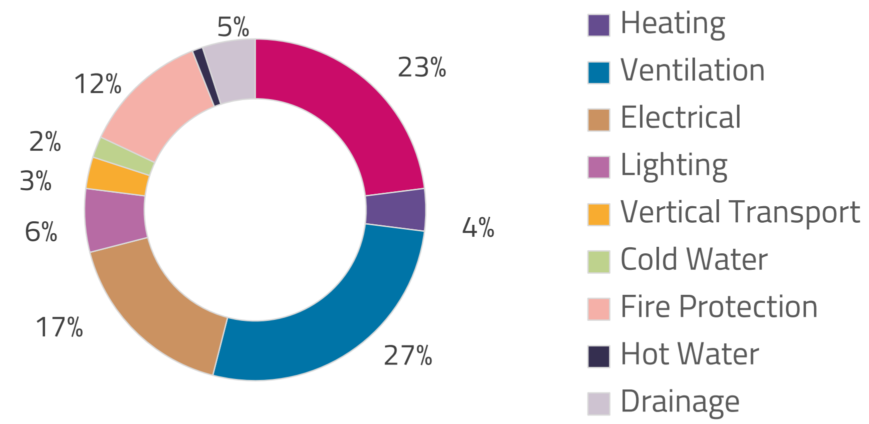
Refrigerant Types
Mechanical equipment that uses refrigerant based systems may present a significant risk of increased embodied carbon due to fugitive emissions. Older refrigerants typically have very high global warming potentials (GWP) and if they leak into the atmosphere, their emissions can contribute massively to the whole life embodied carbon. Using low GWP refrigerants is essential to mitigate this risk.

Replacement of systems
MEP equipment is replaced several times within a building's lifetime and adds to the in-use emissions for the building. Aligning maintenance schedules and replacement cycles along with façade is a great way to determine when retrofit should take place.

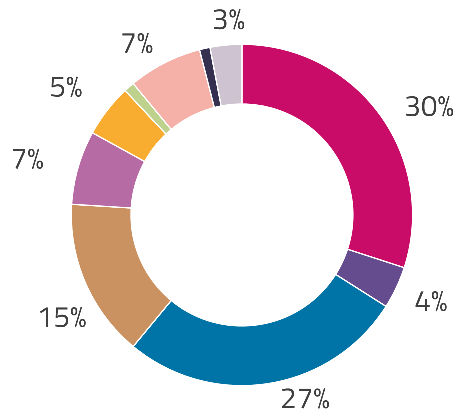
Primary Plant and Distribution
The embodied carbon of MEP equipment primarily comes from the main plant equipment. However, the significance of distribution components is still worth considering especially ductwork and insulation which contributes a large amount to embodied carbon.



Upfront Embodied Carbon



Whole Life Embodied Carbon



Office Buildings. Source: Net-zero Buildings Halving Construction Emissions Today, 2023 – WBCSD
*This should not be used as a benchmark as these numbers are based off a single Arup case study

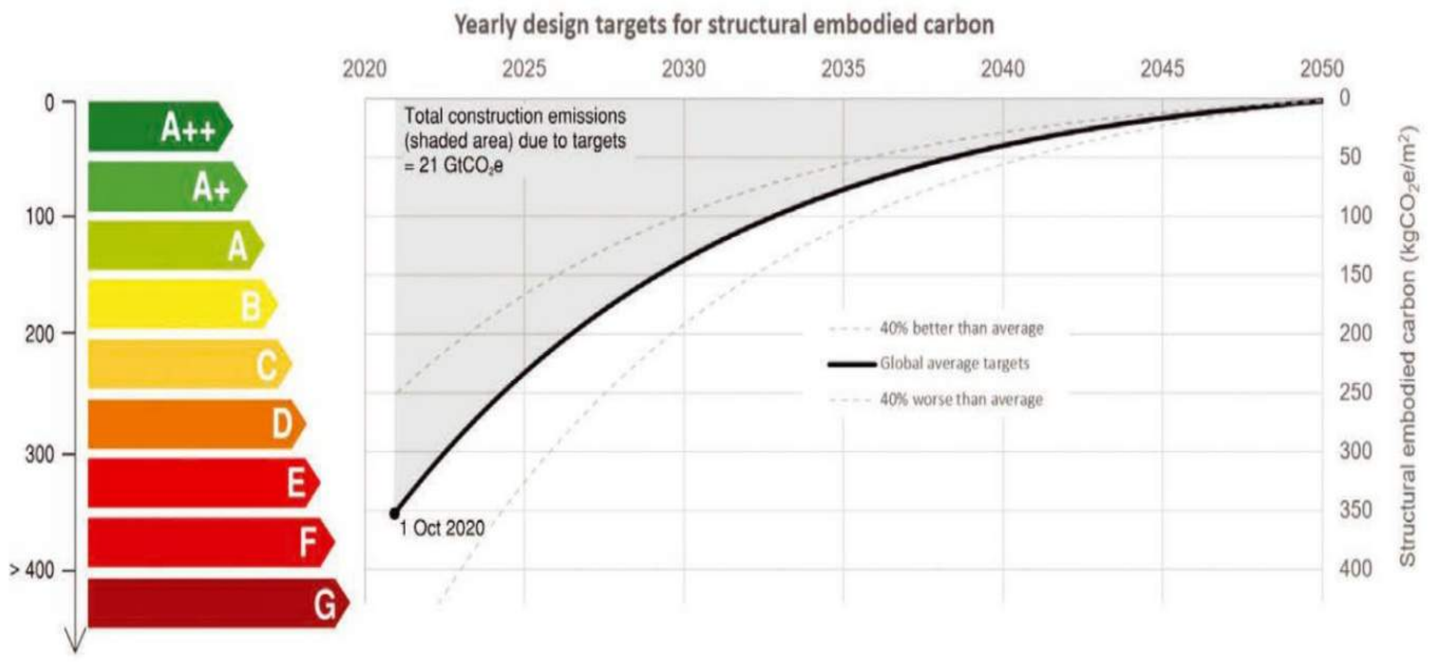
Image:
Arup Office – Oakland
©Aruo

The scale of the challenge

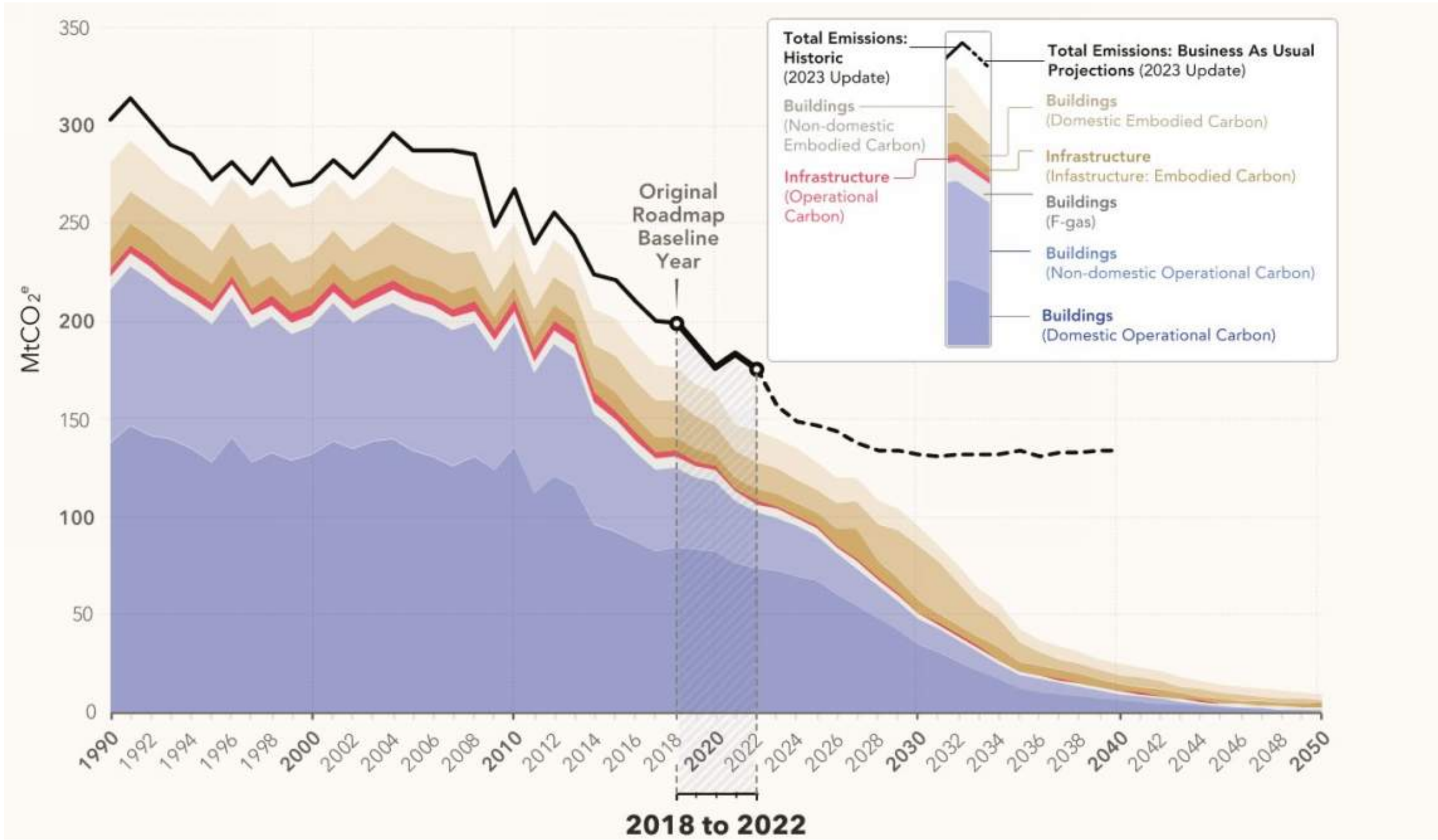
Reducing embodied carbon is one of key motives behind reusing existing building stock rather than building new. The Institution of Structural Engineers[6] have produced a structural carbon rating scheme (SCORS), which assigns a rating to a structural project based on the level of embodied carbon; with the **aim of all buildings being A rated by 2030** and net zero by 2050. Currently, the average embodied carbon for a **new build project in Western Europe ranges between 510-600kgCO_2e/m^2[(7)]** (SCORS rating of G). As operational and supply related carbon is reduced, the embodied carbon value of buildings are going to become a more significant focus towards achieving net zero.

As we progress from 2030 to 2050, the targets will be increasingly difficult to achieve through new build. This emphasises the importance on retrofitting existing building stock, appropriate material choice and adopting circular economy principles. Typical designs will need to achieve a SCORS A rating by the year 2030.

The scale of embodied carbon associated with retrofit projects will be dependent upon the degree of intervention required to facilitate the change of use, with the **'do nothing'** approach being the optimum approach for reducing embodied carbon emissions.



Yearly design targets for structural embodied carbon (taken from IStructE Setting carbon targets: an introduction to the proposed SCORS rating)[6]



UKGBC net zero Whole Life Carbon roadmap (taken from UKGBC Net Zero Whole Life Carbon Roadmap Progress Report)[8]

How are we doing?

The UKGBC assessed the UK's progress towards net zero at the end of 2023; with the UK built environment emissions needing to fall by 19% from 2018 to 2022, but **only 13% was achieved**.[9] Operational carbon reduced in line with the proposed roadmap, but grid decarbonisation and embodied carbon are falling behind the roadmap targets. Embodied carbon **reduced by 4%, against the required target of 17%** between 2018 and 2022; with some of this reduction due to a halt in construction during the pandemic.

UKGBC noted that to realign with the predicted roadmap to net zero, the industry will need to reduce the emissions **nearly twice as fast** by 2025.

Around 80% of buildings which will be occupied in 2050 already exist emphasising the importance of retrofitting existing building. The key to achieving the embodied carbon targets is to **repurpose existing buildings and increase their operational efficiency** rather than building new.

Parallel Guide to Decarbonisation

Regardless of the drivers for the retrofit of a particular building, each project provides a fantastic opportunity to realise significant emissions reductions. Much of the content of this guide points towards the possible energy and carbon savings available. However, for the greatest impact on emissions, a project should be part of a wider Decarbonisation Plan. If a plan is not already in place, a significant refurbishment project can be the catalyst for one to be developed.

A Guide to Decarbonisation has been commissioned by AUDE, intended to help you navigate your way through decarbonising your operations by optimising and specifying a decarbonisation plan that will have real-world impact on emissions.

No two institutions are the same so it follows that all decarbonisation plans should be unique. With high complexity, individuality and importance, a high-quality plan is essential. The risks (and potential costs) of setting off in the wrong direction are high. The Guide clarifies options for those with all levels of decarbonisation maturity. Those at the beginning of their journey will benefit from what are termed 'Foundation Decarbonisation Plans'. They provide the minimum content required to give an institution a route towards targeted emissions reductions.

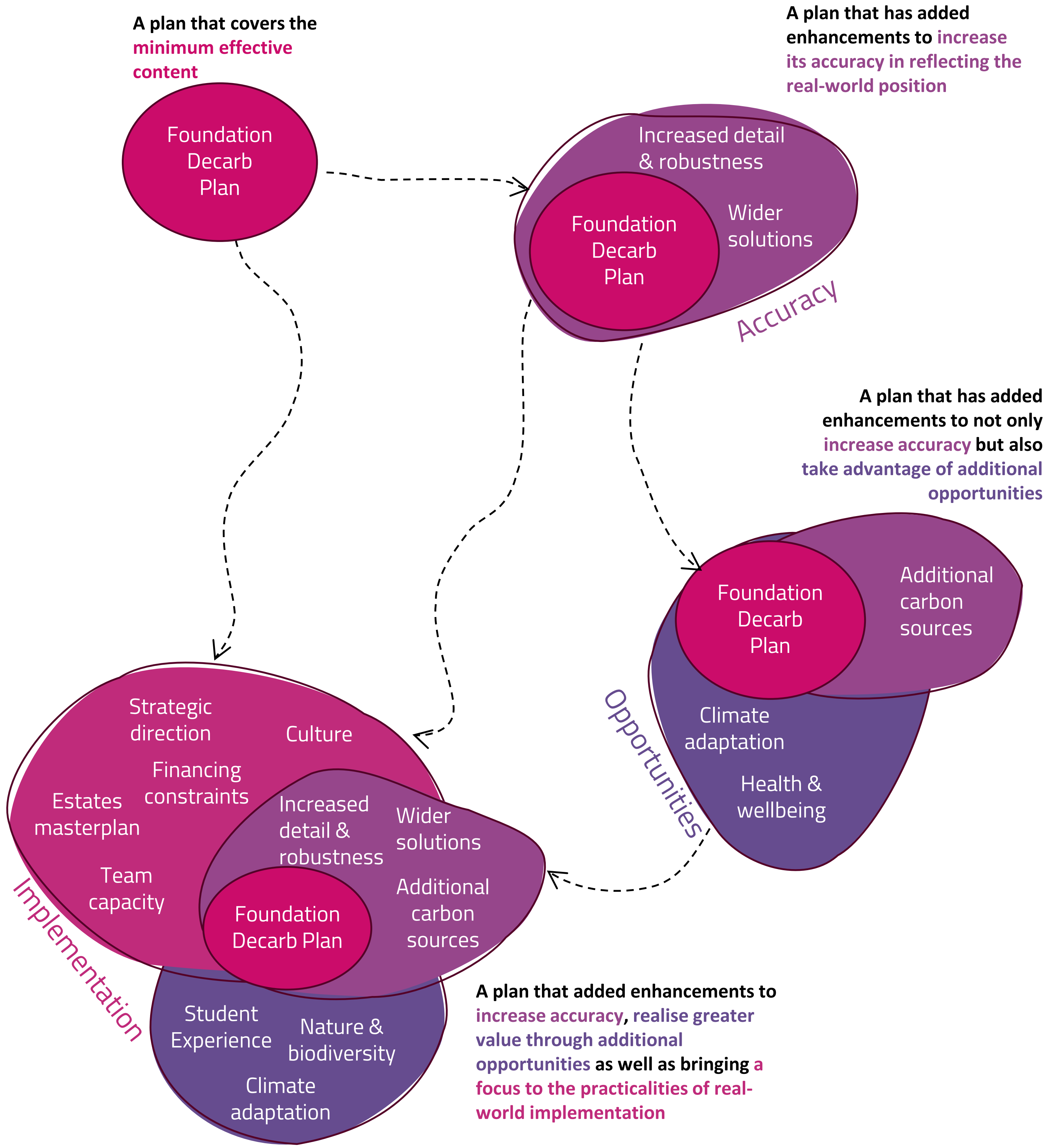
Moving beyond Foundation Plans with a customised study (termed an 'Enhanced Decarbonisation Plan') affords the opportunity to enhance accuracy, opportunities or implementability with a plan tailored to a university's drivers and the characteristics of their institution and estate (as represented by the accompanying graphic):

- **Enhancing accuracy** means bringing in additional components to the plan to bring more detail, certainty and robustness, with additional carbon sources or a greater range of potential solutions.
- **Enhancing opportunities** means having a secondary focus on non-carbon aspects of sustainability maximise the impact and value, considering issues overlapping with decarbonisation interventions.
- **Enhancing implementability** means having a broader view of the institution, reaching far beyond Estates, the traditional home of energy and carbon issues.

The Guide also looks at the implementation of Decarbonisation Plans. It was co-created with the sector bodies representing Finance Directors, Strategic Planners and small institutions in order to meet their needs and bring plans outside of their traditional home within the Estates Department.

A Plan needs to engage senior leadership and must align with the short-term practicalities (e.g. an organisation's structure and culture), the medium-term context (inc. pedagogy change and funding constraints) and the long-term strategic direction of the university, aiming towards where the university will be in 10-20 years' time rather than constraining thinking to the current operations, structure and business model.

Finally, the last section of the Guide contains a set of example specifications that can be combined into Invitation to Tender documents to provide a sound basis for procuring the right partner for you in your decarbonisation journey.



Newton & Arkwright (Nottingham Trent University) - Two very separate Grade II* listed buildings have been joined together and sympathetically refurbished to provide modern teaching and academic spaces. The range of interventions does not compromise the original character but has brought new life to the existing buildings, and the transformation secures their long-term future.

Retrofit for Listed Buildings

A listed building is considered nationally important and to ensure protection measures there is additional legal protection within the planning system. A listing recognises that the building is special in a national context and therefore controls are assigned over alterations, extensions and demolition. The listing classification schemes differ between England and Wales, Scotland and Northern Ireland. All schemes grade buildings according to their national importance into 3 or 4 grades (I, II* or II in England and Wales; A, B or C in Scotland; A, B+, B1 or B2 in Northern Ireland).

Promoting the adaption and reuse of listed buildings is well established in the context of planning policy and legislation. Heritage-led regeneration is a long established and recognised approach. Historic England has produced guidance that looks at the role of listed buildings and the important part they have to play in addressing net zero targets[10].

It is a common misconception that listing prevents any alteration and is therefore a blocker to environmentally-friendly progress. But this is not the case – there are many ways in which owners can enact positive changes to protected buildings. Understanding how to gain the necessary permissions is key for estate directors to deliver projects more seamlessly and ensure positive outcomes.

Follow the legislation

The first thing to know is that it is against the law to carry out unauthorised works to listed buildings. Listed building consent (LBC) is required from your local planning authority for any changes that affects its character or appearance. Some activities that may seem like routine maintenance could also require consent, so it is always best to check with your local conservation officer.

The listing grade or category of the building is an indication of the level of scrutiny involved in assessing an LBC application. Other types of designation, including conservation areas, can also have a bearing. Depending on the listing grade, you may also need to speak to your national heritage organisation (Historic England, Historic Environment Scotland, Cadw or the Historic Environment Division in Northern Ireland) and other groups, known as national amenity societies, which have a powerful voice concerning buildings from certain historical periods.

LBC applications must be offered for public consultation. Taking some time to address any potential objections before you submit your application can substantially de-risk the process.

Understand the building

The local planning authority will consider how well you understand the building the proposals will affect. At the top of the local planning authority's list will be two closely interconnected considerations: the building's condition and performance (essentially how well the building works), and its heritage significance (why it is important).

- **How well does your building work? -** Retrofit solutions should work with the fabric of the building, not against it: it is rarely effective to fundamentally change how an existing building reacts to heat, cold, fresh air, rainwater, humidity, and other factors. Design teams and contractors throughout history have developed responses to these environmental factors, many of which may still be valid. Some may have been compromised over time, potentially by well-meaning attempts to modernise fabric and systems. There are countless examples of 'upgraded' materials creating more problems in listed buildings, as owners attempted to correct perceived flaws which never needed fixing in the first place.
- **Why is it so important?** - the local planning authority will expect the design team to demonstrate that they understand why your building is listed, and which bits of it are more or less important from a heritage perspective. With this information they can assess the impact of the proposals – and then make a case justifying that impact. In heritage terms this importance is known as significance. It is a summation of different values or interests – generally covering aesthetics, archaeological evidence, historical meaning and a sense of how the place resonates with different groups of people. If the proposed changes apply to elements of lower significance they will generally have less of an impact on the overall character of the building and are therefore more likely to gain consent. Many buildings have parts that detract from their overall significance, so altering or removing these parts might help to mitigate more contentious changes elsewhere.

Be creative: opportunities exist

There is a growing acceptance that even listed buildings must be adapted to contribute to reductions in our collective carbon footprint. Keeping a building sustainably in use is one of the best ways of conserving it. From this perspective, one way to mitigate any impacts of the proposed changes can to balance those against its future use and viability.

A creative approach to design and conservation, underpinned by a thorough understanding of the fabric in question, can transform special spaces and make them more resilient, more comfortable, and fit for the future.

Image:
Newton & Arkwright Buildings

Redevelopment Decision-Making Process

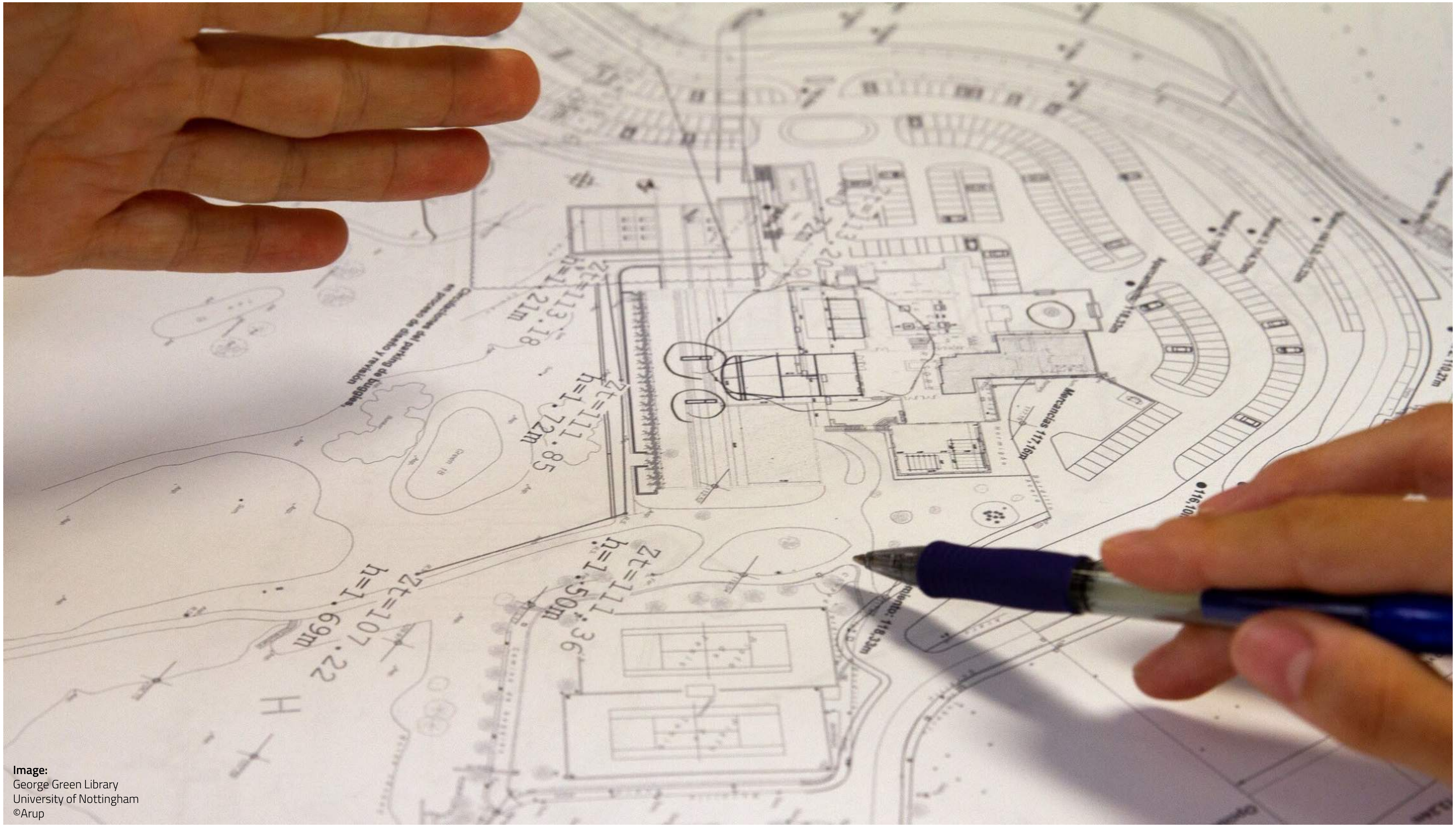


Image:
George Green Library
University of Nottingham
©Arup

Image:
Oxford Brookes University – Clerici & Sinclair replaced facades
© Fisher Studios

Redevelopment Decision-Making Process

Overview

At times in a building's life, critical decisions often need to made: to refurbish, demolish or partially demolish. This **redevelopment decision** requires a thorough understanding of the building's lifecycle and the most appropriate level of intervention, whether it be repair, refurbishment, or repurposing.

The redevelopment decision needs to be balanced and informed, from both a monetary and Whole Life Carbon perspective - not just embodied carbon. Alongside carbon, other important priorities such as social, staff and student views, wider environmental and economic issue should also be factored in.

However, given that typically between 35% and 50% of the carbon used by the building over its entire life is in the building's original materials, there is a new approach that emphasises circularity and material reuse, promoting a **'Retrofit First'** approach is taken. This approach recognises that materials and equipment can be reclaimed and reused, reducing waste and maximising resource value.

This mindset transforms how existing assets are valued, focusing on their potential for a sustainable, circular future.

It is also really important that decisions also factor in the wider campus strategy and masterplan.

Key message points:

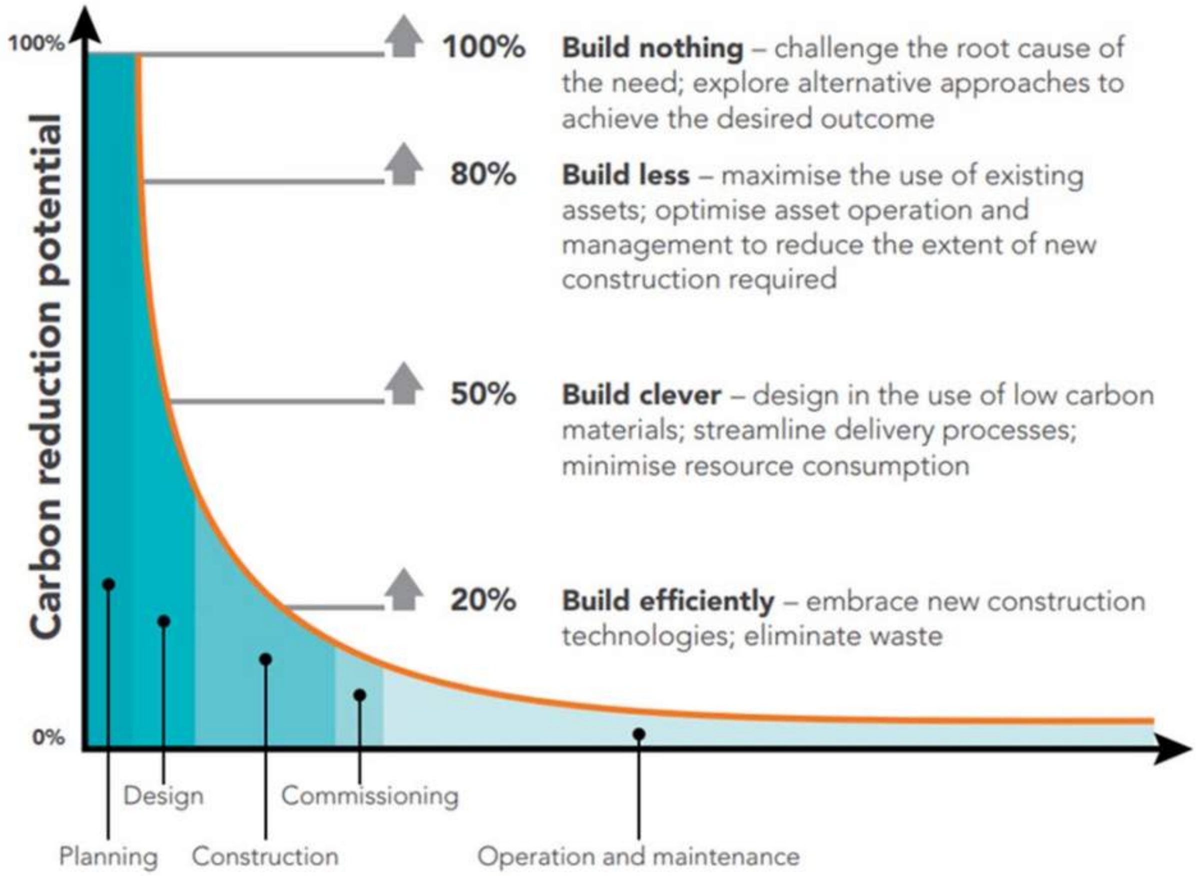
- 'Retrofit First', not 'Retrofit Only' – a balanced decision-making process is required.
- Early decisions and team appointments – key decisions will inform the design briefs and should be made at the onset.
- Decisions need to be informed – robust evaluation through evidence-based methodology.
- These decisions have the greatest carbon saving potential.
- Be an ambassador for circular economy – embed circular economy from the onset.

Redevelopment Decision Making Process

The Impact of Decision Timing

Make decisions early

The process of deciding how and when to build or retrofit is always best done as early as possible. As the design stages progress, it becomes increasingly difficult and costly to try and implement carbon saving strategies. Higher Education directors of estates have a great opportunity to influence these decisions early and therefore drive the most sustainable outcome for their buildings.



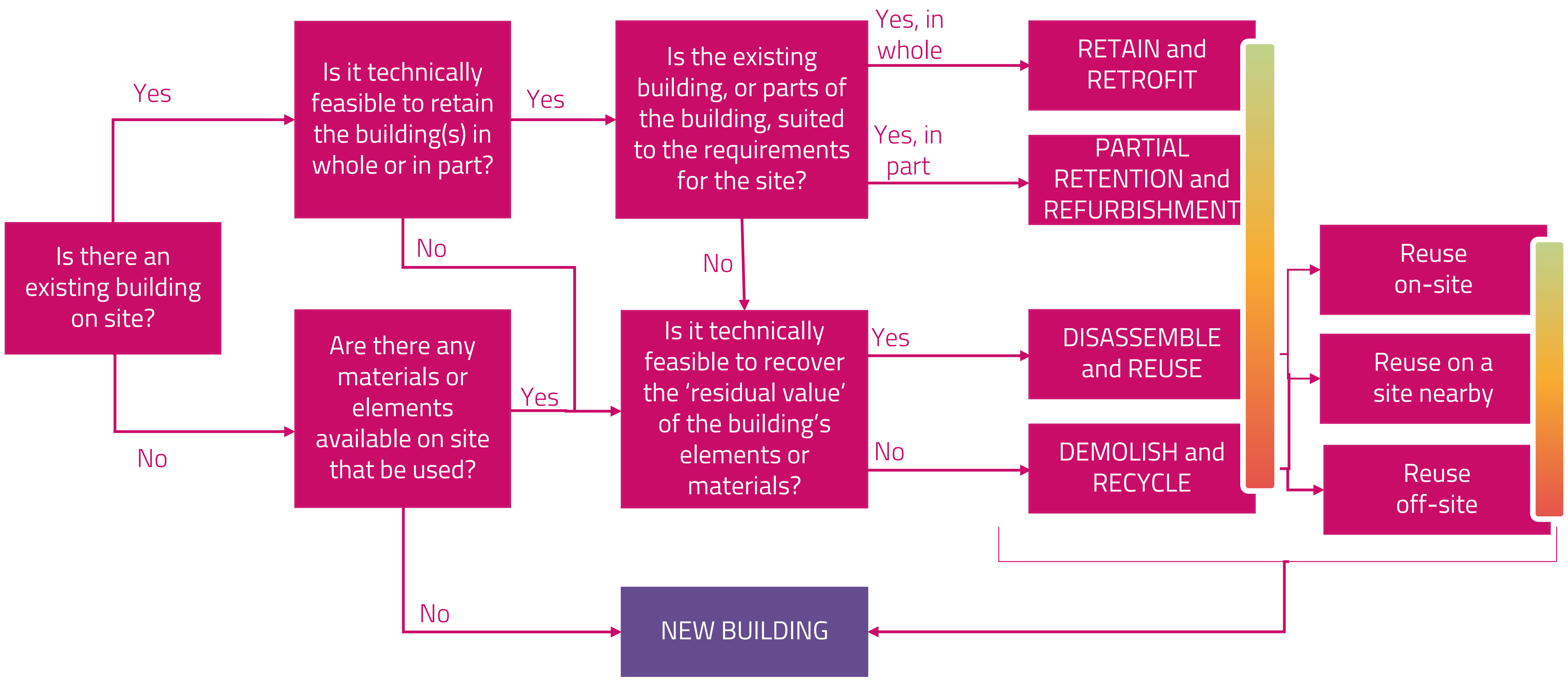
Embodied carbon reduction potential at different stages of a building project
© HM Treasury; Green Construction Board

Image:
George Green Library
University of Nottingham
©Martine Hamilton Knight/Builtvision

Decision-making framework

In terms of defining a methodology to follow in the decision on whether to retain or partially retain an existing building and how to assess against new build options, Greater London Authority (GLA) are leading the way. The methodology laid out in the GLA Circular Economy Guidance[11] can be used as a basis for the decision-making process and is relevant to all building locations and not specific to London. The decision tree for the design approach to follow is shown below; this process should be informed by a thorough evaluation. The tools used to ensure a robust evaluation through evidence-based methodology is covered on the next page. The process will demonstrate how best value can be achieved through retention of the building, whilst at the same time identifying any constraints.

> 'Retrofit First' highlights the importance of material reuse and reclamation, envisioning a more resource-efficient world.



Decision tree for design approach to existing structures/buildings - GLA Circular Economy Statement (2022)

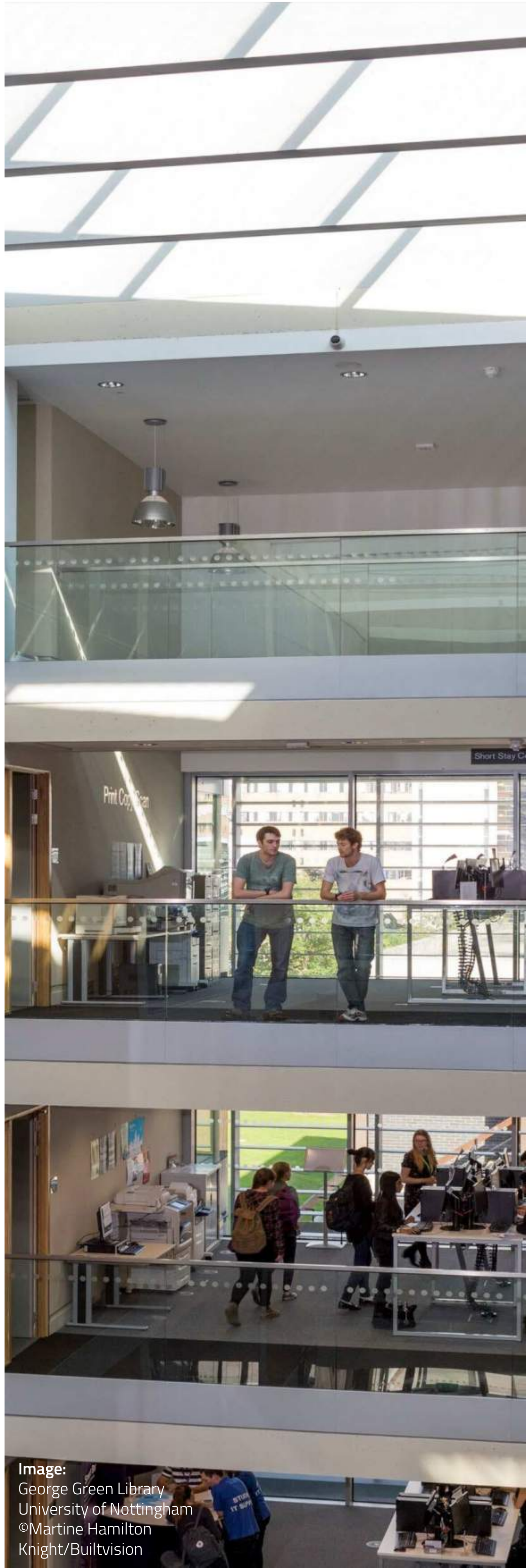


Image:
George Green Library
University of Nottingham
©Martine Hamilton Knight/Builtvision

Image:
Clerici
Oxford Brookes University
©Fisher Studios

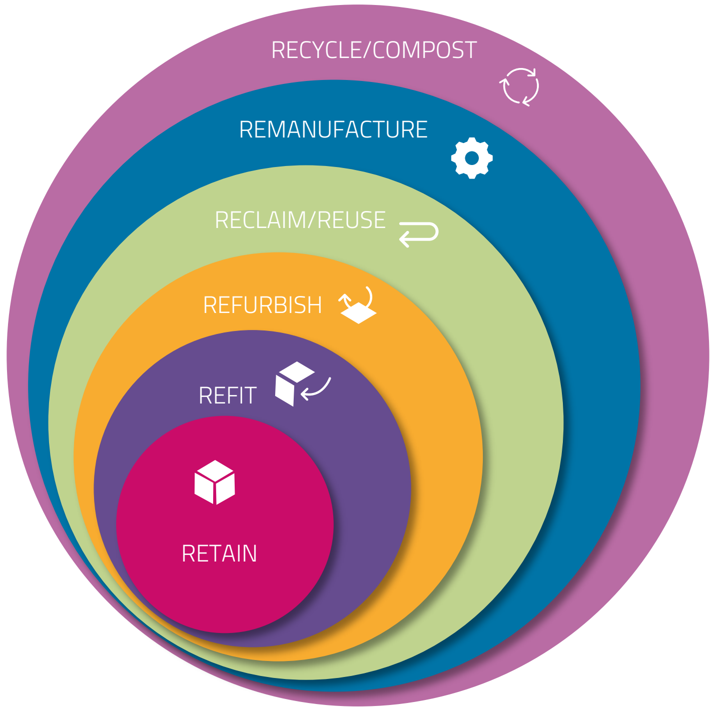
Redevelopment Decision Making Process

Informing Decisions

Evidence-based methodology

It is crucial that the decision-making process is informed and backed up by an evidence-based approach from the outset. The most common tools to inform the decision process are pre-redevelopment audits, pre-demolition audits (if demolition is required) and Whole Life Carbon Assessments (WLCA).

Pre-redevelopment audits take a strategic view of the existing building and the development options available. The pre-redevelopment audit should follow a hierarchy for building approaches looking to retain, refit, refurbish, reclaim/reuse, remanufacture and recycle in that order, with a goal to maximise reuse of materials and their associated carbon.



Circular Economy hierarchy for building approaches – based on Building Revolutions, David Cheshire © RIBA Publishing

To achieve this, you need to understand the existing building and consider the options for redevelopment. For options that do require demolition, the corresponding audit includes a detailed inventory of the existing materials with an aim of reusing them in the proposed development. For more information on this, refer to the circular economy section.

When to carry out a pre-redevelopment audit? To allow the results of the auditing process to inform design brief and feasibility decisions, the audit should be carried out in early concept design.

Pre-demolition audits are required if demolition is required as part of the development. The primary aim is to assign the demolition materials into waste groups and processing routes. There should be a focus on circular economy principles in the pre-demolition audit to maximise efficient use of embodied carbon in the materials.

Pre-redevelopment and pre-demolition audits serve as essential tools in assessing existing buildings before demolition or major redevelopment. These audits are a very important first step on how to progress and are essential in upholding circular economy principles and the Whole Life Carbon assessment (WLCA). These audits provides valuable information to base a considered decision for the redevelopment on.

Whole Life Carbon assessments (WLCA) estimate the total carbon emissions expected to be emitted over the entire life cycle of a building. They include raw material extraction, manufacturing, transportation, construction, operation, maintenance, repair, retrofitting and demolition and disposal of materials. Where multiple schemes are considered that range from full retrofit, partial retrofit or new build, a WLCA should be undertaken for all schemes to allow informed decisions to be made.

The Greater London Authority (GLA) mandates that a WLCA is taken when redeveloping a site and both pre-redevelopment and pre-demolition audits must be carried out. This approach is considered good practice and, although other local authorities may not require it, it is likely that it may become mandatory in the future.

What can estate team do to help?

- The most important thing an estates team can do is be supportive of the process and the circular economy aims.
- Understand and be an ambassador for your university's sustainability aspirations and project KPI's.
- Understand your local authority requirements and keep up to date as there is a high chance of change in this area.
- Appoint a suitably qualified team at the very start of the process.
- Keep asbestos survey information up to date and share with the wider team.

Ways of Reusing Legacy Buildings & Opportunities

Image:
Technological University Dublin
Park House – completed temporary Library

Image: Technological University Dublin Park House – during transformation

Ways of Reusing Legacy Buildings & Opportunities

Overview

A lot of thought, physical effort, carbon and money has historically gone into construction of legacy buildings. Teaching methods, technology and understanding of human performance has developed at a great rate over the past 40-70 years, meaning the drivers behind the original building design are no longer fit for modern university campuses.

Within legacy buildings, there is a variety of ways that transformation can be achieved to give the buildings new life and bring them back in line with modern and future university needs. 'Easy win' engineering modifications and historical overdesign can define efficient paths to change and enable the client and architectural vision to be achieved.

Inherent opportunities in the building can be identified early and instrumental in the direction of travel. This section discusses some typical ways of reusing and opportunities that legacy buildings provide. Each building is bespoke, providing unique opportunities. This section is well complimented by the case studies which show how real-life buildings have been successfully transformed.

Key message points:

- A deep and early understanding of the existing building is key to unlocking opportunities.
- Risk and constraints should also be identified and considered in the decisions.
- Estate teams willingness to be led by the building and the unique opportunities it offers will result in the greatest outcomes.
- Communication and collaboration are vital to project success.

Clerici Buildings (Oxford Brookes)
- Moveable central wall.
- New collaborative lecture theatre.

Image:
Clerici
Oxford Brookes University
©Fisher Studios

Ways of Reusing Legacy Buildings & Opportunities
Architecture

Flexible Spaces

Why is this important?

HE spaces evolve rapidly as teaching methods continuously change, since Covid there has also been a rise in hybrid and flexible working which has further impacted the way we use and interact with space in existing buildings.

Existing HE building stock is often very inefficient and has low utilisation. Spaces such as cellular offices have limited capacity in their function and are difficult to use in any other way than what they were intended for. Similarly, auditoriums tend to be large inflexible spaces that could be better utilised for other uses or additional revenue streams.

Flexible spaces allow for increased utilisation of the building. This feeds into sustainability in that, by maximising the efficiency of the floor plates, it allows the university to build less.

This minimises waste, reduces embodied/operational carbon and maximises utilisation.

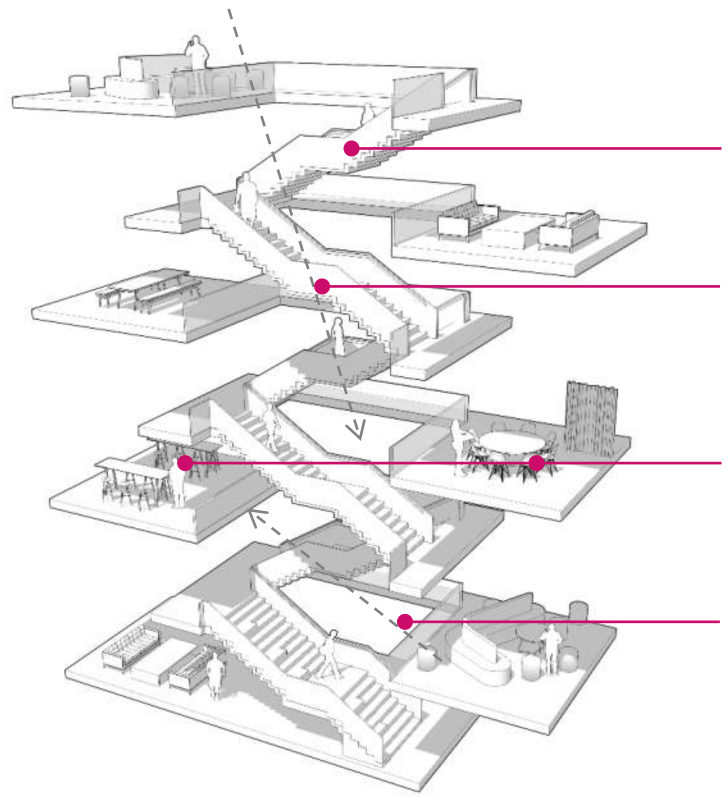
Following the sustainability principal of building less, this also saves on cost, reducing the overall required area for any new/retrofit developments.

Providing flexible space can also help with phasing. Areas can be modified and changed during construction, allowing for parts of the building to remain open and available to students, maintaining revenue streams.

How can you achieve it?

When considering flexible spaces, there are three criteria that should be considered:

- **Adapt(ability) -** This involves small interventions such as removing / reconfiguring furniture and adapting building controls / systems to better suit the required use, this could involve shading, lighting, ventilation etc.
- **Transform(ability) –** This involves moderate interventions such as moveable partitions and retractable, tiered seating which, in varying states, can change the size, shape and function of a space.
- **Convert(ability**) – This involves larger interventions where fixed lightweight or modular elements could be removed, reconfigured or modified. These elements should be considered during the design phase as part of future-proofing and could range simply from choosing panelised wall systems over blockwork up to modular façade / roof elements that could be removed to allow further future expansion.



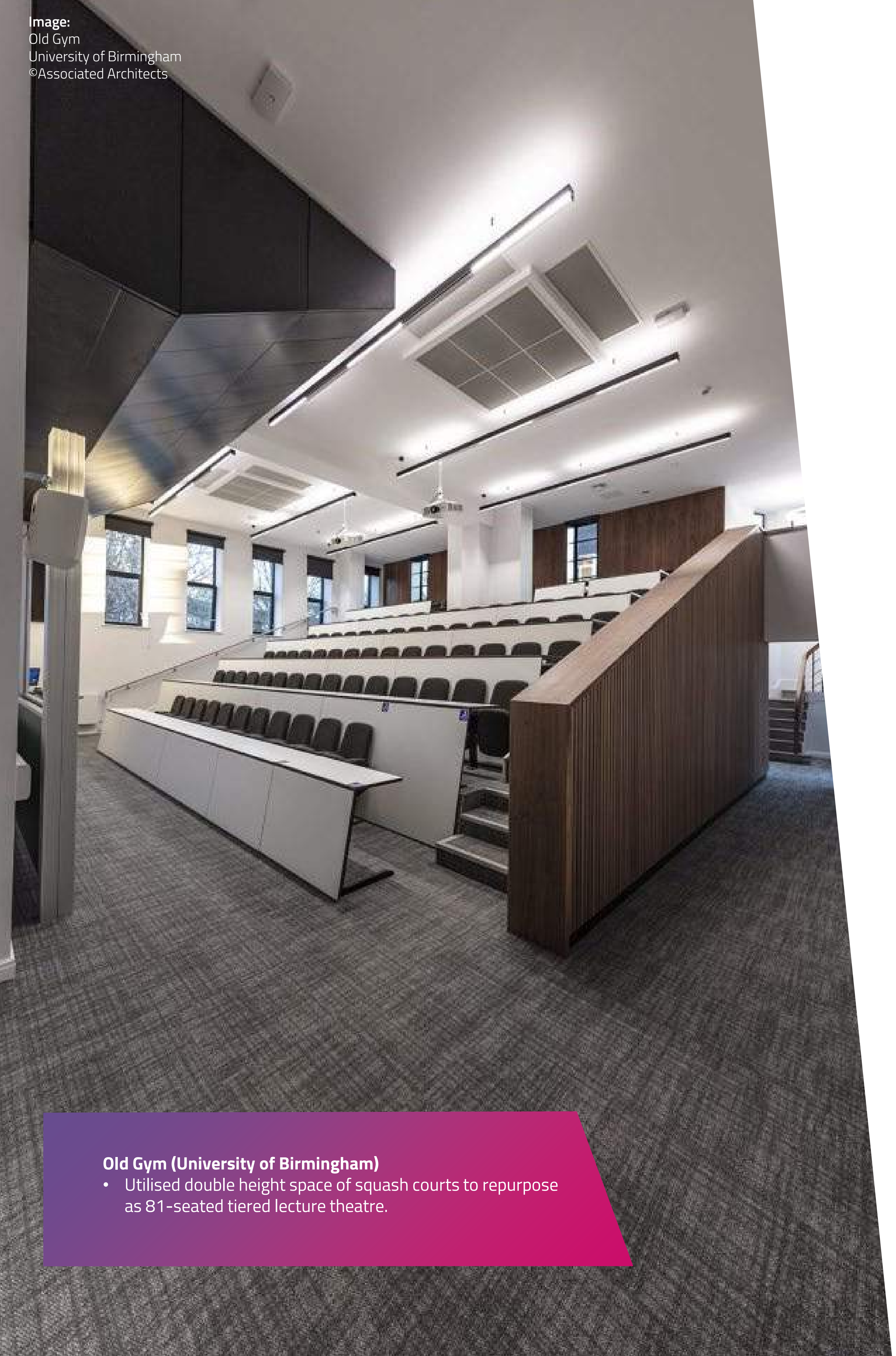


Image:
Old Gym
University of Birmingham
©Associated Architects

Old Gym (University of Birmingham)

- Utilised double height space of squash courts to repurpose as 81-seated tiered lecture theatre.

Ways of Reusing Legacy Buildings & Opportunities

Architecture

Change of Use (Repurpose)

Over the years, space requirements and purposes have changed, especially in the Higher Education Sector. Repurposing buildings through retrofit is an important way for a building to be given a second life when change is inevitable.

Decision making at early stages is crucial to identify if the building is suitable for a change of use. Typical considerations when identifying a potential change of use are:

- **Clear height** – How might the floor to floor heights within the existing building affect the types of spaces that are required, i.e if labs are required is there a comfortable clear height once all of the service zones have been considered? (For further guidance see P31).

- **Grid Spacing** – What is the grid spacing of the existing building and can it work with the new spatial requirements. If there is a tight grid spacing, does this limit the flexibility of the floorplate? How might the structural grid impact any larger spaces such as auditoriums or lecture spaces where clear spans and unobstructed views are required.

- **Circulation** – Existing HE building stock can typically be difficult to navigate with a warren of corridors and cellular spaces. This inefficient circulation and floor plan means that existing buildings can often have a lower occupancy number. When considering opening up circulation and increasing occupancy/utilisation numbers thought should be given to fire escape routes, vertical transportation and stairwells along with the accessibility issues that come with this.

- **Technical requirements** – The performance of any retained or modified building elements should be assessed prior to any change of use. This could include any structural deflection limits that impact on any new façade cladding, vibration issues that could impact the classification of new labs or an uplift in MEP equipment due to performance requirements that may impact on area and the loading of the existing structure.

- **Listed / conservation** – Restrictions on change of use could be imposed through the existing building being listed or in a conservation area. This could impact not only the external appearance and cladding but also the internal layout and reconfiguration of internal walls and partitions. Statutory Approvals might be required.

- **Floor plate** – How might the shape or size of the floor plate impact your layout? Is there a deep floor plate that limits the amount of daylight penetrating into the building? Will this require additional lighting and associated operational costs? Is it possible to introduce new atria into the building to provide natural light into the heart of the building?

Introducing new types of spaces into existing HE buildings, such as cafes and retail units, as well as considering areas that could be made available for hire such as events spaces and conference spaces, can also help to increase revenue.

The wider the variety of spaces and facilities available, the more convenient it will be for students, which would act as a one-stop shop, increasing spending on campus and opening up new revenue streams.

Circulation of People

Why is this important?

Moving away from corridors and cellular spaces to open up the floor plan is important to better visually connect areas and help with wayfinding.

Reducing the extent of corridors and including open circulation into a floor plan will also help to maximise the efficiency of the floor plate reducing 'non place' or 'dead space' that is typically un-usable and has less profitability associated with it.

Providing clear and visible entrances and centralised spaces where students can access any assistance they require from student services is also important. Atria can help to serve as this type of space, creating visual connectivity between floors, bringing in natural light and helping to create a statement entrance or hall.

How can you achieve it?

Considerations for circulation involve:

- **Building Occupancy and density** – Opening up circulation routes and incorporating them into flexible work or study areas creates a more efficient floor plate and as such can help to boost occupancy and utilisation.
- **Fire Strategy** – Any increase in building occupancy or density should be considered alongside building regulations and the existing fire strategy to ensure that protected routes, escape routes and life safety systems are not impacted.
- **Accessibility** – Considering the majority of the existing HE building stock was built before the disability act was passed in 1995, a lot of spaces within these buildings will be considered non-compliant against today's British Standards and Approved Documents. It is important to consider change of levels, thresholds, contrasting / tactile materials, clear widths etc
- **Vertical Transport and Stairwells** – Similarly to the fire strategy approach, any increase in occupancy should be considered against the number of lifts and the requirement for any additional stairwells. These are big ticket items that can add significant cost and time to a retrofit if not accounted for.
- **Atria** – Incorporating an atrium into a retrofit is a great way to create a central hub space within the building whilst drawing more daylight down into the building. These benefits, however, need to be balanced against the environmental and acoustic performance of the space, hence consideration needs to be given to temperature control, ventilation, glare and sound absorption.

Image:
The Learning and Teaching Building – University of Strathclyde
©BDP

Learning and Teaching Building (University of Strathclyde)
- Providing a centralised space where students can access any assistance they require from student services.

Image:
George Green Library
University of Nottingham
©Martine Hamilton Knight/Builtvision

George Green Library (University of Nottingham)

- The free-flowing areas provide ideal access to natural light, whilst the soft and warming materials within the space help with sound absorption.

Wellness

Why is this important?

HE and Campus buildings are where students and staff spend the majority of their time, and as such, these buildings can play a significant role in the health and well-being of its occupants.

With the growing pressures of day-to-day life combined with the climate emergency and decline in air quality, there has been a marked increase in the number of students and staff with mental and physical health issues.

Introducing industry standards and certification such as WELL, can positively influence how both students and staff perform, as well as altering perceptions of what a HE building can be. According to an educational study undertaken by WELL, embracing well-being into the design process can have a positive impact on a number of levels by:

- Creating spaces where students can thrive
- Attracting and retaining top tier talent
- Reducing student and employee burnout
- Increasing enrolment rates

How can we achieve it?

WELL strategies can be implemented through the following:

- **Air Quality -** Monitoring and improving air quality across the campus.
- **Materiality -** Limiting hazardous materials with regards to construction, finishes and FF&E, reducing potential toxins within working environments and their impact on the environment from cradle-to-grave.
- **Physical Activity -** Designing spaces that encourage physical activity throughout the day, through the use of active furnishings such as sit/stand desks and improved ergonomics that allow students and staff to adjust workstations to their needs .
- **Restorative Spaces -** Include restorative spaces within the layout that are designated exclusively for contemplation, relaxation and restoration. These could include quiet rooms, prayer rooms, winter gardens or internal courtyards.
- **Community -** Create spaces for community building and design accessible inclusive spaces. Community spaces help to root the building within the local community and can also be used as additional revenue streams, as spaces that can be hired out when not in use.
- **Noise -** Manage noise with sound absorbing features, sound barrier and sound masking which will help to create a calm productive environment devoid of distractions.
- **Light -** Support healthy sleep habits with circadian lighting design and the enhancement of daylight access.

Certification

Which certifications do you need to be aware of?

Building Certifications Schemes

BREEAM Refurbishment and fit out

BREEAM is a popular and impactful certification scheme that is often used for driving broad sustainability outcomes for projects in the UK. BREEAM has produced a flexible framework specific to refurbishment and fit out projects, covering a wide range of assessment issues from energy to health and wellbeing to land use and ecology. Certification is achieved by credits being awarded for meeting different design criteria. The total number of credits achieved will determine the overall BREEAM rating of the project. Targeting either BREEAM Excellent or Outstanding is recommended.

The certification is suitable for Higher Education buildings and covers a broad range of project types, however, the applicability of this scheme should always be checked against the scope of the project. The Pursuit of BREEAM is often determined by the local authority and exclusions for retrofit projects are often determined on project scope or floor area i.e., small spaces. A BREEAM assessor will need to be appointed to conduct the assessment and can offer guidance on how to meet the requirements.

LEED

The LEED certification scheme is very similar to BREEAM however is internationally accredited so it is sometimes used instead of BREEAM. Different schemes will have different assessment criteria. The Building Operations and Maintenance (O+M) or the Interior Design and Construction (ID+C) scorecards are recommended. A building will target one of BREEAM or LEED. This is often determined by the local authority so these requirements should be checked before pursuing,

WELL

The WELL Building Standard is a performance-based system that measures, certifies, and monitors features of the built environment affecting human health and well-being. Although BREEAM covers health and wellbeing and some similar goals, WELL goes much further. The WELL standard is applied in the same way for new builds and retrofit projects but, because of its extremely broad range of applications, it is still very possible to achieve a high well standard on a refurbishment project. The standard covers 10 main concepts ranging from thermal comfort and sound to community.

The certification is applied by points being awarded for meeting different concepts relating to health and wellbeing of the design and over a 100 points are available with certification levels ranging from Bronze to Platinum.

Fitwel

Fitwell is a similar certification scheme to WELL and is often easier to achieve. However, this scheme does not have the elements of testing in-use and ongoing upkeep that is emphasised in the WELL standard.

There is a different certification approach for existing buildings under the Built Certification route. There are different scorecards for different building typologies and the Multi-Tenant Whole Building Scorecard or Commercial Interior Space Scorecard are the scorecards that are mostly likely to be applicable. However, the certification route should be confirmed by a certified assessor.

Projects can achieve from one to three stars based on their success.

EnerPHit (Passivhaus)

EnerPHit is the Passivhaus retrofit standard and is based on energy performance and thermal comfort requirements. The standard is ambitious and aligns with 2030 newbuild targets. Not all buildings will be suitable for EnerPHit so a full feasibility study should be conducted before this standard is applied. The standard is applied by assessing the energy demand of the space from both a heating and cooling load demand perspective.

There are three main routes to certification.

1. **Heating Demand Method** – The most onerous and best performing approach.
2. **Component Method -** Best for listed and constrained buildings.
3. **Step by step approach** – EnerPHit can be achieved over different phases for Masterplanning or financial reasons. It is applicable to approaches 1 and 2.

Listed buildings, despite their challenges, should not be dismissed due to design constraints. As mentioned, the component method is most suitable for listed buildings and crucial elements can be derogated for reasons such as heritage or moisture concerns. Creative solutions can also be found to improve heating and cooling efficiency in a constrained environment.

NABERS

The NABERS standard focuses on Energy, Water, Waste, and Indoor Environment. NABERS is often used alongside BREEAM or LEED as NABERS attempts to address the performance gap. The standard considers not only design data, but meter data and in-use building performance. NABERS comes from Australia but is internationally recognised and applied. Although it is typically applied to office buildings, it could be applicable to some Higher education buildings as well and has been applied in Schools. This sustainability standard Projects can achieve from one to six stars based on their rating and adherence to the standard

Image: ©Arup

Floor to Ceiling Height Optimisation

Why is this important?

The floor to ceiling height of any building is one of the key design parameters that is explored during the early design stages. Unlike new builds, retrofits come with legacy clear heights that can limit flexibility and restrict the types of spaces that can be incorporated.

Different types of spaces typically require different floor to ceiling heights and this should be considered early on in the decision-making process when assessing if existing building stock might be suitable for retrofit. For example, residential / accommodation blocks tend to have a shallower plan with lower floor to ceiling heights, whereas workplace environments typically have deeper floor plates with higher ceilings. Bearing this in mind, if one were looking at a change of use from accommodation / residential to a workplace, there could be significant issues trying to shoehorn a new layout into the building.

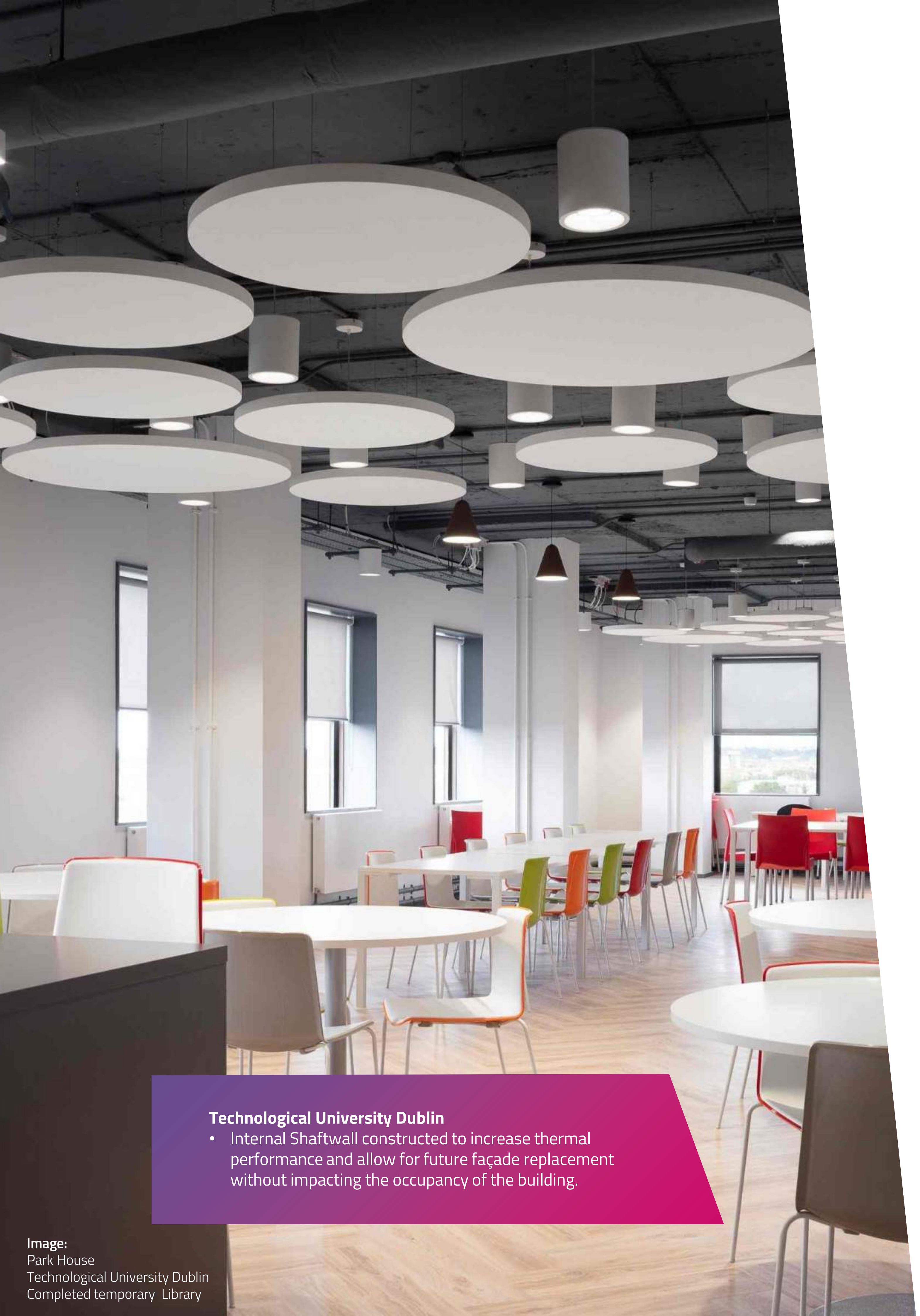
How can we achieve it?

In order to deal with these issues there are a wide range of interventions that can be undertaken from minor to large:

- **Minor –** Can spaces be identified in the existing building that could be utilised as part of the new design? This might include spaces with increased floor to ceiling heights such as gymnasiums or atria that could be repurposed as auditoriums or event spaces.
- **Small –** Adapting the interior design to better utilise the existing clear heights within a space; this could include exposing high level services, this provides an improved perception of height up to the structural soffit, and omits any requirements for bulkheads at the perimeter allowing more natural light onto the floor plate. There is a cost saving associated with removing a suspended ceiling, however, this must be offset against the additional coordination setting out and organising the exposed services.
- **Medium –** Opening up and cutting away the floor plate is another option to address limited floor to ceiling height. Cutting the slab back away from the façade can create double height spaces, allowing daylight to penetrate deeper into the floor plate whilst creating voids in the slab that can open up opportunities for atria or other large communal/event spaces. The increased daylighting levels can help to limit artificial light, however, any operational savings should be considered against any additional structural work required to facilitate this cut and carve approach
- **Large –** A more significant method to address any floor to ceiling issues is to alter the levels throughout the building, adjusting the floorplates whilst retaining the bones of the structure. Although not typically applied to levels above ground, it is more commonly implemented in basements, digging the basement out, lowering the slab/foundations and increasing the clear height. Basement levels are typically plant levels and a generous floor to ceiling height can offer more flexibility in the type of MEP plant that can be installed there. This flexibility can allow plant that may have been located on the main floorplate to be relocated to the basement, freeing up valuable area that may negate the requirement for a new build or extension.

Image:
George Green Library
University of Nottingham
©Martine Hamilton Knight/Builtvision

George Green Library
- Double height spaces to increase natural light.
- Basement level lowered.



Technological University Dublin
- Internal Shaftwall constructed to increase thermal performance and allow for future façade replacement without impacting the occupancy of the building.

Image:
Park House
Technological University Dublin
Completed temporary Library

Ways of Reusing Legacy Buildings & Opportunities
Architecture

Facade

The façade and building envelope is critical part of any building as well as making a visual impact. It is responsible for maintaining a continuous thermal and weathertight line, impacting the internal conditioning, heating, cooling and energy consumption. In this respect, it is a major contributor to both embodied carbon and operational carbon.

Assessing the façade at an early stage will help inform the decision-making process and a strategy can be formulated to align with any funding stages or phasing. Given the embodied carbon associated with a façade, the ideal scenario is to leave it in place and 'build nothing'. However, given that a façade will typically degrade over time and lose performance, this comes at a detriment to operational carbon - a leaky building will put additional strain on MEP plant, energy consumption and could compromise user comfort.

It is important to strike a balance between embodied carbon and operational carbon, upgrades to the façade should consider:

- **Performance –** Is the façade still fit for purpose? If the façade has come to the end of its design life, an entirely new façade system might be the right decision. However, if it is still offering reasonable performance can any replacement be put on hold, potentially aligning with the release of funding at a later date.
- **Circular Economy –** If the existing façade is to be replaced, can any of the components be re-cycled, re-used or repurposed elsewhere in order to reduce the volume of waste headed to landfill. Depending on its grade, glass is a typical example of a material that can be crushed down and reconstituted into road paints, insulation or float glass. For the new façade it is important to consider the carbon impact of new materials as well as 'end of life' - can the new façade be designed for disassembly and its basic components entered back into the circular economy for use on other projects? All of this will help to reduce the impact of embodied carbon.
- **Visual Aesthetic –** Does the building need a facelift? Could over-cladding or a refurbishment be an alternative to a completely new system, reusing the substructure of the façade but applying modern materials and finishes to boost performance and make the façade more appealing to the modern generation.
- **Extent of Glazing –** Thermally, glazing units tend to be the worst performing façade elements and, although it is important to maximise natural light within the building, this should be balanced against thermal gains into the building increasing the cooling load and energy consumption of the building. Minimising or replacing the existing glazing can be a good way to boost performance whilst avoiding a deep retrofit.
- **Insulation –** Does the existing façade contain combustible insulation that if retained might impact on fire safety and building insurance? Do measures need to be taken to encapsulate or remove and replace it?
- **Internal Upgrades –** Can performance be boosted internally using internal shaftwalls? These can be insulated to thermal and acoustic requirements and offer benefits compared to external façade modification/instillation requiring less access around the building, no scaffolding or MEWP access and the work can be undertaken whilst the building is occupied. It also allows for future replacement of the façade at a later date without impacting on operations or occupant comfort. This option, however, would need to be considered against the area requirements of the building as the additional internal buildup would eat into the floorplate.

Ways of Reusing Legacy Buildings & Opportunities

Structural Considerations – Design Loads & Performance Criteria

Why is this important?

Buildings are designed to resist various loads depending on their intended use. Imposed loads are those that can vary, unlike the dead load that account for the weight of fixed materials that seldom vary - the concrete floor slabs for example. These varying imposed loads take account of people, furniture, storage, etc. The magnitude of the imposed loads are dependent on the proposed use to account for the weight of things going in the space, or how many people and how crowded the spaces will be, see images on the right. Both types of loadings are important to consider when retrofitting a building, but typically it's the imposed loads that are more likely to change to suit the proposed change and require more attention - roof and façade build ups being the exception where additional insulation adds weight to the dead load. The original, historical, current and proposed uses all need to be considered in terms of imposed loading.

Performance criteria in buildings typically relate to human perception of vibration and how the structure is used affects the vibration response.

Where is this information found?

Information detailing what the building was designed for is typically found on record drawings or design methodology documentation. Historical photographs documenting the previous loading uses are valuable to the design team and can be used for justification.

	1952 CP3 (1952)	British Standards (1984)	Eurocodes (2005)
Roof (maintenance access only)	0.7 kN/m^2	0.6 kN/m^2	0.6 kN/m^2
Offices	2.4 kN/m^2	2.5 kN/m^2	2.5 kN/m^2
Classrooms	2.9 kN/m^2	3.0 kN/m^2	3.0 kN/m^2
Libraries	9.6 kN/m^2	4 kN/m^2	4.0 kN/m^2
Halls	4.8 kN/m^2	5 kN/m^2	5.0 kN/m^2
Gyms	4.8 kN/m^2	5 kN/m^2	5.0 kN/m^2
Plant Rooms	9.6 kN/m^2	7.5 kN/m^2	7.5 kN/m^2

Increasing imposed load requirement

Summary of code imposed loading requirements over time

Park House – Technological University Dublin needed an interim library space to deliver their campus masterplan phasing. An unused office was chosen; however, libraries generally require a higher imposed load than offices to code requirements. To overcome this, the project team used targeted strengthening and considered the actual loading requirements to minimise strengthening to areas where the proposed use exceeded the original design. This clever approach reduced the cost and carbon impact of the change of use. The strengthening was also designed to be removed as the building reverts to offices.

Image:
Park House
Technological
University Dublin

What do you need to consider?

- **How does the proposed loading compare to the original and previous uses**? There are opportunities and greater flexibility available if the structure was designed for a high load. A 1960's library, for example, is likely to have been designed for higher loading than a modern library, office or classroom. If the proposed change of use requires higher loading requirements, then strengthening or management of the loading will be likely.
- **Does the change of use free up spare capacity in the structure?** This potentially allows cost effective structural alterations elsewhere in the structure?
- **What information is available?** Confirmation of the original design loading holds great value to the design team and can significantly reduce, or remove the need for costly, disruptive and programme extending intrusive investigations and testing to confirm loading related assumptions.
- **Where can new plant be located?** As shown on the summary table to the left, plant loading typically has high loading requirements and should be considered early in the retrofit. Roof mounted plant tends to be lower loads, but typically way above the original designed roof loading.
- **How can I help the design team?** Pass on record information, photographs and any knowledge of previous uses. Consider the actual loading needed as realistic loading can unlock a lot of value in the structure.

Increasing imposed load requirement

1.5 kN/m^2

3.0 kN/m^2

4.0 kN/m^2

5.0 kN/m^2

7.5 kN/m^2

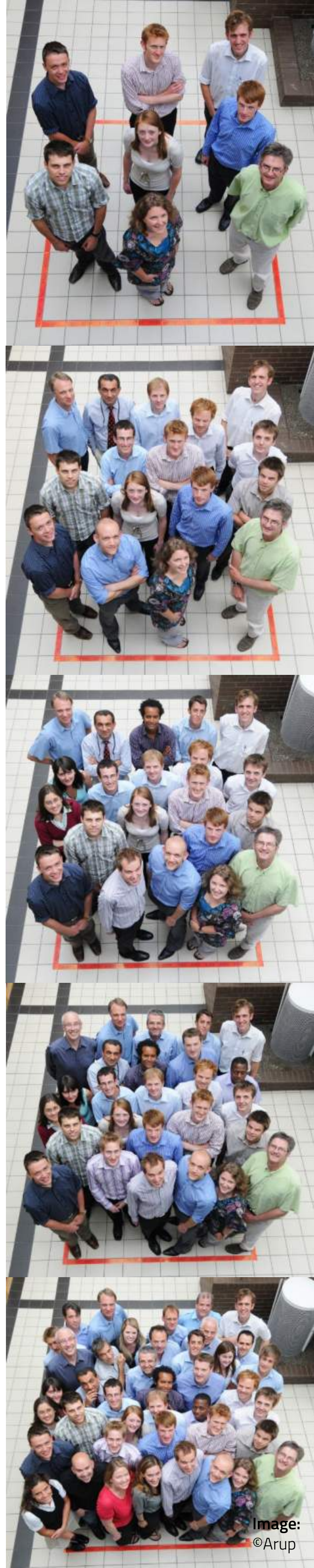


Image:
©Arup

Ways of Reusing Legacy Buildings & Opportunities

Structural Considerations – Vertical Extensions

Adding floors can maximise the potential of an existing building by using up any spare capacity. Utilising the existing frame and foundations makes use of the embodied carbon in the frame and reduces the material consumption and waste associated with demolition and new build. Vertical extensions also do not require additional footprint.

What are the challenges with adding vertical extensions?

- **Vertical load** – the addition of the new floors typically results in an increase in vertical loads. This isn't always the case. In the best-case scenario, vertical load can be load balanced by removing finishes, or the imposed loads have reduced. This is the exception and typically there is an increase in loads on the vertical load bearing elements (foundations, columns and walls) and these may need to be strengthened. Strengthening foundations is a lot more complex than columns and walls and the impact and constraints need to be considered as early in the project as possible. The use of lightweight material for additional floors is recommended to reduce the increase in vertical load.

- **Lateral load** – the additional height in the building creates more façade area higher above the ground that attracts load from the wind. This additional wind, with a greater lever arm, increases both the horizontal loads and overturning that the building has to resist. A structural assessment will be required to determine if this increase results in the need for strengthening of the stability systems. This strengthening would be localised and potentially dealt with by the inclusion of further walls adding to the stability.

- **Robustness** – extending the height may increase the consequent class of the building and the robustness requirements. Retrofitting robustness requirements varies in complexity and depends on the form of construction - in some situations it is not feasible. A significant number of legacy buildings will have been constructed before disproportionate collapse requirements were introduced in 1970.

- **Fire** – increasing the building height may trigger more onerous fire safety requirements and the increased population may affect escape routing and require new routes to be incorporated into the scheme.

- **Building services** – additional space typically results in an increase in plant requirements. On top of this, any roof mounted plant would need to be relocated to allow the extension. How the building is serviced and how congested the service distribution is will determine the scale of the challenge to increase height, and each building will be bespoke.

What are the opportunities?

- **Spare structural capacity** - Typically, structural components work at average utilisation ratios of around 80% down to 60%(1) to allow for flexibility, rationalisation and size of section being governed by non-structural factors.

- **Spare fire and service capacity** – if there is space capacity related to fire escape or servicing then the vertical extension can make use of it and capitalise on it.

- **Planning** – there can be planning opportunities through permitted development rights and ease of obtaining planning if surrounding buildings are higher.

What can estate teams do to help?

- By far the most valuable and helpful thing an estates team can do is **pass on relevant record information** to the design team. This will allow informed viability decisions to be made early in the project. Information related to the foundations and vertical superstructure is particularly valuable as these take the additional vertical load.

- Work with the design team and other stake holders to **ensure additional space and loading requirements are efficient** and not over the top to ensure overdesigned structural works are not provided or worst case prohibitive.

- **Work closely and be engaged in the decision and survey strategies**. The decision to extend or not is nearly always required at the start of the project. If information is not available, then an information gathering, and survey strategy will be needed to provide the information to allow the structural assessments that inform the decision. A balanced, staged and logical approach is required as you don't want to commit significant money to surveys that ultimately show things are not viable. You also don't want to be wrongly told it's not viable, as there is not enough information to base an informed decision on.

- **Be open to new forms and methods of construction**. Modern methods of construction (MMC) are particularly well-suited to vertical extensions as they can be lighter and quicker to build with the majority of the works done offsite.

Old Gym– University of Birmingham added a two-storey roof extension to the building , enabling the addition of significant floor area within the existing building footprint. Grade A offices were housed within a new roof extension, where bespoke open floorplates could be achieved with modern floor to ceiling heights and raised access floors to allow the varied workspace arrangements required. Structurally the vertical extension was achieved through using small-span floors to minimise the additional weight.

Image:
Old Gym
University of Birmingham
©Associated Architects

Image:
The Learning and Teaching Building – University of Strathclyde
©Arup

Learning and Teaching Building – University of Strathclyde created an open double height space to establish a vocal point at the entrance of the building. The removal of the existing floor resulted in the need for strengthening of the double height columns, for them to safely withstand the new load. The new columns were jacketed with concrete and additional steel reinforcement to increase the overall strength of the column.

Ways of Reusing Legacy Buildings & Opportunities

Structural Consideration – Increasing Capacity

Structural frames do not always have spare capacity, and some instances have proven to have insufficient capacity and therefore require intervention. Some alterations alter the structural load paths, meaning additional load is transferred to elements that were designed for it. Structural strengthening is the process of upgrading structural systems in a building to increase its overall structural load capacity. This provides an opportunity to maximise and revitalise existing spaces in Legacy buildings, whilst maintaining a safe structural environment- which is key during the retrofit process.

How is it determined if strengthening is required?

When deciding if strengthening is a requirement for the retrofit of a Legacy building, it is critical to ensure that the building is thoroughly assessed. This procedure would involve: a review of historical records and existing building plans, a survey of the building's current condition - inspecting carefully for damage that may need repairing and the consideration of external factors like the building's environment, and how that may impact the structure in the future. Once the assessment is complete, a decision can then be made of the strengthening requirements of the building.

What are the benefits of structural strengthening?

- **Extended service life** – By adding structural members and/or strengthening existing members, the service life of the building will increase.
- **Increased load capacity** – Strengthening results in the ability for a building to carry higher imposed loads- which provides an opportunity to change the building's function during the retrofit process.
- **Enhanced structural stability** – The ability to carry higher loads will improve the overall stability of the building, which improves the structures safety.
- **Cost** – In comparison to the alternative approach of demolishing and rebuilding a new building, structural strengthening is a much more inexpensive.
- **Space creation -** Strengthening existing elements can help to create more open, aesthetically pleasing settings.

What are the main approaches to strengthening?

There are two different strategies for strengthening that can be used on existing buildings to help increase the load capacity of a structure.

1. **Strengthening through relieving structural loads** - Adding more structural members to the building to decrease the loads acting on existing members.
2. **Strengthening elements to cope with additional loads** - Improving the load capacity of existing members in the building to resist increased loads.

Strengthening through relieving structural loads	Strengthening of elements
Additional Beams - This decreases the loads acting on existing beams, increasing the load capacity of the whole structure.	**Welding Plates / Tees to steel beams** – Increases the stiffness and robustness of the elements, which increases their overall strength capacity.
Additional Columns – Similarly to beams, the addition of columns will decrease loads acting on existing columns, increasing the load capacity of the structure.	**Polymer strengthening** – Helps improve the overall strength of a column or beam by providing extra reinforcement to withstand structural loads.
Bolting steel beams to existing concrete Columns and Beams - This increases the stiffness of the element which increases the Load capacity of the column or beam.	**Jacketing-** Reinforces the original column, increasing the strength capacity of the element.

Ways of Reusing Legacy Buildings & Opportunities

Structural Considerations – Foundation Re-use and Strengthening

Existing buildings have varying types of foundations depending upon their previous use, the age of the building and surrounding ground conditions. By utilising the existing foundations and potentially strengthening them if required, there can be a significant benefit to cost, programme and embodied carbon. This is due to savings on removal, temporary works and new foundations.

What are the challenges to reusing and strengthening?

- **Record information** – when assessing the suitability of existing foundations, the availability of record information is crucial. Given the nature of foundation, it is often extremely difficult to survey without expensive and time-consuming investigations. As such, without record information, it is difficult for engineers to assess existing foundations to determine their suitability and conservative assumptions may be taken at early design stages until the foundation information is known, which may impact on programme and cost.

- **Existing condition** – ground conditions vary across the country, with some buildings located in areas with aggressive ground or areas of historic coal mining activity. Areas with aggressive ground can lead to deterioration of structural foundations, particularly concrete. Historic coal mining activity can also impact the suitability of foundations due to subsidence and ground movements. Desktop studies can assist with identifying the above but commonly a ground investigation is required.

- **Risk** - where limited information is available on existing foundations, there is an associated risk that the estates team must consider. To reduce the level of risk, due diligence surveys are often carried out to inform the reuse assessment, which are often required for building insurers.

- **Undetected defects** – risks associated with existing defects and foundation performance can often be mitigated by the due diligence surveys. However, it is not practical to review each individual foundation's condition and suitability. Monitoring is often used to reduce this risk by reviewing the movement of the structure under its new loading regime to identify any areas where the building is exhibiting greater movement thus potentially having a foundation issue.

What are the opportunities?

- **Change of use -** reducing the load on the building (i.e. swapping a lab building to offices) can lead to spare structural capacity; which provides greater opportunity to reuse the existing foundations.
- **Foundation strengthening –** strengthening is a cost-effective way of reusing existing foundations to provide greater structural capacity without the need of a new foundation. There are varying methods of strengthening available depending upon the type of foundation and structural requirements.
- **Ground improvement–** the improvement of the existing soil can allow for greater bearing capacities to be achieved, allowing for differing foundation types to be used such as shallow foundations rather than deep piled. Having the flexibility of foundation options is beneficial when considering options for reuse and on-plan extensions of existing buildings..
- **Presence of old foundations** – by reusing foundations, it reduces ground congestion where old, unused foundations would potentially hinder further development for the university.

What can estates teams do to help?

- Taking a **'structures first' approach** during the feasibility stage of projects can allow for the desktop assessments of the existing foundations to be undertaken along with identifying if there are any useful record drawings which may assist the design in latter stages.
- Appetite to risk has a big influence on existing foundations and **universities and their insurers need to be open and willing** to consider the opportunity of reuse. If the potential of reuse is identified during feasibility, conversations with insurers can happen early to identify any information they may require to reduce the associated risk.
- Work with the design team to ensure that any **changes to the loading regime are efficient,** and do not have a detrimental impact on the foundations. By doing this, there may be an opportunity to remove the requirement of any strengthening, which has savings on programme, cost and embodied carbon.

George Green Library – University of Nottingham reused the existing foundations to save on cost, programme and embodied carbon. The existing building foundations were lowered using an innovative, temporary works scheme to create a code compliant basement area with greater headroom, daylight and accessibility. No strengthening of the existing foundations was required to achieve the above.

Image:
George Green Library
University of Nottingham
©Martine Hamilton Knight/Builtvision

Ways of Reusing Legacy Buildings & Opportunities

Structural Consideration – Element Removal

To open up spaces, it is often required to remove existing structural elements that constrain and dictate the space arrangements. Opening up is one of the many aspects of a retrofit project that benefits from a '**structures first**' approach. All this means is getting a Structural Engineer who is suitably experienced in retrofit projects to give advice as early as possible. This allows critical constraints, risks and opportunities to be fed into early decision processes.

It is crucial that the structural form of the existing building is known and used to inform structural modifications and associated decisions. The required interventions can decrease the structural performance of the building. Typical examples would be:

- Creating **significant openings (>300mm) in floors and walls** which can affect the structural integrity.
- **Removal of elements that provide stability**, such as vertical bracing, which can affect the overall stability of the structure.
- **Removal of columns**, which can affect both structural integrity and stability.
- **Removal of slabs**, which can be providing buckling resistance to the members they are connected to.
- **Removal of walls**, which can affect both structural integrity and stability. Particular care should be taken with walls as they could be providing inherent stability and their removal could increase movement and manifest in issues.

Such interventions require a full understanding of the existing building. The best way to help inform the process is via record drawings or early surveys and investigations to fill in any gaps in understanding. How the loads pass through the building is also really important and should be based on fact rather than assumptions to move the dial towards certainty rather than risk.

Any transfer structures or previous modifications can have significant impact on how the loads move through the building and into the foundations below. Load paths can often be a departure from what one would expect and often the logic is not obvious.

Structurally, most things are possible, however, they may be cost prohibitive and require significant strengthening works to achieve and they could be much more cost-effective ways to achieve similar outcomes.

Temporary works in order to make the alterations happen should also form part of the decision process and be considered from an early stage as they may have a disproportionate cost assigned to them.

The majority of successful retrofit transformations involve the removal of structural elements to allow spaces to change. There is lots of opportunity and the removal of structure is not something that should be avoided. With the right guidance and a clear understanding of the structure, these adaptions can offer great value and completely change the feel of a building.

At the Clerici Building, Oxford Brookes University, the estate teams brief was to provide a new collaborative lecture theatre. An early structural survey allowed an area of the building where structure could easily (relative to other areas) be removed to open up the space. This was taken through the design process and successful delivered through construction.

Image:
Oxford Brookes University
Clerici Alterations
©Arup

Image:
The Learning and Teaching Building – University of Strathclyde
©BDP

Ways of Reusing Legacy Buildings & Opportunities

Structural Consideration – Element Reuse

Circular economy is a system where materials never become waste and nature is regenerated[12] and is achieved by keeping materials in circulation through reuse and recycling, with the aim to build less and reduce embodied carbon. The most efficient method of achieving this is by adopting the **'do nothing'** approach when retrofitting an existing building. Alongside significant embodied carbon savings, there are also potential project savings associated to programme and cost if the number of structural interventions can be limited.

The reuse of existing structural elements forms part of the **'do nothing**' approach and is the most effective way of retrofitting an existing building. However, an extensive structural evaluation and assessment must be carried out to reach the justified goal that **'do nothing**' is possible for a project.

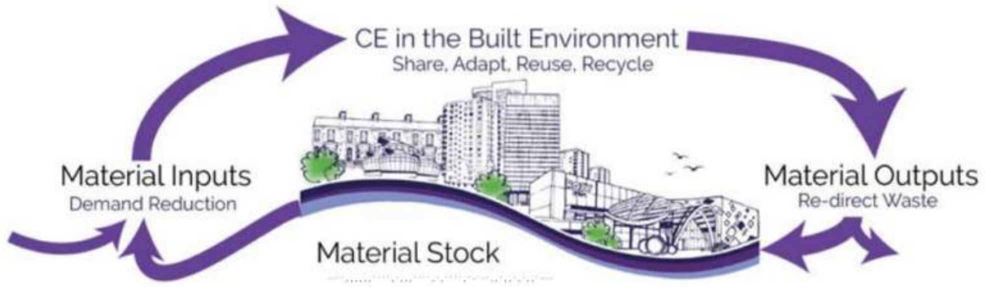
What is required for element reuse?

Typically, structural components work at average utilisation ratios of around 80% down to 60%[13] but this is not always the case and needs to be proven by assessment. Low utilisation ratios often arise from buildings being designed for worst case loading and rationalisation of structural members for ease of construction on site. The justification of element reuse is a detailed process, with some key steps indicated below:

- Prior to any structural assessment being undertaken, a **thorough understanding** of the existing building is required. This includes reviewing record information to understand the building type, the materials and the likely capacity along with visual surveys.
- Gain an understanding of the existing load paths for the building such as presence of transfer structures. The more detailed understanding and accuracy of the existing load paths can potentially lead to **structural redundant capacity** being identified.
- Verification surveys are often required to satisfy that the structure is as anticipated, **regardless of the quality of record information** as late changes are often made on-site which may not be captured on drawings. These surveys can be a mixture of visual and intrusive surveys to confirm structural form.
- The most optimum method of justifying reuse is by a load balance approach by either **matching or decreasing** the proposed load to ensure that the original, or proven design load is not exceeded. By adopting this approach, it is evident that the existing building will likely have the structural capacity to facilitate the change of use . However, there are instances where element sizes are fundamentally undersized and not suitable for the current loading regime.
- Structural engineers may reach the conclusion that element reuse is acceptable but there may be evidence of structural defects which may need to be repaired to allow for reuse.

How can estate teams help facilitate circular economy?

- **Being flexible** with the project brief and requirements can help facilitate reuse. This includes being **realistic** with the intended use of the structure such as loading requirements and chosen finishes. For example, in a modern world of digital storage, could the amount of physical storage now be reduced in the building?
- By taking a **'structures first'** approach, the structural engineer can advise the estate and wider design team on measures to increase the opportunity for reuse.
- Early opportunity to gain a **greater understanding** of structural form through surveys is beneficial for identifying opportunities and limitations for element reuse.
- Opting for **lightweight finishes** rather than cementitious finishes can reduce the load on the structure and potentially unlock additional existing structural capacity.
- Be **willing to challenge the norm** and be open to opportunities for reuse when identified on projects. **Advocate** for reuse and work closely with the design team to maximise potential reuse opportunities.
- **Pass on all available relevant record information** to the design team to allow for reuse opportunities to be recognised early and to also inform potential survey scopes.



Circular economy in the built environment (taken from IStructE Circular economy and reuse guide[13])

George Green Library – University of Nottingham adopted a design philosophy of minimising structural alterations to the existing structure. This was accomplished by careful space planning and consideration of the original design loads to ensure that the new loading did not exceed these.

Known Problems and Solutions

Image:
Oxford Brookes University
Sinclair Façade Before
©Arup

Image:
Honeycombed concrete
©Arup

Known Problems & Solutions

Overview

To reuse an existing building is it really important you have an understand of its condition, how it is serviced and how the services connect and interact with the wider campus.

If you know when, how and why things were built and installed then this can help identify potential known problems.

To keep pace with the intensity of construction post war, and limited material availability new technologies and construction methods were developed. Not all these were successful in the long term, something that only manifests with time.

The issues associated with certain types of buildings and construction are well known, as are the remedial solutions. Record drawings and surveys, if reviewed early can allow retrofit projects to be informed and risks managed and accounted for.

Undertaking a retrofit project also allows safety concerns with the building to be identified and remediated with the wider scheme. Understanding the issues earl allows the timing of remedial activities to be considered and efficiently delivered.

Cost certainty is important in both securing funding and also delivering to budget. Understanding known issues allows the cost to be accounted for and managed throughout the process.

Key message points:

- Understanding of the building condition and how it is services is key to delivering retrofit project.
- Gaining this knowledge as early as possible or identify potential issues to investigation allow risks and costs to be considered and managed.
- Certain age, types and materials used in construction have known issues and solutions.
- Record drawings and surveys are powerful tools in identifying, or discounting, issues.

Image:
©Arup

Known Building Problems & Solutions
Building Services

Heating System Issues

Problems Overview

Gas dominates as the primary heating source for legacy buildings. Replacing gas boilers with an alternative, greener energy source is important and there are a number of ways in which this can be achieved. However, they should be considered holistically within a wider estates strategy.

When making changes to the building services systems, it is important that there is consultation and buy-in from the different management bodies. Decisions on building services should be made in collaboration with the capital finance teams, directors of estates and the estate management team who oversee maintenance of the systems.

Phasing

Retrofit projects can be disruptive to heating system operations. Not all higher education institutions will have the luxury of being able to use a decant building. This means that often building services need to be operable whilst works or maintenance is being carried out . Phasing and planning of projects are very important to overcome this and ensuring that there is good buy-in from the relevant estate manager teams and building occupants.

Heat Networks

District Heat Networks can be a cost-effective solution for large building networks such as university campuses. Using Heat Networks to supply heat to a building with should always be considered first and needs to take into account the larger Masterplanning and site-wide strategies, existing infrastructure, and financial capabilities. Where existing carbon intensive heat networks are in place, you may consider decarbonising the energy centre through air source or ground source heat pumps or alternative waste to energy schemes. It is also important that the local authority's planning is being considered. A detailed feasibility study will need to be done to assess the viability of this option both technically and financially.

Replacing systems directly

The most straight forward solution often involves replacing the gas boilers with appropriately sized heat pumps. However, this does present several challenges.

Problem		Solution/Considerations
Electrical Capacity	Installing heat pumps will introduce greater electrical load, and this can strain electrical capacity for the building and the campus, possibly impacting the wider electrical utility network off-campus.	Conduct a high-level electrical infrastructure survey to determine the grid capacity constraints on a campus wide and building level. Identify buildings where electrical capacity could be a concern. Liaise with the distribution network operator or private network operator to understand local limitations, and the distribution network operator to understand upstream limitations.
Space requirements for heat pumps - Gas boilers cannot be swapped out directly for heat pumps in a like-for-like situation	Air source heat pumps (ASHP) need to be installed outside to allow for sufficient air flow.	A survey should be conducted to determine the suitability of roof space or on the external wall at ground level for ASHPs
	Ground source heat pumps (GSHP) need to be installed using a trench or a borehole so there needs to be sufficient space outside for digging to take place	A ground (thermogeological) survey will need to be conducted to determine the appropriateness of GSHPs. These are typically more expensive to install than ASHPs but can have better efficiencies. This is more appropriate for larger estates or in establishing a central heat network.
	Water source heat pumps (WSHP) require an accessible water body (lake, river etc.) and can be very costly.	If a water body is easily accessible, then this can be considered. A full feasibility assessment will need to be conducted to confirm appropriateness. This solution can be costly because of additional tariffs for discharging into water bodies and this option should be explored with caution

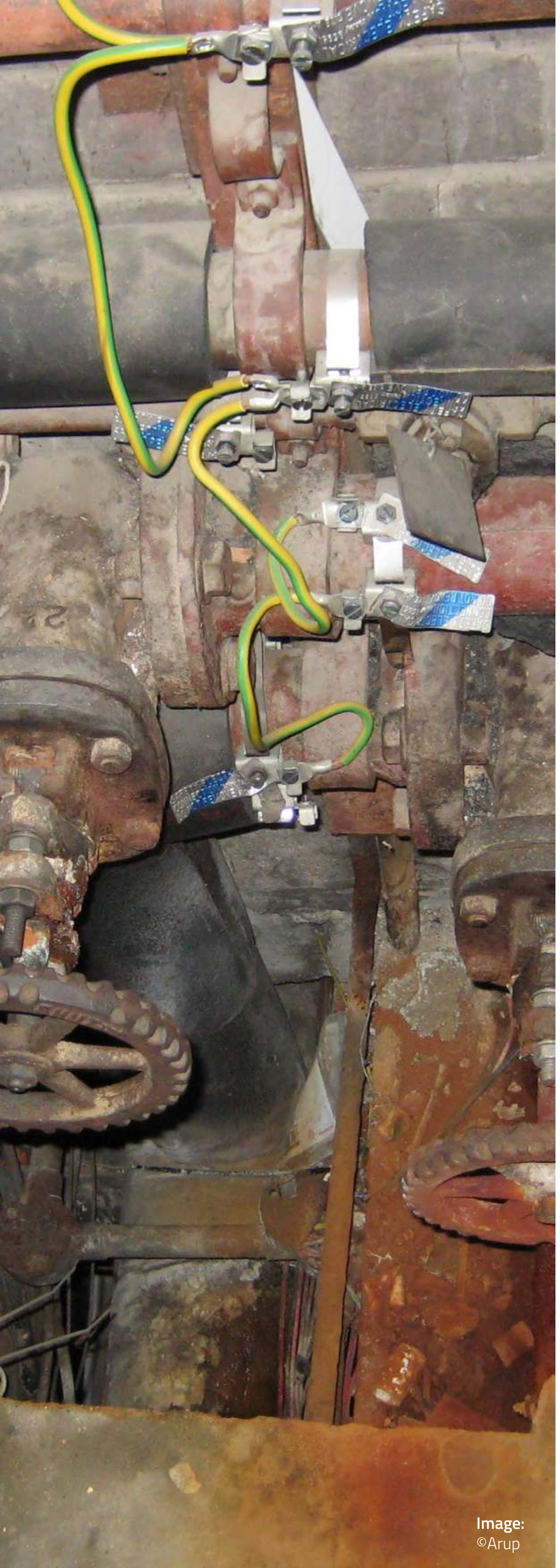


Image:
©Arup

Heating System Issues

Problem		Solution/Considerations
Heat distribution and emitters	Distribution and emitters may need to be upgraded or replaced. Gas boilers operating on a LTHW typically have smaller radiators and pipes than what is needed for heat pumps which operate at a lower grade of heat (<45 °C).	Install high temperature or 2-stage heat pumps that can reach higher temperatures, but these come at a higher capital cost. GSHPs can achieve this too. Conduct surveys to determine whether the existing distribution network and emitters are appropriate to use with heat pumps. Heat Pumps are typically suitable for large emitters such as radiant panels and underfloor heating. FCUs and as traditional systems with large emitters can work.
Mismatching systems	There is often wide variability in systems, types of systems, makes and models. This makes maintenance of building service equipment particularly challenging. Heat Pump system maintenance requires a different set of skills to gas boiler systems.	Use standard design guides that are consolidated campus wide. Consider training courses on upskilling staff on how to maintain heat pump systems where necessary.
Connecting buildings and extensions with different systems:	When refurbishing or extending a building, connecting the MEP systems between the older and newer parts can be challenging due to differences in their ages and technologies. Compatibility issues often arise and can interfere. Old systems can be damaged when new systems are installed, causing problems. Pumps can be over specified, causing pressure issues and often pipework that is left disconnected can corrode and rust.	Often it is necessary to keep the extension on its own isolated system when they are not compatible. Consider exploring linking the buildings via a localised district heat network where heating and cooling can be shared between buildings through plate heat exchangers. A full feasibility study of this option should be included prior to the MEP systems being installed. Take the time to survey the system to ensure the specifications are right and don't leave pipework disconnected for long periods. Take care when installing systems and consider full-scale replacement where feasible. Check all insulation and connections throughout network when job is complete.
Maintaining MEP system operations during retrofit	Highly disruptive retrofits in one part of a building can cause systems to go down in other parts of the building thus limiting the building's functionality.	Isolating systems using zoning and controls where possible. Having the estates team as a part of the process and buy-in early on is important. They should be consulted on models and on maintenance plans. Phasing the project appropriately is also essential to allow schedules to align and reduce disruptions.
Operating costs	Running costs of gas boilers are generally cheaper vs heat pumps due to the lower unit price of gas.	Future costs of gas are likely to increase, meaning that efficiently ran heat pumps should be cheaper in the future.
Reusing and recycling plant equipment	Old plant equipment is difficult to reuse once it has reached its end of life. Similar problems arise for pipework and emitters.	Some manufacturers offer refurbishment and recycling opportunities for some bits of equipment. This is often dealt with on a specific equipment and manufacturer case basis.


Image: ©Arup

Ventilation System Issues

Problem overview

Ventilation systems typically have service life of around 25 years, and it is likely that many legacy buildings need ventilation upgrades. Ventilation is closely related to heating. Improvements in ventilation can aid in improving heating loads. Legacy buildings are likely to have natural ventilation.

Problem		Solution/Considerations
Heat Recovery on mechanical ventilation	Introducing heat recovery on mechanically ventilated air can be difficult to implement retrospectively. Installing heat recovery can only be done if there is sufficient space on the Air Handling Unit (AHU) to do so. If the AHU is in a small plant room, the limited space may restrict this option.	Surveying early will allow for the designs to consider the amount of space needed to accommodate heat recovery. Installing run-around coils (RACs) is a space efficient way to help implement heat recovery on an AHU. It is worth noting that RACs are not usually as efficient as other heat recovery options (e.g. thermal wheel / plate heat exchanger).
Natural vs Mechanical ventilation	There can be a trade-off between making a very efficient mechanically ventilated and airtight buildings and using natural ventilation, unless suitable design considerations are made around mixed-mode systems. Natural ventilation will offer the lowest in-use energy consumption but will have performance gaps.	Consider using mixed-mode ventilation for buildings that already have natural ventilation. The type of ventilation will often be driven by the client's thermal comfort, performance, and energy requirements as well as building use and occupancy.
Connecting buildings and extensions with different systems:	When refurbishing or extending a building, connecting the MEP systems between the older and newer parts can be challenging due to differences in their ages and technologies. The main issue with connecting to existing systems is the condition of ductwork and spatial fit (e.g. more air needed than older regulations and ductwork isn't "big" enough).	Often a full replacement of the system is advisable. If this is not feasible, it is necessary to keep the extension on its own isolated system when they are not compatible. Heat recovery in one part of a building can be linked to providing heat for a neighbouring building.
Maintaining **Air-tight spaces**	Legacy buildings are often very permeable and there are considerable air changes within the building which can strain the heating and ventilation loads. Draughty service points, old window frames and leaky doors can contribute to this.	Upgrade draught proofing materials around service points. Replace window frames with aluminium or UPVC casements that are more air-tight. Install draught lobbies on high traffic doors.
Night Cooling?	Nighttime purging can be effective in naturally ventilation building but poses issues with security (windows left open) and water ingress (rain at night).	Mechanical actuators can help remedy this by closing automatically if linked to a weather / rain sensor.
Building Regulations	Newer AHUs have more onerous performance requirements (Specific Fan Powers) than existing systems, this may impact on unit site, i.e. larger units.	Derogations can be made in some instances where necessary.

Electrical System Issues

Problem overview

Electrical systems often need to be upgraded during a retrofit as they are no longer fit for purpose in a number of ways.

Problem		Solution/Considerations
Electrical Capacity	Installing heat pumps will introduce greater electrical load, and this can strain electrical capacity for the building and the campus, possibly impacting the wider electrical utility network off-campus.	Conduct a high-level electrical infrastructure survey to determine the grid capacity constraints on a campus wide and building level. Identify buildings where electrical capacity could be a concern. Liaise with the distribution network operator or private network operator to understand local limitations, and the distribution network operator to understand upstream limitations.
Outdated controls/BMS and mismatching systems	Older buildings often require BMS control upgrades as their systems are often not optimised for heating and electrical efficiency.	Get a BMS engineer to look at the system and suggest ways in which it can be optimised. Install BMS sensors around the building to ensure that the systems are integrated and working.
Inefficient lighting	Legacy buildings commonly feature old incandescent and fluorescent lighting which is energy inefficient.	Upgrade all lighting to LED fittings. Often the lighting fixtures can be replaced with easily replaceable alternatives.
Mismatching systems	Like mechanical systems, electrical systems can have mismatching systems when integrating new and old buildings or adding extensions which can pose compatibility problems.	Electrical systems can be stripped out and replaced with upgraded systems if feasible.
Inadequate distribution systems	Often there is insufficient space in existing electrical panels to accommodate new controls and infrastructure	In this instance, the only solution can be to replace the panels and replace the relevant systems.
Power quality issues	Harmonics introduced in the network due to legacy equipment	Complete a harmonics study and where necessary install active harmonic filters.
Poor power factor	Historically, there has been poor power factor on some university sites, and power factor correction has been installed. However, introduction of measures such as LED lighting and inverter drives typically means the power factor is near unity nowadays on most refurbished sites, and power factor correction can be removed to improve energy efficiency.	Measure power factor with power factor correction turned off. Isolate power factor correction where the power factor is greater than 0.95 lagging.
Transformer losses	Fluctuations in electrical demand on university campuses, and the provision of additional transformers for improved resilience can often lead to transformers being under-loaded, and inefficient.	Where approaching the end of their working life, consider relacing transformers for super low-loss transformers, which have significantly lower losses, particularly at low output.

Image:
©Arup

Electrical System Issues

Problem		Solution/Considerations
Outdated equipment - Non-compliance with current standards	Older systems may no longer be compliant with current electrical safety standards. Especially with regards to surge protection and RCD protection.	Upgrade and replace equipment where feasible and necessary
Inadequate back-up supplies	Power outages can occur and there is often no backup supply, or the supply is too small to support the building services.	Provide UPS to critical supplies such as ICT and security systems. Consider providing temporary generator connection points to allow temporary generators to be easily installed in the event of a power failure or planned maintenance. Consider permanent generators for the most critical buildings.
Renewable energy integration	On-site renewables can pose an energy security problem and often need to have grid supply as backup. Their integration with the grid can complicate the electrical supply to the building	Consider feeding into the grid or if local battery storage could be used. Liaise with the distribution network operator to understand export limitations.
Lack of documentation	Record drawings and schematic may be out of date, and labelling may be incorrect.	Conduct electrical surveys to re-establish system mapping and update information.
PV Arrays on plant equipment	PV arrays can interfere with functionality of plant equipment on a roof	Further considerations should be made when placing PV arrays on top of chillers and air source heat pumps as they can interfere with air-flow. Maintenance access also need to be preserved.
Emergency lighting compliance	Lack of compliance with emergency lighting systems and un-auditable test records.	Regularly test emergency lighting systems and keep record in an auditable format. Consider provision of self-test systems with central reporting facilities, to simplify testing and provide a full audit trail, if required,

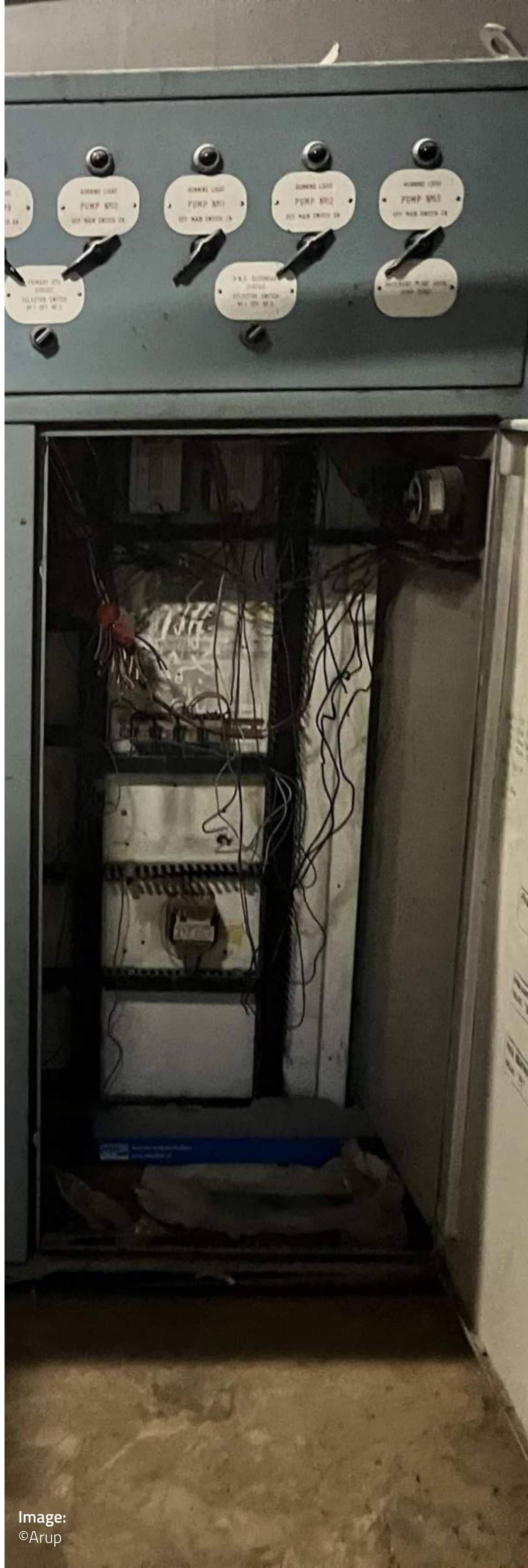


Image:
©Arup

Image:
©Arup

Known Building Problems & Solutions

Structural Known Problems – Typical Structural Defects

There was a significant increase in UK higher education buildings being constructed post second world war. This demand for rapid construction and the shortage of some materials led to new innovative ways of building. These substantial advancements in construction materials means the variety and cause of structural defect can be extensive. Structural defects through this time period typically fall into the following:

- **Defects relating to design deficiencies -** there was significant development in design codes.
- **Construction and durability related defects -** some innovation is now known to be problematic.
- **Condition related defects** where elements are exposed to environments or movements they were not designed for.

It is important to first understand the age of the building you are looking to retrofit to help establish its likely form of construction and any known typical defects associated with that form of construction. Common structural material used over the timeframe of legacy buildings are as follows:

- Natural stone tended to be used as cladding to steel or concrete frames rather than in load bearing capacity.
- Brickwork and blockwork was used as both loadbearing and infill walls.
- Structural timber was used primarily in roof construction and floor joists.
- Structural steel frames were well established and popular.
- Concrete – reinforced, precast, pre-tensioned and post-tensioned.
- Steel - concrete composite became popular around the 1980's.

The following pages highlight some typical structural defects. Concrete buildings built in this period in particular are known to have typical defects due to its rapid development and innovations. Other materials were more known and defects with them tend to be related to condition.

There are typical solutions to the known defects outlined in this section. Each situation should be assessed by an experienced Structural Engineer who will tailor the solution to the unique circumstances. The key is identifying the problem as early as possible so a solution can be developed and implemented in a considered and managed process.

Image:
©New Civil Engineer

Image:
©Arup

Known Building Problems & Solutions

Structural Known Problems – Concrete Defects

What are the typical defects found in concrete?

Defects in concrete structures can be broadly divided into five categories:

- Design and detailing deficiencies
- Construction related defects
- Durability related defects
- Materials related defects
- Accidental damage, i.e fire, impact or poor structural alterations

Design and detailing deficiencies:

- **Lack of robustness** – this is particularly an issue in Large panel system (LPS) buildings built up to 1970's. The partial collapse of a residential tower block at Ronan Point (image on left) brought to everyone's attention the fatal design flaw. Inadequate tying between precast concrete elements gave poor robustness performance
- **Lack of shear reinforcement** – it wasn't until 1985 that design codes brought shear design up to modern standards. Inadequate shear reinforcement was a particular issue in concrete framed buildings designed before 1972. Shear failure can be brittle with little or no warning and result in partial or total collapse.
- **Lack of tying or bearing of precast units –** this lack of tying can result in collapse of precast units which could potentially lead to a domino style progressive collapse. This defect is also known to be present in some precast stair units.
- **Incorrect detailing** (particularly at joints between elements) – detailing refers to the complex arrangements of steel reinforcement bars embedded within the concrete that resists tensile, shear and torsion forces. The arrangement of the bars and how they overlap is vital to the reinforced concrete having sufficient strength.
- **Inadequate assessment of critical load paths** – this could be a design error or oversight in how vertical and horizontal loads are transferred through the structure into the foundations. The error could be due to an error in how the loads are distributed or how vertical and horizontal elements are connected.

Construction related defects may include:

- **Honeycombing** – this creates voids in the concrete due to poor compaction and grout loss that can result in a reduced durability protection to the reinforcement.
- **Lack of cover** – cover is the embedment distance to the reinforcement and is important to provide the intended durability protection to the reinforcement.
- **Poor quality concrete** or inadequate care during the curing process.
- **Inadequate formwork** resulting in sagging or grout loss.
- Defects that have primarily **aesthetic implications**.

Clerici Building– Oxford Brookes University originally had an architectural statement staircase (top image) in the entrance gateway with cantilevering reinforced concrete stair trends . The reinforcement for the cantilevering stair trends was placed on the wrong side of the cantilever, meaning that there was no reinforcement in the tension side of the cantilever. This could have been caused by a design, drawing or construction error. The staircase had to be encased in a steel frame (below image) to support the staircase which significantly reduced the visual quality of the stairs. The stairs were removed as part of the retrofit of the gateway.

Image:
©Arup

Known Building Problems & Solutions

Structural Known Problems – Concrete Defects

In reinforced concrete, the steel is protected from corroding by an alkaline environment. In these alkaline conditions, a protective layer is formed on the surface of the steel, which protects it from corrosion. This protection is referred to as **durability**. There are a number of problems related with a change to this protective environment, which leads to corrosion of the reinforcement. Durability related defects may include:

- Reinforcement corrosion from carbonation
- Reinforcement corrosion from chlorides
- Freeze-thaw damage
- Chemical attack
- Erosion and abrasion
- Salt weathering

There were numerous innovations and developments to concrete over the period of legacy buildings that tried to address the short comings of concrete, such as the speed of curing, self-weight or even availability of materials. There are now known defects associated with concrete materials including:

- **High alumina cement (HAC)** was popular after the second world war due to its resistance to the effects of sulphate, and the speed at which it could reach peak strength, much quicker than normal concrete. This speed made it popular for precast elements as they could be made quicker and result in greater profits. The issue is that HAC with time lost strength (in certain conditions) and has increased porosity, making it less durable and susceptible to corrosion. The height of use was 1950-1970. It can be hard to detect so chemical analysis is required to determine the type of cement used.
- **Calcium chloride** was added as an accelerator in the concrete mix; the height of use was between 1950-1970. Excessive chlorides in the mix caused a reduction in alkalinity, leading to corrosion of reinforcement.
- **Alkali-silica reaction (ASR)** is a reaction between certain aggregates and the cement and occurs only in the presence of moisture. The products of the reaction are of greater volume, resulting in expansion. This expansion causes random 'map' cracking (image on right) that is used to identify the issue. It was popular between 1960 and 1980.
- **Reinforced autoclaved aerated concrete (RAAC)** – due to the recent attention on RAAC, the subject is covered in greater detail on the next page.
- **Woodwool** slabs are made from wood shavings bound together with cement. When woodwool was used as permanent formwork for concrete slabs, the concrete was typically poorly compacted due to the compressibility of the woodwool board, this led to durability issues in the concrete.

Image: ©Arup

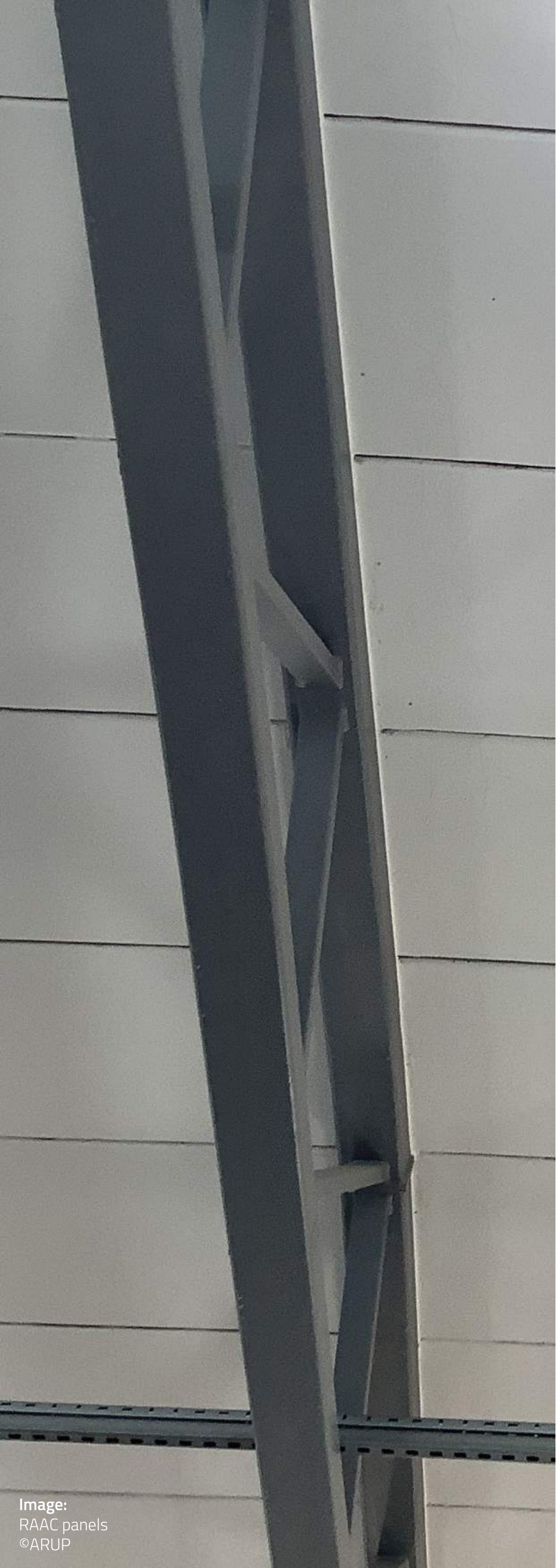


Image:
RAAC panels
©ARUP

Structural Known Problems - Reinforced Autoclaved Aerated Concrete (RAAC)

Reinforced Autoclaved Aerated Concrete (RAAC) – was used widely in the UK between the 1950's and the mid 1990's, where panels were used for constructing roofs, floors and walls. Substantial defects and inherent problems with RAAC panels have been exposed and a number of structural failures have occurred. Concerns regarding the structural adequacy of RAAC elements was raised in the UK in the early 1990's and there has been increased focus on addressing RAAC issues since the sudden collapse of a school roof in 2019. The inherent material properties of RAAC that led to the structural issues are:

- **Low compressive strength**, around 10% the strength of typical concrete.
- Because of the aerated nature of the material and the smooth reinforcement, the **anchorage is via transverse reinforcement**, in normal concrete the anchorage is via bond between the ribbed reinforcement and concrete. Therefore, the position and condition of the transverse reinforcement over the bearing ends is critical.
- The **aerated material is highly permeable** and therefore does not offer corrosion protection to the reinforcement as normal concrete does.
- The aerated nature and fine aggregate means that the **elasticity and creep characteristics** are substantially inferior to traditional concrete which can lead to large deflections over time.

There are a number of known defects associated with RAAC that can be split into performance, manufacturing and construction related defects. Below is a summary of RAAC defects taken from the Institution of Structural Engineers (IStructE) RAAC guidance [14].

Performance Defects	Manufacturing defects	Construction defects
• High in-service defections • Cracking and spalling in the soffit of panels • Corrosion of reinforcement • Deterioration in condition • Panel distress caused by overloading • Panels acting independently with limited load sharing	• Misplaced transverse reinforcement • Insufficient anchorage of longitudinal steel • Voidage around reinforcement • Incorrect cover to tension steel	• Cutting of panels post manufacture • Short bearing lengths • Missing reinforcement e.g., linking dowel anchorage • Structurally damaging builders work

Shear/bearing failure is the critical structural risk with RAAC as the failure can be sudden and without warning. The other critical risks are associated RAAC are:

- **Panel penetrations** – there are numerous instances of builders' work holes being formed on site that reduce the panel strength and reinforcement corrosion from increased exposure.
- **Loading** – changes in loading from the original design loading, examples being roof water ponding, support of building services or snow drifts.
- **Water Ingress** – When the panels are saturated, there is a notable reduction in strength, bearing capacity and increase in deflection.
- **Cracking and spalling** – can lead to material becoming loose and falling onto the floor below, causing a safety risk to occupants.

What should estate teams do?

The Department for Education (DfE) has published guidance [15] on the identification, risk assessment and management process for RAAC panels. Estate departments should read, understand and take guidance from the latest published information.

- Firstly, look for evidence of RAAC in your buildings using the latest identification guidance [15] – at time of writing the latest edition was April 2024.
- If unsure, or where RAAC is suspected, appoint an appropriately qualified building surveyor or structural engineer to confirm if RAAC is present.
- Work with your appointed specialist consultant throughout the process, which would typically involve the following staged approach:
    - **Information collection and desktop study**. This is the part that the estate department can help significantly by providing all relevant information.
    - An **initial site visit to establish the presence or otherwise of RAAC**. If confirmed RAAC is present immediately inform the DfE.
    - **Where RAAC is present a more detailed panel-by-panel survey** will be required by a chartered structural engineer to establish particular risks, and to inform the scope and parameters of interventions.
    - **Development of a management strategy and / or structural interventions** will be done by a chartered structural engineer.

What interventions are used to address RAAC?

Following a detailed appraisal of RAAC panel defects and risks, steps for management and interventions can be taken. Typically, one of the following options are implemented:

- Minor remediation and implementation of management strategy. Examples of minor remediation could be additional supports to damaged areas or providing new support to equipment supported by the RAAC panels.
- Minor remediation and additional bearing supports and implementation of management strategy.
- Full 'failsafe' system installed to take over the structural function from the RAAC system. Examples could be new steel frames or timber joists placed underneath.
- Remove RAAC and replace structural elements with new.

The IStructE guidance[14] suggests timeframes for undertaking the interventions. Where high-critical issues are identified by the specialist consultant then they will discuss these with you with consideration to undertake immediate action, such as installing exclusion zones or temporary propping.

Image: ©Arup

Known Building Problems & Solutions
Structural Known Problems – Condition Related Defects

Condition related defects in existing buildings tend to be caused by either an ingress of water, poor maintenance or unexpected ground movements.

The **ingress of water** is mostly commonly attributed to poorly maintained roof coverings, drainage, gutters and downpipes, in particular. Care should be taken when the roof drainage system is internal and hidden behind finishes, as issues can go undetected for longer and be more widespread. Examples of structural issues associated with allowing water to ingress include:

- **Decaying timber joists**, especially when they are built into walls which are damp from water ingress.
- **Corroded steel beams**, especially in embedded steel elements and if the applied corrosion protection was based on the steel being in an internal dry environment.
- **Corrosion of masonry wall ties** which can lead to instability of the wall panel.
- **Erosion of mortar** in poorly-maintained brickwork.

Attention should be paid to the hard to reach and inspect areas of the building as structural issues in these areas tend to be left unnoticed and allowed to escalate.

Ground movement tends to result in foundation movement which translates to above ground defects in the structure. Ground movements tends to be related to:

- Changes in **groundwater levels.**
- The **presence of trees** (or trees being removed).
- Large **adjacent excavations,** causing localised movements.
- **Poor underground drainage** maintenance or leaking services.

Structural defects can also be caused by **poor maintenance and ill-conceived alterations**, examples being:

- Repointing using a **cement-based mortar to replace a lime-based mortar** will most likely cause accelerated deterioration of the brick. This will affect heritage buildings on campus, but not modern masonry construction that uses cement-based mortar.
- Sealants or non-breathable paint can **trap moisture** in the brick, leading to freeze-thaw decay.
- Alterations to improve energy performance can **trap in moisture** and instigate deterioration.
- **Inappropriate cleaning methods** can cause substantial damage to masonry by removing the hard outer surface of the brick, exposing the less durable inner material.
- **Vegetation growth** on masonry can cause significant damage to mortar joints and the foliage can prevent the masonry from drying out.
- Intended structural **movement joints** that are not maintained and lock up add thermal stresses to the structure that they were not designed for.

Known Building Problems & Solutions

Inclusive Design

What is inclusive design?

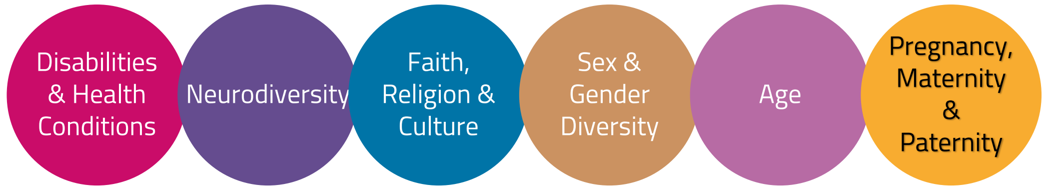
The British Standard (BS8300) defines Inclusive Design as "*an approach to the design of the environment, including buildings and their surrounding spaces, and managed and natural landscapes, to ensure that they can be accessed and used by everyone*". Accessible design is usually about designing environments for people with disabilities whilst Inclusive design aims to produce environments that are accessible and usable by everyone, whatever their ability, age, culture, faith, gender, family or economic status. Designing in this way is both principled and efficient, minimising the need for subsequent changes to accommodate the needs of future generations of users.

Accessible design considerations in buildings rose to prominence in the 1990s in the UK through the Disability and Discrimination Act (1995) and follows trends from the USA.[16] The guidelines on improving accessibility have been expanding and improving since and now form part of building regulations and standards, many of which have had very recent publications and updates.

Why is inclusive design important?

The Equality Act 2010 provides a legal framework which enshrines equal opportunity for all and is fundamental to improving the access of buildings. The public sector needs to be proactive in being compliant with the Act and there are a host of benefits to be realised from improving the inclusiveness of spaces.

Inaccessibility often results from design and barriers in society. Disability alone doesn't make buildings inaccessible; it's the design that can do this. Inaccessible design can exclude not only disabled individuals but also others based on demographics like gender or age. It is important that someone does not only view accessible design as wheel-chair accessible. There are a host of considerations that help to make design inclusive.[17]



All institutions benefit from inclusivity and having as many people as possible feel like they belong in a space. By not considering it, you are limiting the number of people who can use that space effectively and could lead to broader consequences that are not always immediately apparent such as negative publicity, loss of students and staff, legislative action and the need to future design actions (unsustainability).

Known Problems

Outdated design

Most legacy buildings are very unlikely to the meet the accessibility and inclusive standards of today and will have accessibility issues that limit people's ability to access and egress buildings independently and use facilities and which limits the effective circulation of people. This impacts the staff and students directly but also impacts the relevant building and estates management through additional responsibilities to ensure reasonable adjustments are made to meet individual needs. Retrofit presents a great opportunity to address these issues.

However, it must be acknowledged that the constraints of retrofitting an existing building may mean it is simply not possible to address all the accessibility issues through design and appropriate management strategies may need to be developed. It is important, at the very least, that a balance is achieved that shows inclusivity was considered. [18]

Where the project is a residential building, different design considerations and standards may apply.

Stakeholder engagement

When attempting to understand the inclusivity challenges of a building, achieving the right level of stakeholder engagement is a challenge however there are tools available to address this.

Physical constraints

In existing buildings, the landings, dimensions and core are often fixed and cannot be altered.

Image:
©David Chipperfield Architects
Arup Design
London School of Economics

35 Lincoln's Inn Fields (London School of Economic and Political Science) lies within a sensitive heritage setting, located in the Strand conservation area and between Grade II listed buildings. The building was formerly home to the Royal College of Surgeons and was built shortly after the end of World War II. It will be part of the LSE's central London campus. The design strategy has been for adaptive re-use - large parts of the existing structure will be retained to help make it LSE's first net-zero carbon building – and the design team are striving to achieve BREEAM 'Outstanding', WELL 'Platinum' and Passivhaus accreditations. Over 60% of the existing structures will be re-used, with the two principal façades preserved and step-free access provided to the building for the first time. An open lobby at ground floor has been designed to create a welcoming entrance space, with a new agora space to support new ways of learning and interaction, a café, and accessible and inclusive toilet facilities are also provided. A new atrium between first floor and level 7 – created by removing existing structure in the centre of the building and replacing it with new timber construction - will bring-in natural daylight, improve visibility and connectivity between floors and support wayfinding.

Solutions

Stakeholder engagement

Stakeholder engagement provides an opportunity to understand the existing barriers and challenges, especially ones that are often overlooked, that different users face. It also presents an opportunity to identify benefits and possible alternative mitigations. It's important to engage with all potential users because building staff, teachers, students and visitors may use the building in different ways. It can be good to tap into internal networks within the higher education institution to achieve this (societies, disabled staff etc.) .

- **Desktop & Demographic research –** limited data and data protection laws can limit opportunities here, but it can highlight which groups to include for other stakeholder engagement tools. Case studies and context can be found.
- **Occupant Surveys and Questionnaires -** Inclusivity and access challenges can be sought out through surveying the occupants. These issues can be fed to the design team for addressing.
- **Focus groups/workshops** – Engaging with people in this way is about co-creation and embodies design *with* as opposed to design *for*.

Accessibility and inclusive design audit

Conduct to understand the existing condition, prior to design through site surveys. Some estates team may have existing principles/framework outlining expectations for their buildings, including accessibility requirements, - to ensure a consistent experience for users across sites. If not, this could also be developed as part of a wider strategy.

End-user Personal Journey

From before the occupant enters the building, their user experience can be tracked throughout their use of the building. It is sometimes a CDM requirement for this to be considered.*

Appoint an inclusion champion

As suggested in the RIBA: Inclusive Design Overlay. A dedicated person to help drive inclusivity can be helpful

What are the relevant inclusive design standards and resource to consider?

It is important to note that mere compliance with building regulations is rarely sufficient to have a fully inclusive environment. These codes tend to focus on access for disabled users and only sometimes will have inclusive design considerations. There are other documents to consider when trying to achieve good practice in inclusive design.

Known Building Problems & Solutions

Inclusive Design

Standards and Regulations

- BS 8300-2:2018 Design of an accessible and inclusive built environment Part 2: Buildings — Code of practice
- PAS 6463: 2022 Design for the mind – Neurodiversity and the built environment
- Access to and use of buildings: Approved Document M
- Fire safety: Approved Document B
- Toilet accommodation: Approved Document T

Good practice guidance

- Inclusive Design for Structural Engineers: IStructE (2024)
- Inclusive Design Overlay to the RIBA Plan of Work (2024)
- Inclusive University Built Environments: The Impact of Approved Document M for Architects, Designers, and Engineers (2020).
- CLEAPSS guidance (up to GCE & A-level but may have relevance to some higher education facilities e.g. lab design).

RIBA Work stages & Inclusive Design flags for intervention.

- RIBA Stage 0-1: Begin engaging with previous building occupants about what the access and inclusive design issues were and engage with different groups to understand what some of their needs are.
- RIBA Stage 2-3: This stage is important as often it is dimension rather than area that helps with delivering access and inclusive design solutions. This stage helps you to understand what the constraints and opportunities are for delivering inclusive design solutions.
- RIBA Stage 4: Project brief to be approved by Inclusive Design lead (champion)
- RIBA Stage 5: It is important that inclusion is considered for any changes on site. Too often, changes are made for other added value and then inclusivity is destroyed.[19] Further consideration should be made for how accessibility can be maintained during disruptive works. Temporary way-finding and contingency plans need to be made. It is also critical that Health and Safety standards are maintained during construction, especially where intrusive works can infringe on public spaces.
- RIBA Stage 6-7: Conduct Post Occupancy Evaluations with a focus on accessibility and inclusivity.

Retrofitting Legacy and Historic Buildings

Historic England have produced a guide on Easy Access to Historic Buildings. This guide outlines how and when the *Planning (Listed Buildings and Conservation Areas) Act (1990)* is applied and how to seek planning permission to alter listed buildings. The guide does not cover all aspects of inclusive design.

The Burro Charter is commonly referred to when retrofitting historically significant buildings and takes the philosophy of *changing as much as necessary but as little as possible.*

Image:
©David Chipperfield Architects
Arup Design
London School of Economics

Legacy Building Asset Management

Image:
Old Gym
©Associated Architects

Image:
Oxford Brookes University – Clerici & Sinclair replaced facades
© Fisher Studios

Image:
Engineering Building
©University of
Leicester / Simon
Kennedy

Legacy Building Asset Management
Overview

One of the key drivers for retrofitting is extending the service life of a building. Asset management plays a vital role in extended the service life. By looking after your buildings and being informed on how they are working and deteriorating allows the time between major interventions to be extended.

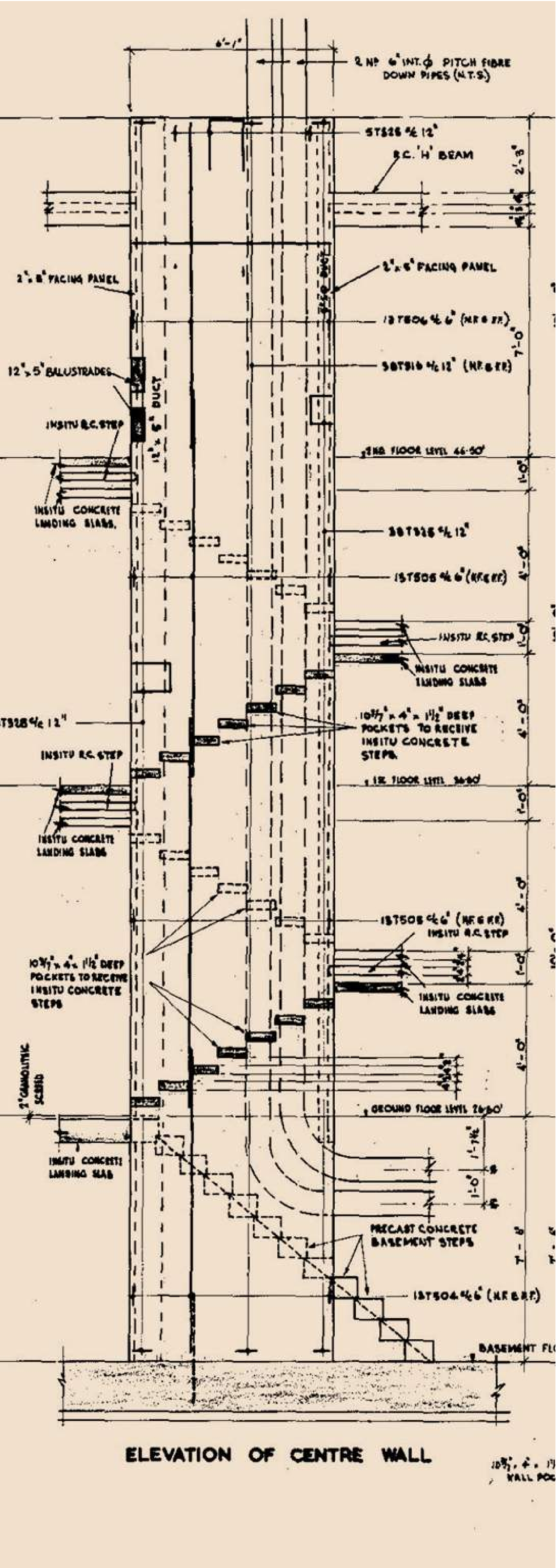
Keeping and managing records in terms of historical record information and operational data allows asset management and retrofitting decisions to be informed. The value in record drawings is sometimes not fully appreciated and things go missing. One drawing can provide more information than expensive and disruptive surveys. Surveys play an important role in retrofitting and can confirm condition and verify record information.

A building is made of many different systems, components and materials, each of which will deteriorate at different rates and will require replacement on differing cycles. Understanding these life cycles allows informed decisions to be made for maintenance and retrofitting cycles.

Decisions should be data-driven to ensure the right solutions and interventions are delivered. Understanding how people use a building and how the building is operated provide vital insight into what improvements and interventions are necessary.

Key message points:

- Asset management plays a vital role in extended the service life of a building and equipment.
- Record drawings and data hold great value in informing retrofitting and asset management.
- A life cycle view should be adopted.
- Decisions should be data-driven.



Legacy Building Asset Management

Record Information

In universities, the construction tends not to be self-revealing due to it being covered by cladding, screed, plaster, etc to provide the intended aesthetic. Therefore, most information about the construction is concealed from view and **record information offers massive value when retrofitting**. Record information provides information to the estates teams and designers, providing early risk mitigation and informed design process and removes the need for costly intrusive surveys.

Critical decisions that often have a large impact on the embodied carbon, programme, cost and outcome of the project are made early in the process. Record information is the best way to inform these critical decisions as it is often prior to any intrusive surveys. For foundations and concrete structures, the record drawings are particularly valuable as the key design information is either buried and embedded or expensive, disruptive and takes time to uncover.

As well as adding value to the retrofitting process, owners have an obligation under CDM regulations to pass on relevant information to the designers.

Where can the information be obtained?

- **Private archives** – the best source of specific information and those of most value are the original design and construction material for the building. These are normally kept in archives and can provide the best inspect into the buildings.
- **CDM health and safety file** – from 1994, there is a duty to compile a health and safety file that is handed over to the client at the end of the project. The file contains valuable information to inform projects including residual risks, key structural principles, hazardous materials used and as-built information for building elements. These should be well maintained and passed onto the designers.
- **Statutory bodies** – The UK government's planning portal contains valuable information submitted as part of the planning process and can typically be easily obtained. Building control records are private and can only be inspected by the owner, or if they grant permission.
- **Map regression** – historical maps are reviewed to understand the timeline of development on the site. Your designers should have access to only systems for historical mapping.
- **Research** – if the structure is of significance or constructed using a proprietary system (such as CLASP), then drawings, calculations, lessons learnt reports, etc may be available.
- **Personal experience** – the personal experience of estate team staff can be a great source of knowledge, especially from on-site facilities and maintenance. The additional insight experience often provides overwritten information is context on the original decision-making process which is seldom formally documented.

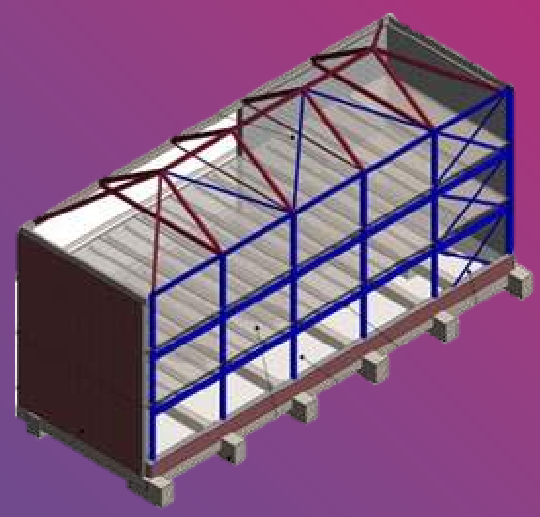
It is prudent to copy information to pass onto design teams as, despite best intentions, the source of missing information is often none-returned loans.

As suggested in this section and evidence in many case studies, record information provides massive value to the process, however things change on-site and records might not be 100% correct. Physical confirmation of the construction is typically required to verify critical assumptions.

Case Study Nugget:

Clerici Building– Oxford Brookes University needed to allow natural light into a space originally designed as storage and was being transformed into a light and airy office space. The detailed structural record drawings contained sufficient information to allow the foundations to be reused and the temporary and permanent works to be implemented with minimal investigations. This reduced university (client) risk, construction programme and informed the permanent and temporary design to completely remove and replace the load bearing façade.

On the flip side, there were elements of the project where knowledge of the concrete strength and reinforcement was required to justify the existing structure for the proposed modifications that increased the loads resisted by the elements. No record information was available and therefore expensive and disruptive intrusive concrete testing was required. This cost the university £30k and required significant stakeholder communications and management due to the noisy and messy nature of the intrusive investigations.



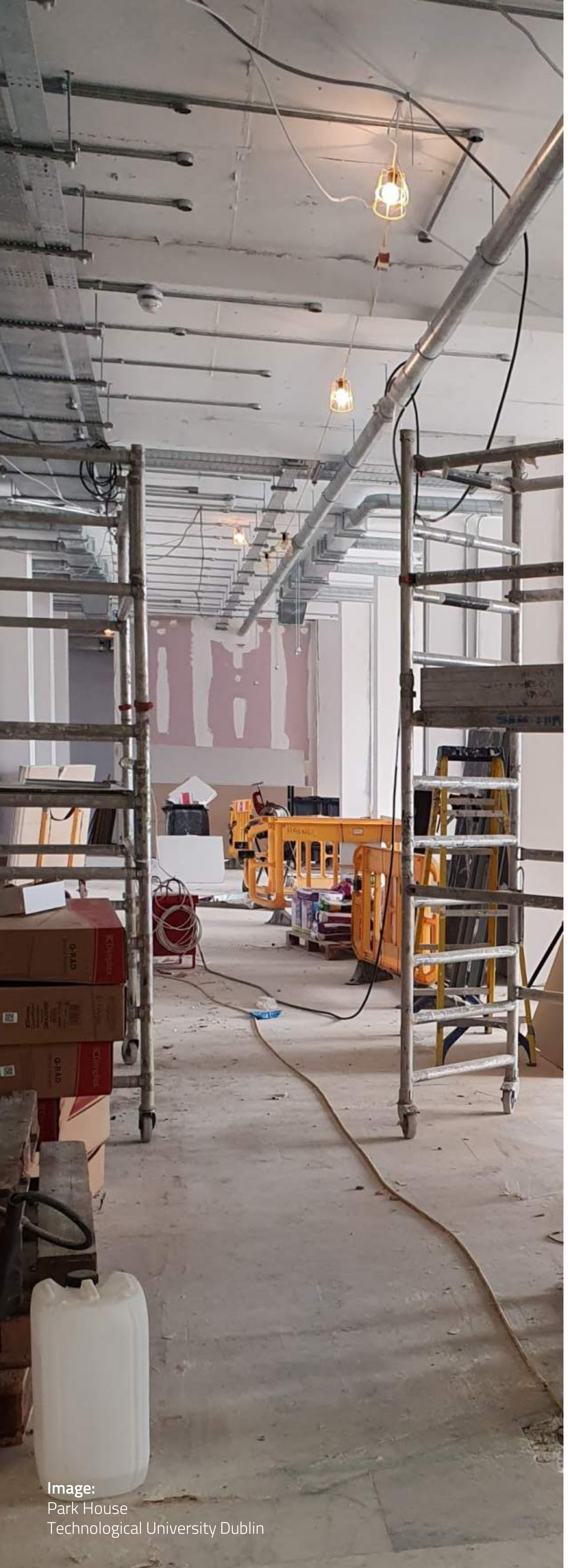


Image:
Park House
Technological University Dublin

Design Life

All buildings deteriorate over time. The rate of deterioration depends on the aggressiveness of the environment (climate and pollution), the degree of care taken in using the building, and the effectiveness of the maintenance regime. A building is made of many different systems, components and materials, each of which will deteriorate at different rates, and each of which will require defined inspection and maintenance routines.

In the UK, the design life of buildings is defined in the Eurocode 2 as the 'indicative design working life'. The indicative design working life refers to the assumed period which a structure is intended to be used for its purpose without requiring major repairs, in essence, 'lifetime to first major repair'. This covers both accessible and hidden structural elements.

Most buildings on a university campus will typically have an indicative design working life of 50 years (Category 4) with a few exceptions requiring 120 years which fall into the monumental building structure category (Category 5).

The design life reflects the balance between functionality, durability, and maintenance considerations.

The design life and service life of building elements are not the same thing. The service life is the actual life based on real-world results. BS 7543:2015 defines service life as period of time after installation during which a building or its parts meets or exceeds the performance requirements. Generally speaking,, the service life is less than the design life when provided. However, the right servicing and maintenance can extend the design life. Service life can therefore be seen as the point in which servicing, and maintenance intervention is required. It is always a good idea to carry out inspections before the service life is reached.

Due to the widely differing nature of the systems, components and materials, design life must first be categorised as follows:

Category description	Life	Typical examples
Short-term	Shorter life than the building and readily replaceable	Door actuators and motors, taps
Replaceable	Shorter life than the building and replacement can be envisaged at design stage	Most floor finishes and services installation components
Maintainable	Lasts, with periodic treatment, for the life of the building	Most external cladding, doors and windows
Lifelong	Lasts for the life of the building	Foundations and main structural elements

Categories of design life[20]

How can I extend the life of a building?

The design life of a building is a decision taken at the original design stage and cannot really be extended. It is the serviceable life of the building that can be extended and this is dependent on management, inspections and maintenance regimes. There also becomes a point where it becomes more economical to replace elements rather than to continue repair and maintenance. When a building reaches the end of its original intended design life, it does not mean the building is unsafe and provides risk to occupants.

Extending the building design life can be achieved through some key approaches:

- **Maintenance** – address any problems promptly to avoid costly repairs later. Have a clearly defined routine and planned maintenance regimes.
- **Inspections** – undertake periodic inspections to identify any changes or new defects at the earliest opportunities. It is important to highlight areas that cannot be inspective and derive a plan.
- **Choice of material** – specify and use the material suitable of achieving the intended design life or consider material capable of lasting longer.
- **Drainage** – a well-designed drainage system will prevent water accumulation and associated damage. Inadequate drainage can result in accelerated deterioration. Water ingress into the building and foundation problems.
- **Ventilation** – moisture can lead to mould, rot and other structural issues, hence ventilation is key to preventing moisture buildup.
- **Damp** – is typically a result of poor drainage or ventilation and causes accelerated deterioration.
- **Roof maintenance** – the roof plays a vital role in the durability of the internal building elements ensuring they remain in the internal environment they were designed for and should be regularly inspected and maintained.

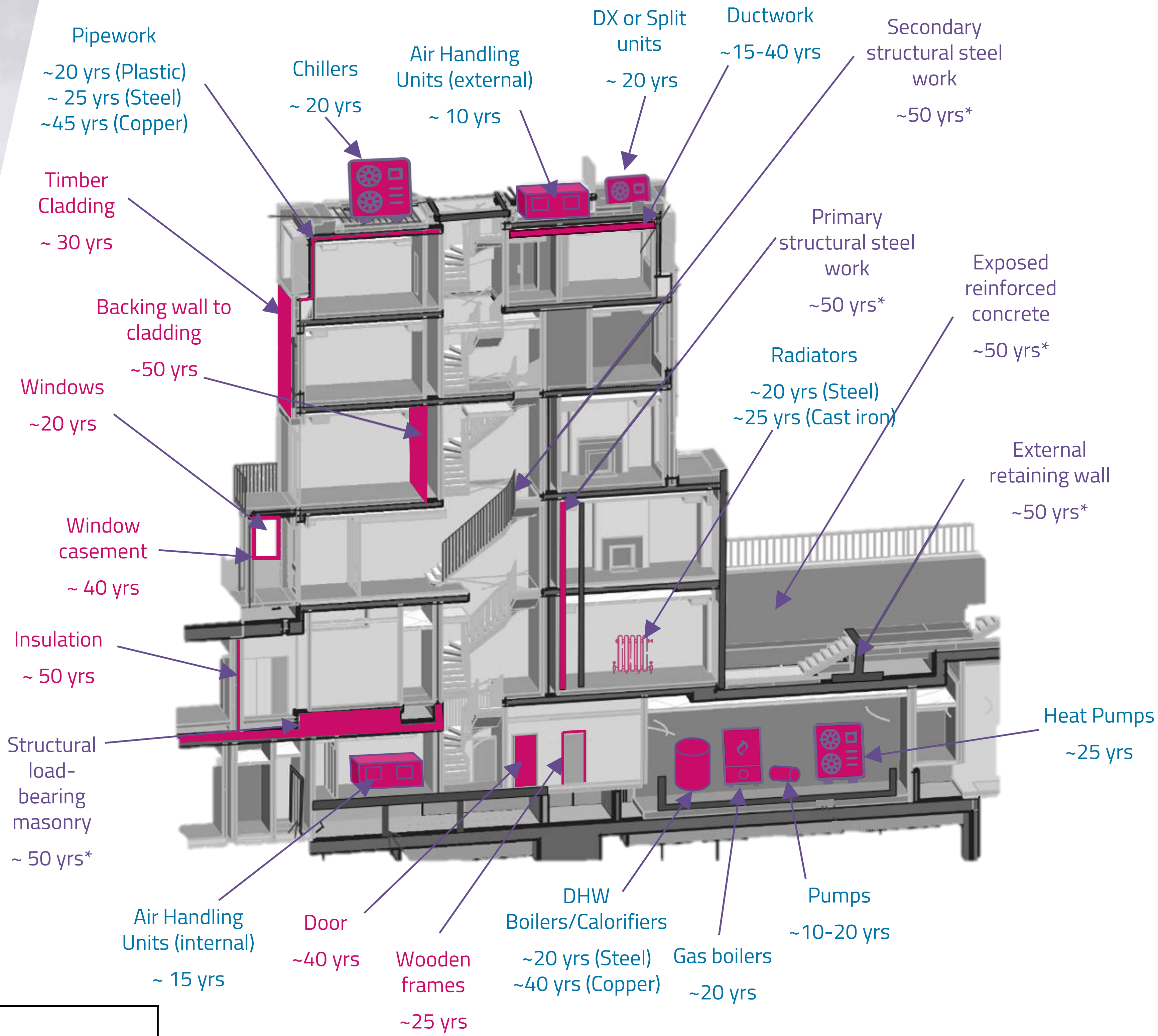
Many existing structures may harbour defects that are challenging to detect, even after detailed and extensive surveys. It is not viable to expose every single foundation to confirm condition, for example. Engineers focus on identifying critical defects and addressing them to extend the building's lifespan.

It is also worth taking into account that the financing of building construction often assumes a design life that is at least as long as the period of any loan used to finance the building.

Legacy Building Asset Management

Service Life

Average Service Life of Building Elements[21]

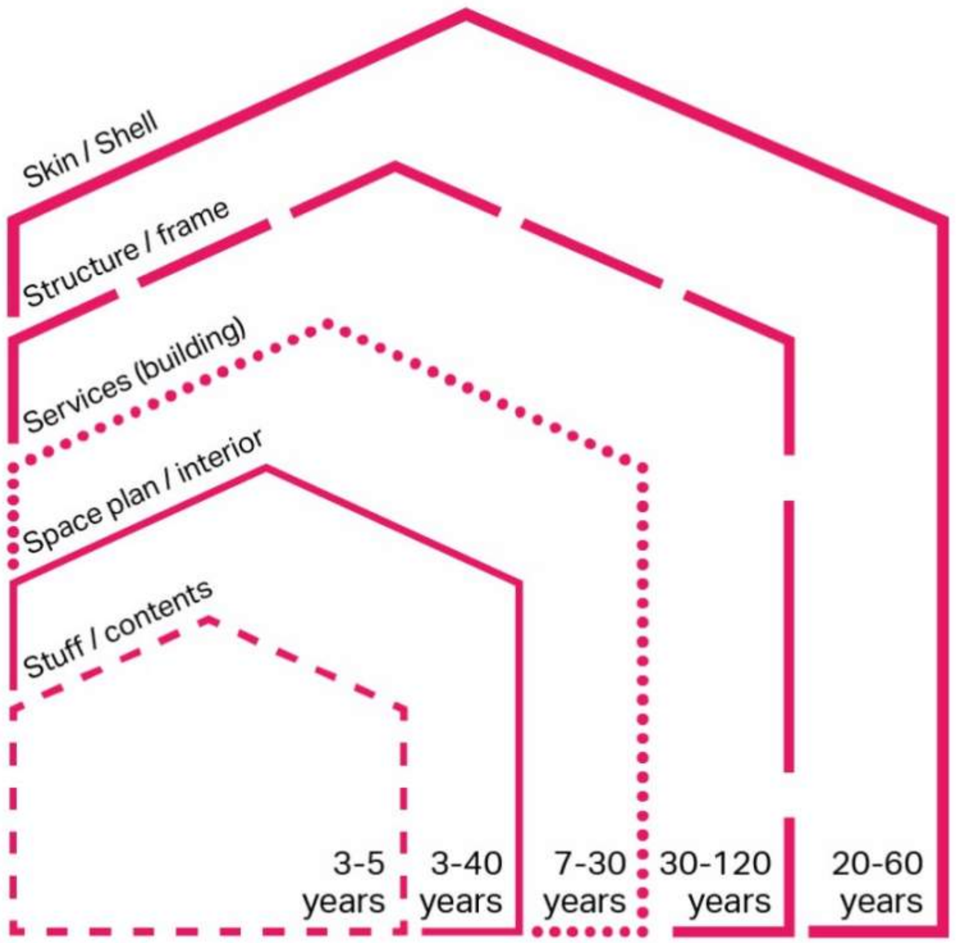


Key:
MEP Elements
Structural Elements
Façade & Fit-out Elements

*50 years is the design working life for Category 4 buildings which is the most common for most university buildings. Some Category 5 buildings can have extended design lives of up to 120 years

Building Layers

The Greater London Authority describe the various building element lifespans in terms of layers, where each layer has its own life cycle, life span, and circular design approach. The key point there are getting across is to use circular economy through reuse and recycling; the different layers should be independent, accessible and removable whilst maintaining their value. This is especially important for layers that may need more frequent replacement, such as building services and internal fit-outs. An example where lifespans potentially contradict, and which is common in some forms of legacy buildings, are load bearing façade panels. These panels, despite intended lifespans are likely to need replacement before the internal structural frame due to exposure to the elements. However, the panels are part of the structural load bearing system.



Building layers and their indicative lifespans (taken from GLA Circular Economy Statements guide[22])

Image:
Oxford Brookes University
Clerici Façade Before
©Arup

Image:
Oxford Brookes University – Sinclair replaced facades
© Fisher Studios

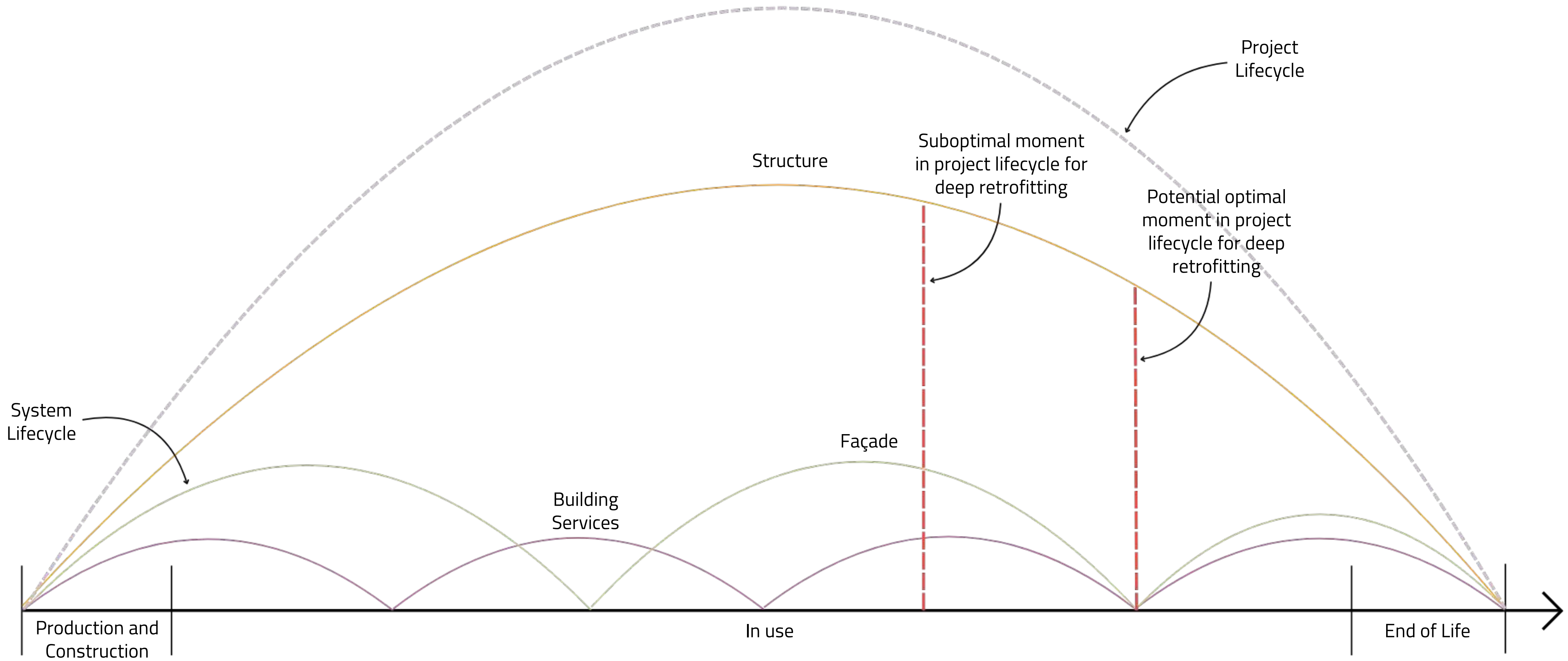
Legacy Building Asset Management
Retrofitting Cycle

When is the optimum time to retrofit?

A building is made of many different systems, components and materials, each of which will deteriorate at different rates and will require replacement on differing cycles. To ensure maximum financial and carbon efficiency it is worth looking ahead and trying to plan for the optimal moment to undertake deeper retrofits. It is unlikely that stars will align perfectly, and a balance will be required with some compromises being necessary. The main 3 building elements to consider are the structure, façade and building services. The image below is to demonstrate the differing time frames of element lifecycles and the benefits that can be achieved through considered timings. The image is over simple, and it also only considers one building. Estates departments need to balance deteriorating elements campus wide over multiple buildings and systems alongside maintenance and project funding. Estate director need to consider the universities short-, medium- and long-term timeframes, direction of the institution and Estates Masterplan.

Key message points:

- The lifecycle of the differing building elements need to be considered to inform timings and depth of retrofitting to maximise efficiencies and returns.
- Estate director need to consider the universities short-, medium- and long-term timeframes, direction of the institution and Estates Masterplan.



Building Surveys

Building Survey Overview

Why is this important?

Building surveys are a critical component to achieving a good retrofit project. It is widely recognised that detailed surveys done at the right stage can save lots of time and money down the project line. The associated cost of uncovering an issue during the earlier phases is always considerably less than discovering that issue during the construction phase. The purpose of a building survey is about information gathering that is first-hand and building specific, thus helping to inform decisions and design.

What are the key reasons for surveying?

- **Reducing risk** – Existing buildings may have many unknown problems and surveys present an important opportunity to uncover these problems early, helping to inform design and make construction safer and more efficient.
- **Save costs** - Taking the time early to survey thoroughly will reduce the risk of having to deal with unforeseen issues further down the project line which can have greater financial penalties.
- **Identify constraints** – surveys can inform the design by highlighting constraints that were not known. This allows the designs to mitigate for the constraints and reduce the implications against outcomes.
- **Highlight opportunities** - Surveys also offer a chance to identify opportunities and highlight new ideas for the way in which a design can be improved and more efficiently adapted.

What are the main types of survey?

Surveys can take on very different scopes and intentions and should be bespoke. This means that it can be very difficult to predict the exact cost of a survey, the disruption and value they will bring.

- **Measured Survey** – taking dimensions of the space. These vary significantly in cost and complexity and should be aligned to individual projects.
- **Condition Survey** – a visual inspection to understand condition of the building elements such as façade, structure and building services
- **Opening up works** – disassembling façade panelling, ceiling tiles etc., to gain access to building elements that are usually hidden during a condition survey
- **Intrusive survey and testing** – may involve breaking out, core drilling etc to validate or inform structural design or testing of MEP systems

A survey strategy should be developed in collaboration between the estate and design teams. Often the best plan is to have staged surveys that are carried out as earlier as possible. The level of disruption, and / or cost may prevent surveys in occupied buildings happening, confirmation of internally located foundations for example. This should be clearly communicated and covered in risk registers.

Matterport dolls house model of York Guildhall, managed by The University of York

What are the other survey types to consider?

- **Virtual survey** through Matterport technology. Digital capture technology is a fast-moving technology and provides huge benefit to surveys of existing assets and helps quickly identify risks, opportunities and provides clarity on the building layout. Matterport has been used very successfully by engineers to aid in building surveys.
- **Drone surveys** for when places are unsafe to access.

What else do you need to consider?

- **Hazardous materials** - asbestos, lead paint etc. may be present and appropriate management reports may need to be issued. A review would be necessary to confirm they are relevant to the proceeding level of intervention.
- **Disruption to occupants** - do surveys need to be conducted out of hours? How much noise, vibration and dust will be produced?

Director of Estate insights:

The AUDE member questionnaire revealed that directors of estates often wished they had surveyed earlier on in the project.

Some respondents noted that costly delays were often caused by issues arising that could have been spotted during surveys.

An up-to-date and comprehensive 'asset register' for all built assets as well as condition surveys add massive value and allow informed decisions on what maintenance/repair activities to carry out and when.

Image:
CLASP Surveys
University of York
©ARUP

Legacy Building Asset Management

Building Surveys

How can you help to get the most value from surveys?

Survey Early

Surveying early reduces the risk of issues coming later down the project line and is always the most cost-effective way of uncovering issues. It also allows the survey results to be incorporated into the design process, gaining maximum value out of your consultant teams.

Provide information and documentation

Surveys can be risky as the environment is unknown to the surveyor. Provide floor and site plans, asbestos reports and previous survey reports. At best, the information from these reports is sufficient and reduces the need for a site-visit survey. At worst it helps make the survey more efficient by helping the surveyor be more familiar with their environment. Depending on the intrusiveness of the survey, a Management Asbestos survey may be sufficient or, in some cases, a Refurbishment and Demolition Asbestos Survey is required. Providing previous asbestos management plans is important.

Develop a survey strategy

Having a survey strategy that clearly outlines the different kinds of surveys and who will be responsible for carrying out the survey is important. It is also important that the relevant estates team members are included in this strategy to ensure that access can be provided when it is needed. It is important to note that not all surveyors are permitted to access areas that have hazardous materials present (such as asbestos); it is therefore critical to understand the permissions and limitations of the appointed surveyors beforehand.

The reason for the survey will often define its scope. It is important that a written brief, that clearly states the scope of the survey, is agreed between all parties (i.e., the client, the design team and the surveyor) well before the site visit takes place.

Maximise opportunity for efficient surveys

A surveyor can only survey what they have access to. Surveyors often travel far and can be expensive to conduct. To ensure that the surveyor can use their time as effectively as possible and maximum value can be obtained, pre-survey arrangements need to be made and agreed upon.

- Provide key and relevant access
- Arrange and sign roof access permits
- Organise the relevant staff to receive and accompany the surveyor where necessary

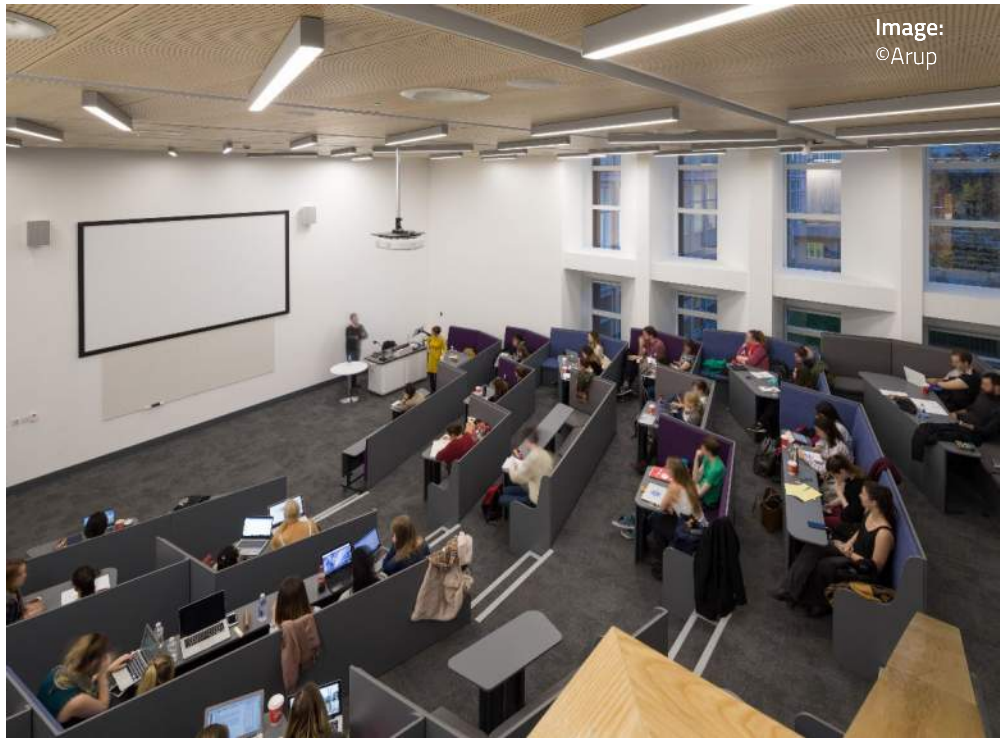


Image:
©Arup

Clerici Buidling– Oxford Brookes University uncovered some good design opportunities during an early site survey with the estates team and the design engineers. The survey revealed the opportunity for a new collaborative lecture theatre that required minimal structural alterations thus saving on construction costs and achieving a key project outcome efficiently.

Maintenance Plans

Why is this important?

Maintenance has a critical role to play in extending the service life of building elements and helping them reach or extend their design life thus ensuring you get the most value from your assets and return on investment. Well-maintained buildings often result in more efficient retrofit projects where money can be spent on transformation rather than repair.

Furthermore, maintenance is critical for mitigating risks associated with building element and asset failure.

Legacy Buildings are of the typical age where many of the systems are reaching their end of life and are in need of maintenance and/or replacement. This often means that retrofit can coincide with maintenance plans thus allowing much of the changes, equipment replacement, and additions to be absorbed into the maintenance budget.

Proactive vs Reactive maintenance plans

Proactive maintenance helps to reduce unforeseen replacements of broken equipment and is the most cost-effective and efficient way to manage campus assets. Both routine maintenance and maintenance plans are important to proactive maintenance.

Routine maintenance

Routine maintenance typically consists of high frequency inspecting and servicing of equipment that is non-intrusive to building operations. This type of maintenance can often be carried out by the estates team.

Planned maintenance and maintenance plans

- **Alignment -** Good practice for developing maintenance plans is to align the maintenance plan with an inspection plan. The maintenance that needs to be carried out will be informed by the observations from the inspection plan. Routine maintenance should also be used as an opportunity to adjust the maintenance plan.
- **Reduce disruptions** - Maintenance can be disruptive so scheduling maintenance to be conducted outside of term time is effective to minimise disruption to the function of the HE intuition. Often external contractors may need to be appointed to carry out major works and planning for their availability to reduce disruptions is important.
- **Overcoming the mismatching of systems with maintenance plans** - Mismatching systems and services can complicate the maintenance plans and places strain on the expertise required to maintain the systems. By using the maintenance plan, you can take the opportunity to replace systems and ensure that there is better alignment between the make, model and specifications using a phased approach that still gets the most out of your existing assets.

What else do you need to consider?

- **Hazardous materials** - asbestos, lead paint etc. may be present and appropriate management reports may need to be issued when opening up works might be carried out for inspections or maintenance.
- **Disruption to occupants** - do surveys need to be conducted out of hours? Outside of term time presents good windows for when maintenance can be carried out and can help prevent repairs needing to be carried out when the asset is in use.
- **Access** – it is difficult to maintain assets that cannot be easily accessed for inspection. These kinds of assets typically will run until failure and will need repairing or replacing instead of maintaining, This will often result in the service life of the asset not reaching its intended design life and can be costly.
- **External assets and water -** External assets that are exposed to the elements always require more maintenance than internal assets of the same type. This is important to be aware of when developing a maintenance plan.

How does retrofitting help with maintenance issues?

Access – Retrofit projects present a great opportunity to improve access to assets that were difficult to maintain in the past. The Engineering Building at the University of Leicester is a great example of addressing this challenge.

Energy efficiency – Improved energy efficiency from retrofit will reduce the strain on MEP systems and help them to last longer.

Environmental control – Retrofitting allows structural repairs to be made and building finishes repairs and to be reinstated to ensure internal elements are kept dry and protected from moisture build-up and damp. Being within an environment elements were designed for will reduce maintenance requirements.

Image:
Engineering Building
©University of Leicester / Simon Kennedy

Cost & Finance Considerations

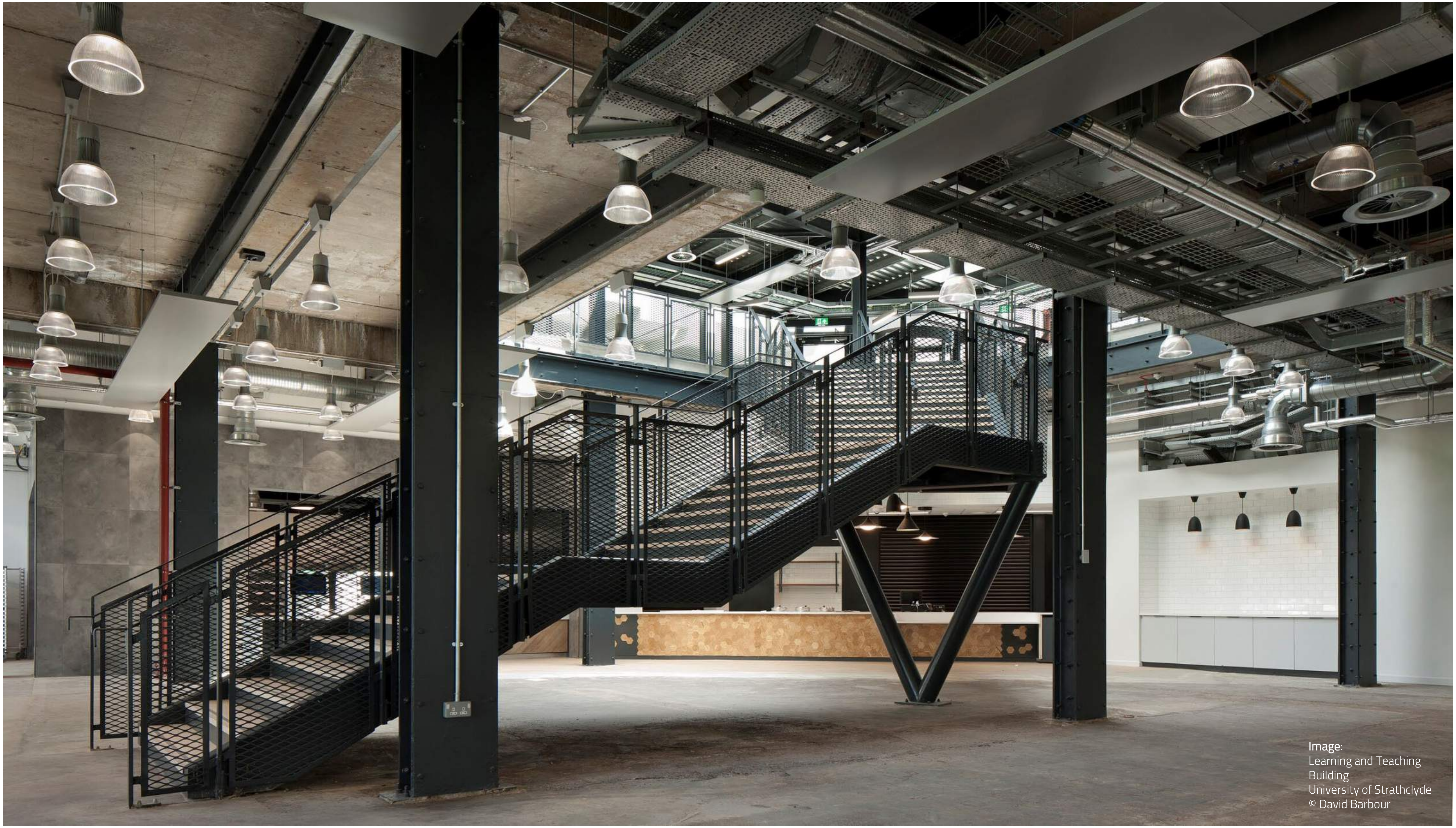


Image:
Learning and Teaching Building
University of Strathclyde
© David Barbour

Image:
Park House
Technological University Dublin

Cost & Finance Considerations

Overview

Universities have to balance financial pressures alongside many other factors such as achieving net zero targets and attracting students and staff.

Retrofitting has potential financial benefits compared to demolition and new build. Construction programmes can be shorter with reduced material and labour costs. Construction materials prices can swing drastically with global events, retrofitting can provide protection and cost certainty.

There are financial challenges to retrofitting and securing funding. One such barrier in the UK is that 20% VAT is paid on most refurbishment projects, were new builds typically pay 0-5%. There are campaigns to address this penalty for doing what's right for the environment.

There are different levels of retrofit interventions and measures. Understanding the returns for the various retrofitting options allows informed decisions on what and when to be made.

Hopefully retrofitting will be financially incentivised in the coming years to encourage the industry wide shift required to achieve ambition climate targets.

There are financial risks as well as rewards for retrofitting. An honest and informed risk profile for the project is recommended. The risk profile should only be reduced if information is known, not purely before the project has moved on a stage.

Key message points:

- Retrofitting has potential financial benefits compared to demolition and new build. Construction programmes can be shorter with reduced material and labour costs.
- There are different levels of retrofit interventions and measures. Understanding the returns for the various retrofitting options allows informed decisions on what and when to be made.
- Project risks should be considered on an individual basis and fine-tuned as the project progresses.

Funding Opportunities

Funding key challenges

Finding the funds to drive sustainability outcomes presents a significant challenge for universities.

- **Long payback periods -** Although retrofit projects will result in more energy efficient buildings that can save on annual energy bills, the high capital costs of some interventions mean that many may not payback in the short-term. However, there are many benefits to retrofitting that are not as easily quantified against an individual project, but do have financial benefits, increased student numbers for example through an improved campus environment.
- **Constrained budgets -** Universities face financial pressures and have several competing priorities to use their money on.
- **Lack of dedicated funding -** Although there are pots of money being made available by initiatives such as the Public Sector Decarbonisation Scheme (PSDS) and Low Carbon Skills Fund (LCSF) backed by the Salix Finance, the phasing of these schemes means that they are not always available when your project needs funding.
- **People want shiny new things -** It can be a challenge to compete with projects that promise to deliver new buildings - the most cutting-edge building designs with modern architecture.

Where retrofit offers a solution to some of these challenges

Retrofit projects can present a favourable project when compared to other New Build or Decarbonisation schemes for the following reasons

- **Lower capital cost than new builds**. By retaining much of the original structure, retrofit projects can deliver better payback periods than new builds – especially when a WLC approach is considered.
- **Quicker turn-around time for project.** Retrofit projects typically take less time to complete than new build projects which offers functional and financial benefits. This is both from a faster planning process
- **Co-benefits offer wider funding opportunities.** Retrofit projects can meet a number of sustainability outcomes which can open up opportunities to apply for funding by making the project appeal to funding bodies that grant funding for this specific reason. When funding may be limited or too competitive for decarbonisation schemes, your project may be able to apply for funding that is granted based on improving Health and Wellbeing. This does not constrain you in achieving other goals during the project.

Funding tips and advice

- There are significant advantages to align some retrofitting interventions with planned maintenance, especially for light retrofit projects. See the pervious page on retrofit life cycle.
- Some projects may still have considerable capital costs and, to manage the resource requirements, it is recommended that the larger capital projects be spread across the overall refurbishment strategy timeframe.

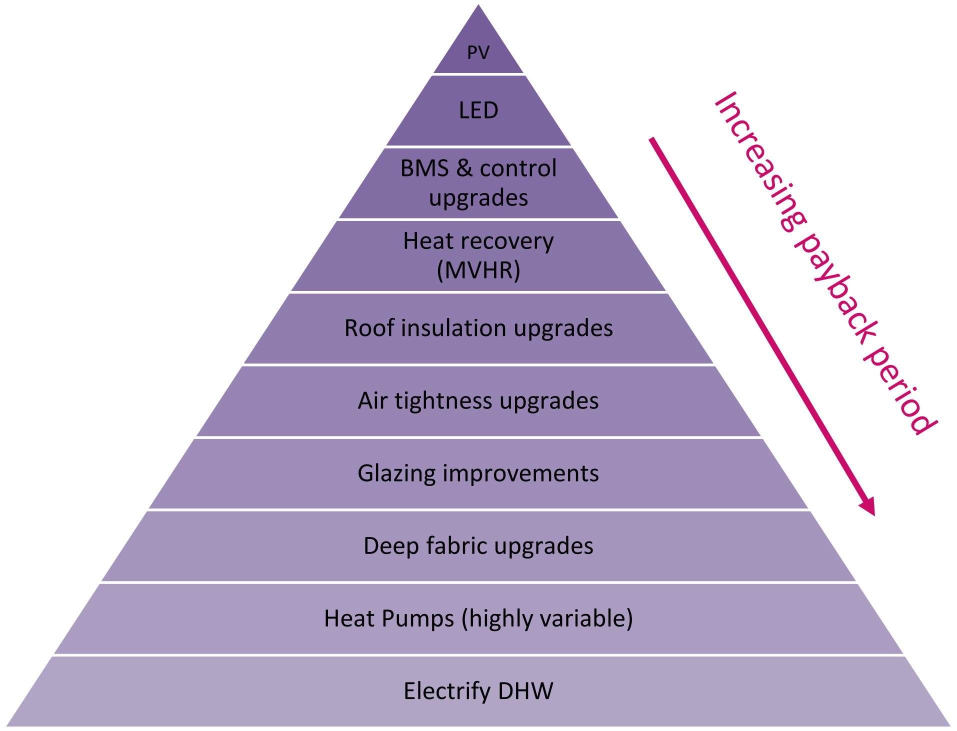
The UK government aims to incentivise and support decarbonisation efforts to achieve Net Zero targets. As a result, there are grant schemes and funding opportunities that could potentially supplement the university's resources for capital-intensive projects. These funding opportunities are explored on the next page.

Image:
George Green Library
University of Nottingham
©Martine Hamilton Knight/Builtvision

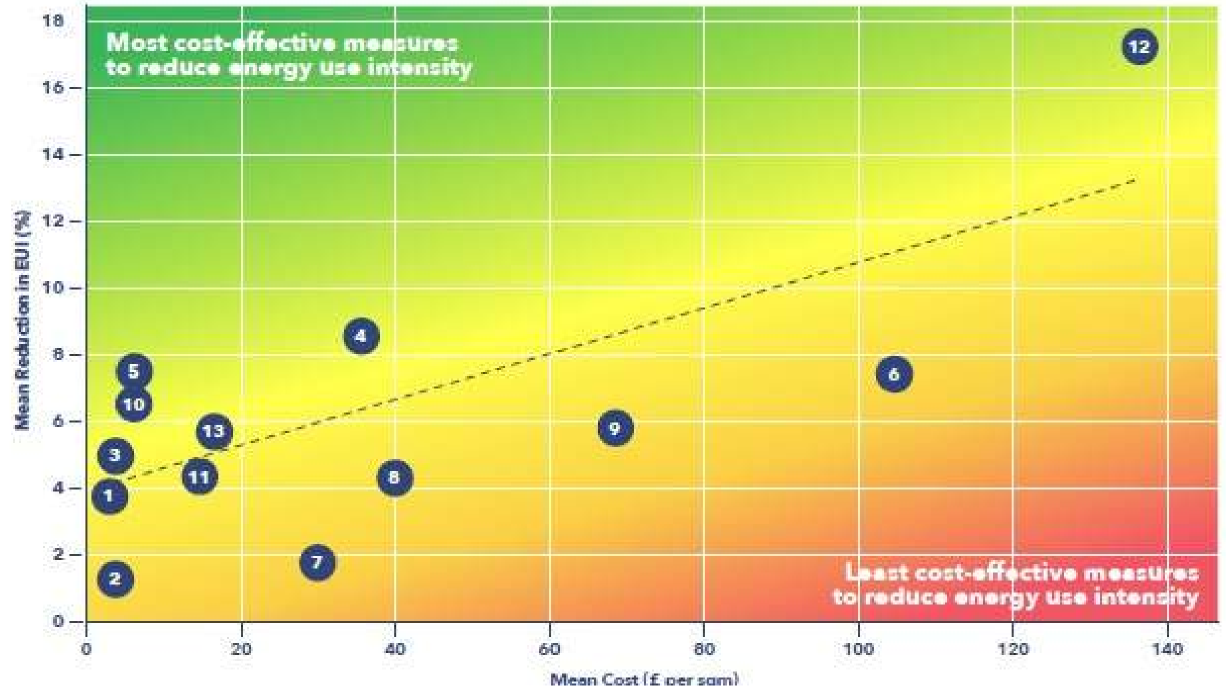
Cost-effective interventions

Some interventions offer significantly better payback periods than others. In a constrained environment, it may be necessary to prioritise those interventions.

Calculating payback periods is very important as it helps to provide important context on the long-term financial viability of a scheme. Calculating payback periods accurately can be always uncertain, especially with volatility in electricity and fuel prices and future prices on carbon that need to be factored into the equation.



Source: Arup project experience



Mean reduction in EUI of retrofit measures against cost per square meter
Source: UKGBC Building the case for net zero: Retrofitting Office Buildings

1. BMS health check
2. Pump motor replacement
3. Lighting controls
4. Low energy lighting
5. Building airtightness
6. Window replacement
7. Roof insulation
8. Wall insulation
9. MVHR
10.CO, ventilation control
11.ASHP for DHW
12.Decarbonisation of heat (ASHP)
13.Solar PV

Retrofit vs New Build

The high-level costs of retrofit work are always case specific and can be hard to quantify. It is also important to consider the capital costs vs the potential savings and ultimately the business case should be built on pay-back periods. Pay-back periods can be from a cost perspective and a carbon perspective. The UKGBC's Building the case for Net Zero: Retrofitting Office Buildings has some very insightful tables and graphs which help to indicate the relative cost of different retrofitting interventions. The mean impact EUI cannot be added directly.

On average, it is expected that by retaining the substructure and superstructure, you can save around 30% of the overall project cost compared to a new build. [23]

Double counting

When trying to calculate the energy savings of different interventions, you cannot simply add the percentage savings numerically. Interventions are often not mutually exclusive and the order in which you do the interventions and therefore count the savings matters. For instance, you can lower your heating demand by insulating the façade and then the energy percent reduction of installing heat pumps. This affects the expected savings of the interventions.

Intervention	% reduction in EUI
Insulate Facade	11 %
Heat Pumps	5 %
Insulate Façade, then Heat Pumps	5 % + 11 % does not work In reality: 5 % < reduction in EUI < 11%

York Guildhall – Retrofit by City of York Council and now managed by The University of York. York Guildhall is situated in an idyllic and prominent position in York, nestled between the River Ouse and surrounding buildings. This location, however, had a huge impact on the construction methodology and costs as construction deliveries, disposals and installations had to be via the river.

Image:
York Guildhall
©Arup

Cost & Financing Considerations

Cost & Programme

The industry is more familiar and comfortable with cost and programme estimation for new builds, which is one of the big advantages and draw towards them over retrofitting. There are some important cost considerations for delivering retrofit projects, below are some of the significant ones:

- **What is the building age and what is the form of construction?** A 1950's building that uses a proprietary system of construction is going to be more complex to retrofit than an early 2000's steel framed building.
- **What is the heritage significance of the building?** A listed building will add cost, complexity and time to design, approval and construction stages.
- **How much temporary works are involved?** Temporary works and construction sequence needs to be considered by your design team early as these can have a big impact on costs and programme. If left to a contractor to solve at tender, then you may get a surprise when the true nature of the intervention to achieve the outcome is considered.
- **How much do you know about your building?** If there is limited record information and the structural frame is hidden behind finishes, then significant amounts of survey cost and time is likely to be required. Are there any unknowns?
- **Procurement?** The right procurement route for a project is very individual and depends on several factors. For a retrofit project, significant consideration needs to be given to the apportion of risk, early contractor involvement or separate work packages may be a key to getting the best balance of risk and cost certainty for riskier elements of works.
- **How do you cost estimate?** Due to the bespoke nature of retrofit projects and the varying level of intervention needed benchmarking against other projects is challenging. Detailed cost modelling should be used as early as possible to provide cost certainty for the scope and highlight risks. Benchmarking of retrofit projects is likely to improve as retrofitting becomes more popular, but care will be needed as no two retrofit projects are the same.
- **How constrained is the building?** What is the site access and lay down space like? Is it compromised and likely to increase contractor preliminaries?
- **How much value are you keeping?** It's important to also consider the value of the elements you are keeping. The foundations and structural frame alone are typically 35% of the total project cost. Even if needing some repair works, retaining structure offers great value over new build.

Risk management throughout the project is a really important aspect of the cost management. The contingencies required for a retrofit project are typically higher than new build due to the uncertainties and the bespoke nature. There is an example of how risk allowance compare with new build and retrofit through the project in the CIRIA repurposing and reconfiguring buildings guide[7]. This is purely an example for consideration - given the unique nature of retrofitting projects, each project should be considered on its own merits.

-	RIBA stage		Low risk	High risk
New build	0	Strategic definition	10.0%	15.0%
	1	Preparation and briefing	10.0%	12.5%
	2	Concept design	7.5%	10.0%
	3	Spatial co-ordination	5.0%	7.5%
	4	Technical design	2.5%	5.0%
Reuse	RIBA stage		Low risk	High risk
	0	Strategic definition	12.5%	20.0%
	1	Preparation and briefing	10.0%	15.0%
	2	Concept design	7.5%	12.5%
	3	Spatial co-ordination	5.0%	10.0%
	4	Technical design	3.5%	7.5%

How risk allowances compare on a retrofit vs. new build project (taken from CIRIA repurposing and reconfiguring buildings guide[24])

Impact of Retrofit Measures

Where best to spend your money?

The levels of interventions available in a retrofit is a sliding scale and how far they get you towards your desired outcomes also varies. The main opportunity for retrofit highlighted in the estate directors' questionnaire was net zero gains, whilst the main blockers were funding and high costs. This page discusses the impact of the various retrofit measures for the different scales of retrofit and looks at the carbon and cost outcomes.

This only measures retrofitting on a carbon and cost perspective and does not take into account the various other drivers that determine the level of intervention for the project. Drivers such as utilisation, circulation, inclusiveness, appearance and maintenance are also key factors in deciding what best to do with a legacy building.

The table on the right was developed by UKGBC[25] to highlight the benefits that can be achieved by retrofitting existing commercial office buildings. These buildings face similar challenges to universities and the conclusions of the reports are relevant to retrofitting legacy buildings. UKGBC concluded the following:

- Building optimisation can have a significant impact on energy use, but lack of consistent data is a key barrier.
- Long-term retrofit strategies should be developed and updated as priorities, opportunities and pressures shift.
- Intermediate steps can be carried out through light retrofit in advance of deep retrofit.
- Needs to be aligned with decarbonisation.
- Interventions that improve fabric efficiency are necessary to achieve reductions in operational carbon. However, there is a high embodied carbon associated with replacing façades, so it needs to be done at the right time and part of a wider strategy.

The information covered on the page is useful for strategic planning of your retrofit projects and determining when best to carry out measures and whether they achieve the outcomes you need at the various stages. You may choose to focus funds for deep retrofitting certain buildings and concentrate on optimisation and light retrofit elsewhere to gain significant carbon impact and reduced running costs. A good way to look at your campus' existing buildings strategically is through a campus wide 'triage' system where you rank existing buildings on defined drivers against each other.

	Reference	Measure Type	Impact on Baseline Energy Use Intensity (EUI) 'Reduction' (0 – 10% – 20% – 30% – 40% – 50%)	Mean Impact on EUI	Relative Embodied Carbon Impact	EPC Impact	Cost £/m² GIA	Notes
Optimisation	1	Reduce Tenant Loads		-23.1%	Green	N/A	Varies	Dependent on tenant operations, moving to cloud servers can be most significant contributory.
	2	Building Management System (BMS) Health Check/Upgrade		-4.0%	Green	Low	£1 - £3	Cost of replacement BMS £20-£50/sqm impacts dependent on scale of improvements possible.
Light Retrofit	3	Pump Motor Replacement		-1.2%	Green	Low	£2 - £5	
	4	Lighting Controls		-5.7%	Green	Med	£1 - £5	Lighting controls implemented at the same time as low energy lighting, can result in significant combined reductions in EUI.
	5	Low Energy Lighting		-8.5%	Green	Med	£10 - £60	
Deep Retrofit	6	Building Airtightness		-7.2%	Green	Med	£2 - £10	Some air tightness improvements can be carried out as light retrofit, however significant improvements require deep retrofit.
	7	Window Replacement		-7.4%	Amber	Low	£60 - £150	Improved air tightness is a co-benefit of window replacement. Higher results may incorporate the impact of air tightness.
	8	Roof Insulation		-1.5%	Red	Low	£10 - £50	Little whole building benefit as the positive impacts are limited to the top floor.
	9	Wall Insulation		-4.1%	Red	Low-Med	£20 - £60	Wide variation in EUI reduction reflects the significant differences in material specification and their application.
	10	Façade Replacement		-11.4%	Red	Low	£640* and over	Wide variation in EUI reduction reflects the significant differences in available technologies and their application.
	11	Mechanical Ventilation and Heat Recovery (MVHR)		-5.8%	Green	Low	£40 - £100	
	12	CO_2 Ventilation Control		-6.5%	Green	Low	£2 - £10	
	13	Air Source Heat Pump (ASHP) for Domestic Hot Water (DHW		-4.8%	Amber	Low	£10 - £20	
	14	Decarbonisation of Heat (e.g. ASHP)		-17.6%	Green	High	£50 - £220	Wide variation in EUI reduction reflects different technologies available and the degree to which they can be implemented.
Renewables	15	Solar PV		-5.3%	Green	Low	£3 - £30	Dependent on roof area available.

TABLE 1: The Impact of common retrofit measures, as implemented in current projects.
*Refers to £/m² GIFA, rather than GIA

Key to Graph
Average reduction in EUI
← Lowest reduction in EUI
→ Highest reduction in EUI

Relative Embodied Carbon Impact	upfront embodied carbon is...
Red	>100%
Amber	50-100%
Green	<50%
	...of whole-life operational carbon savings

EPC Impact Scores	
Low	0-5
Medium	5-15
High	15+
...added to baseline EPC rating scores.	

The impact of common retrofit measures
Source: UKGBC building the case for net zero: retrofitting office buildings[25]

Image:
© *Photo by Josh Appel on Unsplash*

Funding Opportunities

Public Sector Decarbonisation Scheme (PSDS)

The Public Sector Decarbonisation Scheme (PSDS), managed by Salix on behalf of the Department for Energy Security and Net Zero, offers funding for the public sector to decarbonise by 2037. Applications for phases 1, 2, 3 and 3 have already closed with Phase 4 underway and future phases are anticipated.

This scheme provides grants for public sector bodies to finance heat decarbonisation and energy efficiency measures.

However, it's important to note that the current funding limit is £325/tCO2e, which may limit the applicability of the scheme, and any funding gap would need to be covered by the university.

Close attention should be paid to grant timing and financial schemes, as these factors are outside the university's control.

Other Salix Funding Schemes

Other public sector funding schemes are advertised on the Salix Finance Website. These funding opportunities are often only applicable to certain regions or available to certain organisation types and will have their own unique qualifying conditions.

It is important to note that many of these funding opportunities are carried out in phases and are dynamic in their availability. It is expected that future schemes and phases will become available, and it is always a good idea to check what the latest updates are when considering these funding sources.

Other funding pots

VEOLIA has a match funding scheme which will help to fill gaps in funding for some sustainability related projects and is worth exploring.

There are also opportunities to explore green bonds and sustainability linked loans that can offer favourable interest rates.

Case Studies

Image:
Engineering Building ©University of Leicester / Simon Kennedy


Image:
George Green Library
University of Nottingham

Legacy Building Guide

Case Studies

Contents:

Image:
George Green Library
University of Nottingham
©Arup

Introduction

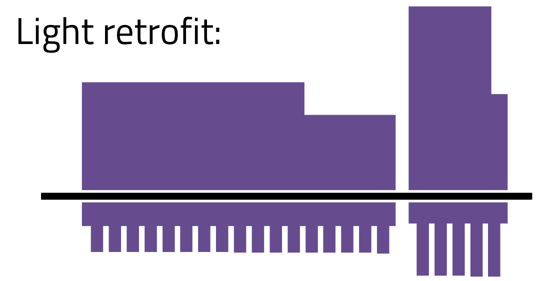
There is a significant number of successful, often multi-award winning, retrofit projects that have been completed throughout the UK Higher Education sector in recent years. This section brings together a selection of these retrofit projects, showcasing the 'art of the possible'. Unrecognisable transformations of tired and unloved buildings into vibrate modern facilities are presented. It isn't always easy or straightforward working with existing buildings so lessons learnt, and pain points are shared. These case studies confirm that extending the life of existing buildings without sacrificing flexibility or quality isn't just possible, but advantageous. Historical, cultural, cost and programme benefits can be realised through retrofitting rather than demolition and new build.

Each case study will discuss:

- The previous condition and the main drivers behind the decision to retrofit
- Considerations in the decision-making processes
- Interventions required to achieve the project objective, covering:
    - Architectural
    - Façade
    - Structural
    - Building Services
- Cost and finance considerations
- A view on the benefits of the project
- Lessons learnt

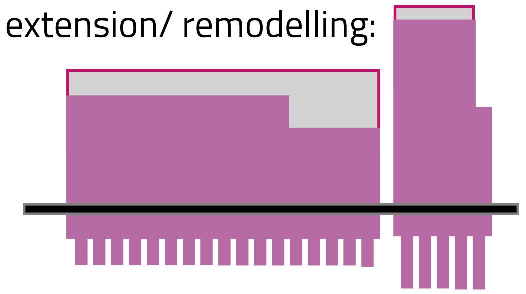
The extent of retrofit required to achieve the project outcomes varies from light touch to major interventions and can include significant new build elements. The following symbols are used throughout the case studies to categories the level of retrofit.

Light retrofit:



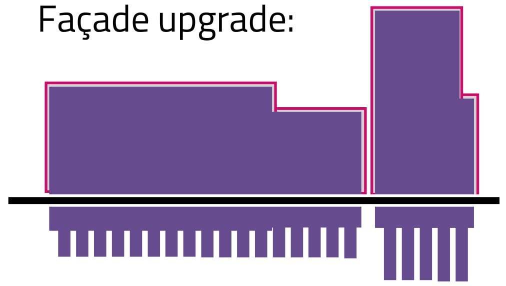
Includes one or several of these elements:
- Retention of structure
- Architectural uplift
- Some new MEP/ energy systems
- Minimal façade upgrades
- Working in an occupied building

Significant extension/ remodelling:



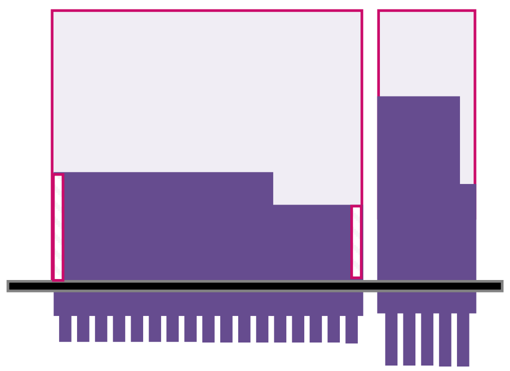
Includes one or several of these elements:
- Minimal structural strengthening
- Some additional floors
- Limited infill of existing building
- New MEP/ energy systems
- Some façade upgrades

Façade upgrade:



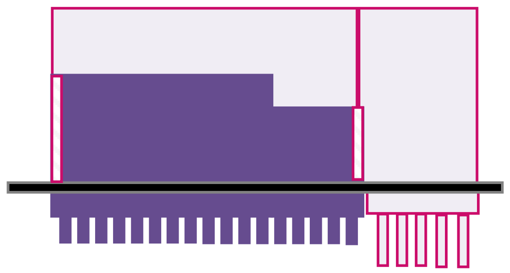
Includes one or several of these elements:
- Façade upgrades
- Retention of structure
- Architectural uplift
- Minimal new MEP/ energy systems

Deep retrofit:



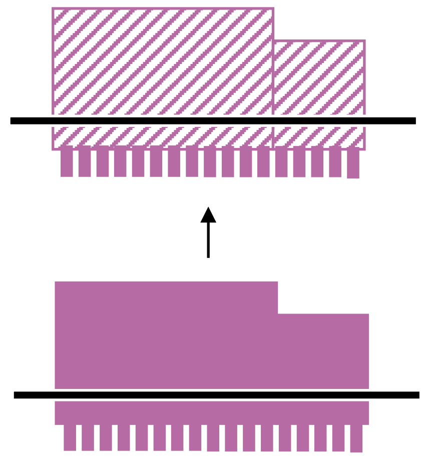
Includes one or several of these elements:
- Significant strengthening/ new structure to deliver additional floors
- Infill of existing site
- New MEP/ energy systems
- Major facade upgrades

Deep retrofit including significant extension:



Includes one or several of these elements:
- New extension added
- Significant strengthening/ new structure to deliver additional floors
- Infill of existing site
- New MEP/ energy systems
- Major facade upgrades

Building use repurpose:



Includes one or several of these elements:
- Change of use for part/ all of a building
- MEP/ façade / architectural interventions.

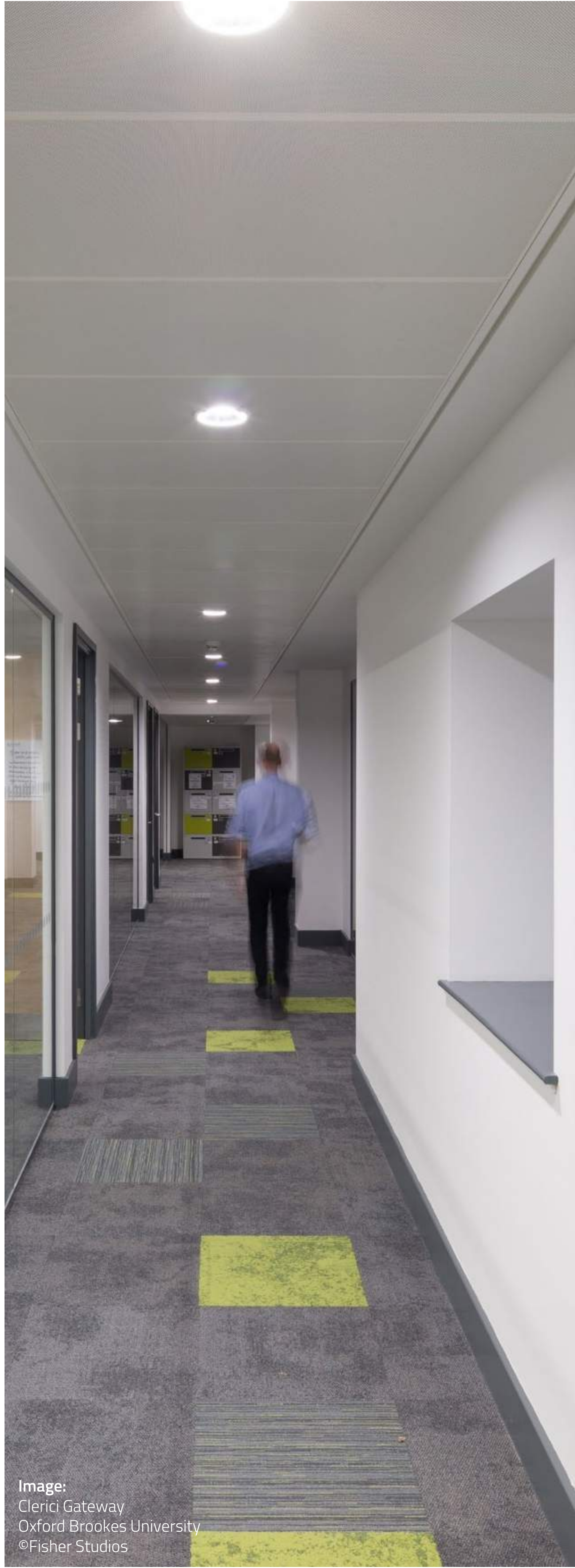
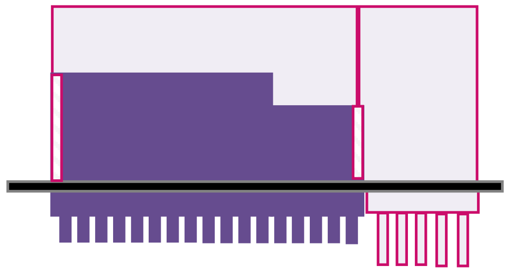


Image:
Clerici Gateway
Oxford Brookes University
©Fisher Studios

Clerici Building – Oxford Brookes University

Project Overview



Major retrofit including significant extension

Architecture

Facade

Structure

Building Services

Overview

In 2018, Oxford Brookes University's Cleriri was refurbished with the main lecture theatre demolished and replaced. The project transformed a tired, underutilised and inflexible building that had become a poor relation to newer high-profile buildings on the campus. This £22m project allowed consolidation of the campus providing a reinvigorated gateway into the wider estate offering flexibility and an increased quality of accommodation.

Client:	Oxford Brookes University
Extent of Retrofit:	Architecture, Façade, Structure & Services
Building Age:	1950s
Year of Retrofit Completion:	2018
Cost of Retrofit:	£22m
Original Building Size:	9000m^2
New Building Size:	9000m^2
Architect:	Berman Guedes Stretton
Structural Engineer	Arup
Building Services Engineer:	Arup
Façade Engineer:	Jonathan Wood Associates
Main Contractor:	McLaughlin & Harvey
Project Manager:	Turner & Townsend

Image:
Clerici Gateway
Oxford Brookes University
©Fisher Studios

Clerici Building – Oxford Brookes University

Project Considerations

Previous Condition/Issues & Main Drivers for Project

The building was originally used as library, office and teaching spaces with a feature entrance. The spaces were disorganised, cellular and inflexible leading to poor utilisation of the spaces resulting in commercial challenges for the university.

Once a flagship building for the campus, Clerici had become tired, dated and overtaken by newer more dynamic and exciting buildings on the campus. The internals were segmented and uninspiring for staff and students.

The original library areas had really poor natural lighting which limited use potential. The thermal performance of the original single glazed and thin spandrel panel façade was very poor and didn't meet current regulations and comfort standards.

The disabled circulation routes were poor with multiple changes in levels only accessible via stairs. the distance between lifts was unacceptable so improving DDA was a key focus of the retrofit.

The buildings internal layout was disorganised and sporadic with a library that was no longer in operation. Changing the use of the building allowed consolidation of the wider estate.

The building was around 50-60 years old, with minor defects and maintenance issues starting to be more prevalent, especially with the roof.

Considerations in the Decision-Making Process

The brief could be met within the existing footprint of the building therefore steering the client to retrofit being the right decision. The exception to this was the Main Hall where it was not possible to meet the brief and therefore a new build was taken forward.

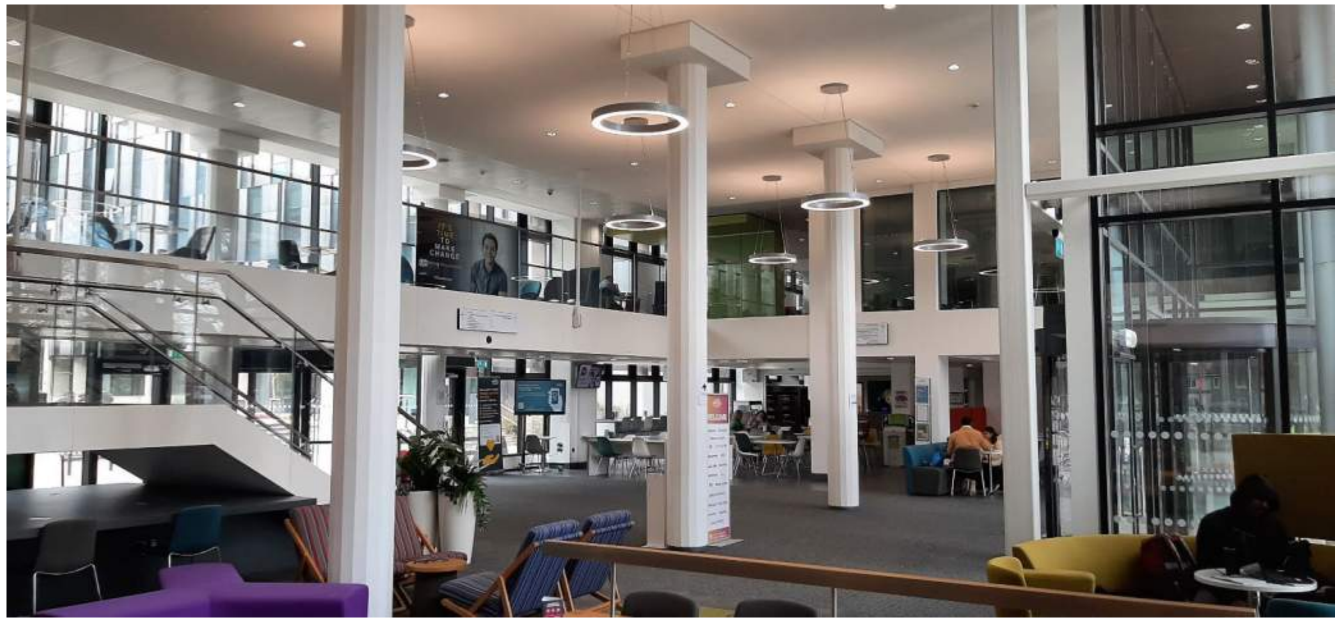
The cost of the scheme was a key factor in the decision making, with the ability to re-use the majority of the existing foundations and structure a significant cost saving measure. This was further verified at tender when one contractor submitted a demolition and new build option that come back 50% above retention tender prices.

It was vital that the key services that fed other parts of the campus and shared data lines with Oxford University and the Hospital remained live throughout the project. This was a much simpler requirement to meet with retention over new build.

Programme length was an important factor in the decision to retain as reuse of the existing structure had significant programme benefits. Reducing the planning risk and time associated was also a key factor in the decision to retrofit.

The original building entrance was a feature design with an open feel.

Over time, the entrance gained ad hoc infills and the sense of openness and grandeur was lost, whilst not addressing the poor access constraints.



The refurbished gateway opened back up with clear views straight through into the campus beyond.

Clerici Building – Oxford Brookes University

Interventions

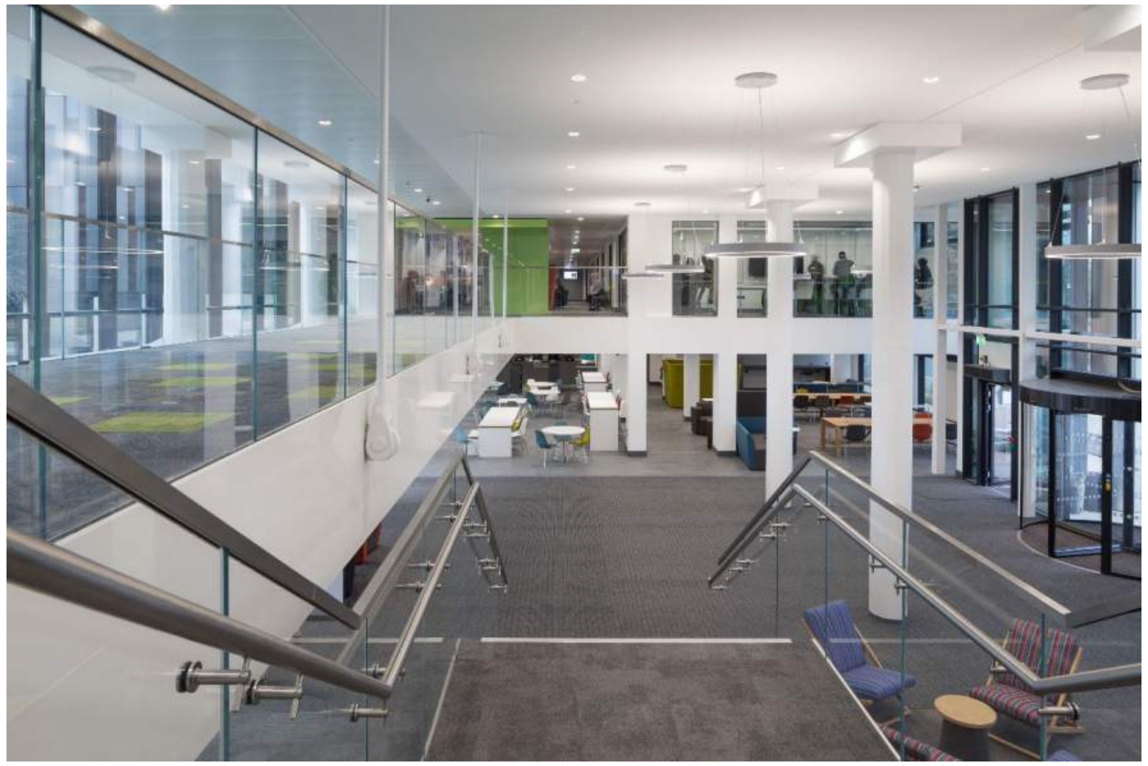
Architecture Interventions

Flexible spaces were created including a new collaborative lecture theatre to increase the utilisation. A new main hall was provided that was designed to provide flexibility via a moveable central wall.

The entire façade was replaced giving the building a fresh modern design language which complimented adjacent buildings. The internals were given an updated appearance with exposed soffits and consistent finishes throughout.

A new feature gateway entrance was provided to improve movement through the building and wider campus. Additional lifts were added to improve DDA access along with the raising of a significant portion of the ground floor to provide level access.

A new café was included as well as social spaces to create an environment where students could relax, as well as enabling them to spend longer continuous periods in the building. As well as the café, spaces were designed with the flexibility required to host conferences and talks, opening up new revenue streams.



The feature gateway entrance provides a social space and with an obvious flow internally and to the wider campus beyond ©Fisher Studios

Facade Interventions

A new aluminium façade was installed which wraps around the entire perimeter including both extension and original building, giving a fresh modern look.

The redundant library load bearing façade was replaced with a new structure and façade system that allowed significant more natural light into the area.

A new thermal envelope includes high performance insulation which has significantly improved operational energy efficiency and comfort levels. Solar shading was provided to the Southern elevation to reduce solar heat gain.

Image:
Old Library Façade

Image:
New Office Façade

The upgrade from the old library façade to the new significantly improved the external appearance, internal lighting and thermal performance ©Arup

Image:
Clerici Southern Façade
Oxford Brookes University
©Arup

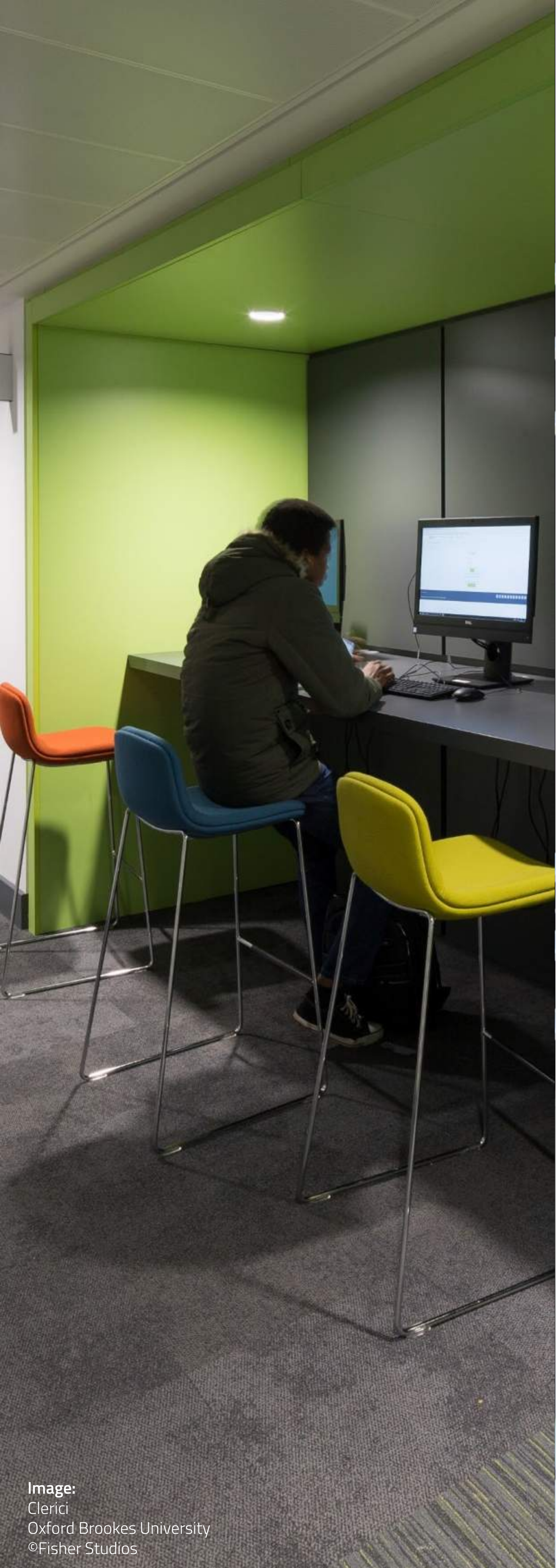


Image:
Clerici
Oxford Brookes University
©Fisher Studios

Clerici Building – Oxford Brookes University

Interventions

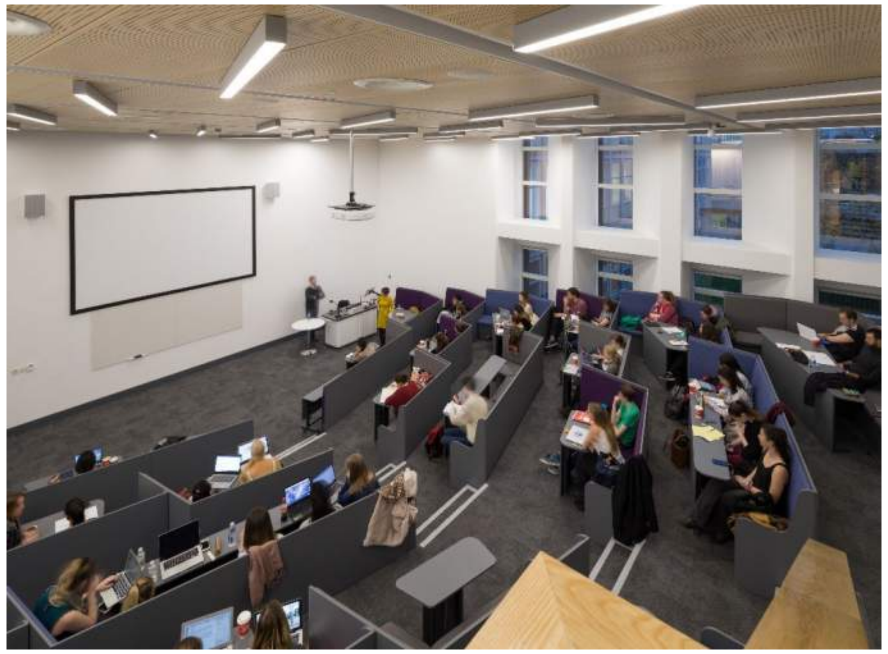
Structural Engineering Interventions

Localised strengthening of beams, columns and foundations were required to allow structural modifications including additional floor infills and suspended walkways.

The main hall was demolished and rebuilt to allow greater flexibility through retractable walls and seating. The new structure allowed the associated mechanical equipment to be installed and hidden at roof level. This was essential to provide the required thermal comfort whilst achieving planning.

An area of existing building was identified early as requiring minimal removal of structure to allow a new collaborative lecture theatre to be added. This allowed the required flexibility of space to be realised. Localised portions of slab were removed to create new lift shafts; the shafts were constructed prior to the openings to remove the need for temporary works.

There were some minor concrete repairs required, but generally the concrete frame was in reasonable condition. The exception being some significant structural remedial works to the existing roof structure. There was no record or knowledge for the reason for the remedial works, so the design team had to carry out a forensic exercise to inform the best way forward resulting in no additional works.



The opportunity for a new collaborative lecture theatre was identified at an early stage by the engineering team, and required minimal structural alterations. ©Arup

Removal of non-original structural additions was required to change the feel of the entrance gateway whilst retaining the primary structural frame. ©Arup

Building Services Engineering Interventions

The old gas boilers were stripped out with installation of a new LTHW system connected to the district heating system to ensure efficiency. Phasing of systems was an important consideration as parts of the system needed to be left operational.

A natural ventilation system was introduced where possible with the larger, densely occupied areas ventilated using mixed-mode. The inherent thermal mass of the existing concrete frame was utilised as part of the natural ventilation system.

For discrete areas requiring mechanical ventilation air handling units with built-in heat pumps were utilised that sustainably increased efficiencies of the systems.

Windows with actuators for automatic control and intelligent BMS allowing switching between the systems, minimising impact on the thermal conditions.

LED lighting was introduced with an automated control system.

Water was connected to the ring main serving other building on campus, so phasing was a key consideration.

To reduce operational carbon emissions, photovoltaic panels were installed on the roof of the existing building as well as the roof of the new Main Hall.

Clerici Building – Oxford Brookes University

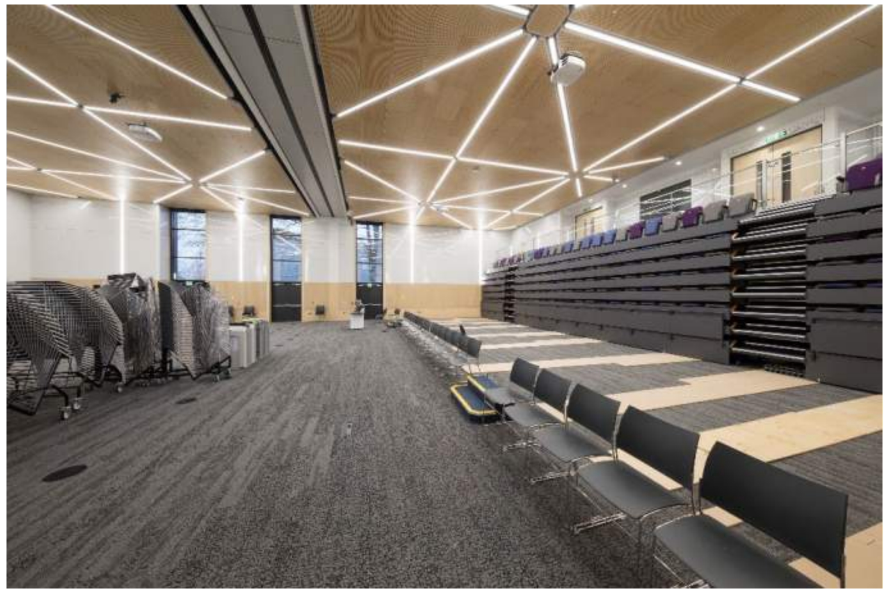
Commercial considerations & key learning points

Cost & Finance

To fund the project the University took out repayment loans informed by an outline business plan based on predicted student income and the wider consolidation of the estate that the project unlocked. With no third-party contributions the project business case needed to be stand alone.

Retrofitting of the existing building was proposed by the University and client design team as it was considered the most cost-effective and only commercially viable option. Utilising the existing structural frame and foundations saved significant costs associated with material and construction programme. The approach was verified at tender as one tenderer recommended that a new build would be cheaper and less risk. However, the demolish and new build tender quote was 50% more than the retrofit tender returns so was not pursued.

The project was delivered on time and to budget.



The new mixed use main hall provided the flexibility the University required through retractable walls and seating. ©Arup

The external look of the buildings were modernised with a consistent design language ©Arup

Benefits & Lessons Learnt

The project was considered a huge success due to the improved feel, look and flexibility of the refurbished buildings, leading to improved utilisation of the spaces and occupant happiness, wellness and pride. The new café and breakout spaces transformed how the building was used. The updated gateway created a much more inviting and obvious Southern entrance into the wider campus.

The upfront time, effort and consideration into the phasing and temporary relocation of departments paid dividends through the construction stage. Regular meetings with faculty staff, mock-ups of rooms and lecture theatres alleviated concerns and kept departments informed.

The project was engineering-led with opportunities identified at the outset of the project that were developed and constructed. The standout engineering-led successes were the collaborative lecture theatre and replaced office elevation structure that were incorporated by working with the existing structure, minimising the required intervention.

The importance of record information was highlighted during the delivery of the project. The replaced office elevation is an example of the benefits and reduced costs associated with having good record information where the existing foundations were reused without the need for investigation. Whereas the remainder of the structure required intrusive investigations which were costly and disruption and impacted on programme.

The project won the Oxford Preservation Trust - Large Building Conservation 2018 award.

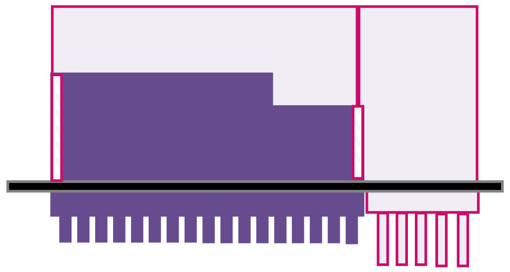
Image:
Clerici
Oxford Brookes University
©Fisher Studios

"Visitors to our modern campus which is perfect for a modern University are disbelieving when they see the plaque which says the Clerici building was opened by HRH the Duke of Edinburgh in 1963. Three of the four buildings around the central quad use the original Oxford Polytechnic buildings as their core, and only the terrazzo staircases, which I'm really glad we retained, give away their proud heritage. The fourth side of the square is just ten years old, yet there is no sense of "old" and "new", just a cohesive University that serves our students and staff well."

Mark Tugwell, Deputy Director of Estates, Oxford Brookes University

Brynmor Jones Library – University of Hull

Project Overview



Major retrofit including significant extension

Architecture

Facade

Structure

Building Services

Overview

The redevelopment of the Brynmor Jones Library at the University of Hull involved the refurbishment of two existing buildings: the original art-deco 1950s library and the iconic 1960s concrete tower sat adjacent. The scheme improved accessibility, environmental performance and the student and staff facilities. It also created public spaces including an atrium café and art gallery.

Client:	University of Hull
Extent of Retrofit:	Architecture, Façade, Structure & Services
Building Age:	1950s and 60s
Year of Retrofit Completion:	2015
Cost of Retrofit:	£28m
Original Building Size:	-
New Building Size:	16,000m2
Architect:	Sheppard Robson
Structural Engineer	Arup
Building Services Engineer:	Arup
Façade Engineer:	-
Main Contractor:	BAM
Project Manager:	-

Image:
Brynmor Jones Library
University of Hull
©Jonathan Davis –
Sheppard Robson

Image:
Brynmor Jones Library
University of Hull
©Jonathan Davis –
Sheppard Robson

Brynmor Jones Library – University of Hull
Project Considerations

Previous Condition/Issues & Main Drivers for Project

The university wanted to redefine the library, which sat at the heart of the campus, to create a unifying space for students, staff and the public.

The library and the tower were considered outdated and disjointed, having not experienced a major renovation in many years. They needed to be brought up to 21st century learning standards.

In the past, several internal remodelling projects had introduced mezzanine floors. These affected the circulation and general environment within the library, which needed improving.

Aesthetically, the library was a mishmash of conflicting architectural styles, which the university wanted to bring together for a more cohesive look.

New social spaces ©Jonathan Davis – Sheppard Robson

New breakout study spaces ©Jonathan Davis – Sheppard Robson

Considerations in the Decision-Making Process

The university was keen that the students and staff felt valued throughout the works. Several workshops were held between the design team and end users. This was fundamental to informing the design and ensuring that the architecture and services strategy met the stakeholders' objectives. These meetings continued throughout the construction phase of the project.

The library needed to remain open during the works. Noisy works were usually completed out of hours or programmed to commence in the summer holidays. Close co-ordination with the university was achieved via weekly meetings with the library staff. Students were updated using visual displays and presentations at various locations within the library.

As Arup designed the Tower in the 1950s, they had access to the original structural drawings, reinforcement details and calculations, which made planning the works significantly easier, and removed risk due to unknowns.

Brynmor Jones Library – University of Hull

Interventions

Architecture Interventions

The refurbishment introduced a 2,500m² welcome space, an 80-seater café, a gallery and an exhibition hall.

A new four-storey central atrium was added to connect the two buildings, alongside a new main entrance connecting the library with the surrounding public realm. This extension contained two additional lifts and a feature staircase, which resolved the level differences between the two buildings and reduced traffic elsewhere in the building.

A wide range of social spaces were added throughout the building, including the open plan ground floor, which is now open to public during the daytime.

In the East building, the ground mezzanine floors were removed, and the vertical circulation was altered. The West Tower podium levels were remodelled to provide a new entrance, cafe and communal learning space. These alterations aimed to improve circulation and enjoyment of the buildings.

The new art gallery ©Jonathan Davis – Sheppard Robson

New entrance and atrium ©Jonathan Davis – Sheppard Robson

Facade Interventions

The 1960s tiled podium of the Brynmor Jones Library was fully reclad, featuring large areas of glass, brise-soleil and masonry to produce a more contemporary facade and create a striking library entrance.

External solar shading and high-performance solar glazing were introduced, with the dual benefit of improving the thermal performance of the façade and reducing unwanted solar gain within the most occupied spaces.

On the ground floor of the East Building, specialist glazing was added to protect valuable artwork, which would be housed in the Gallery and Exhibition spaces, from damaging ultra-violet radiation.

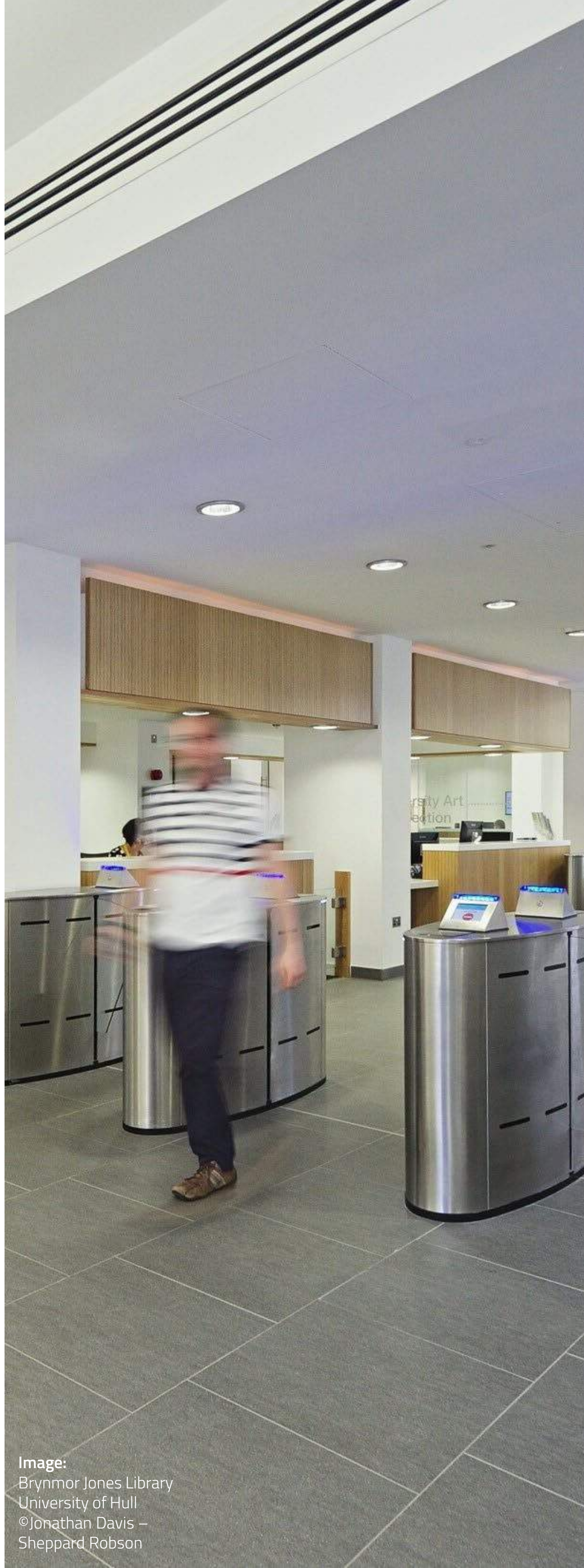


Image:
Brynmor Jones Library
University of Hull
©Jonathan Davis –
Sheppard Robson

Image:
Brynmor Jones Library
University of Hull
©Jonathan Davis – Sheppard Robson

Brynmor Jones Library – University of Hull
Interventions

Structural Engineering Interventions

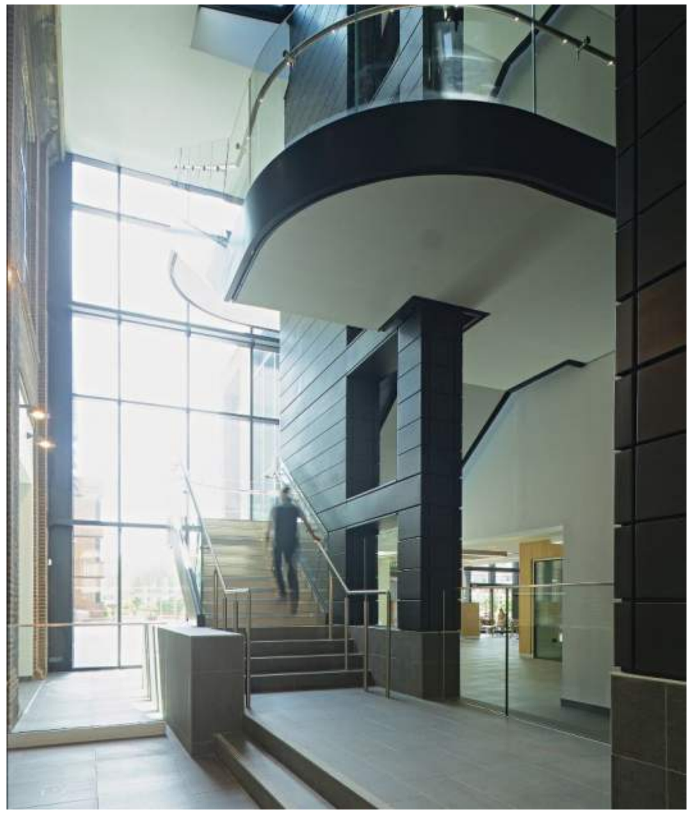
The scheme looked to work with the existing structure as much as possible, to reduce the amount of demolition and new construction materials required. At the beginning of the project, significant surveys and testing were conducted to provide sufficient information for a comprehensive structural analysis.

A series of complex structural strengthening works were required to create new open spaces, such as strengthening columns after the removal of floors, and adapting to increased loads from higher building services requirements. Careful analysis was carried out to ensure the most sustainable structural techniques were used. Where possible, the extent of works was minimised by justifying the capacity of the existing building through investigation and calculation.

In the East Building, a lightweight mezzanine floor was removed and replaced with a clear span steel mezzanine.

In the Tower, the double storey basement was extended. Piles were installed directly adjacent to the deep basement, and a deep excavation was conducted involving considerable temporary works. Differential settlement between the existing and new basements was also a major concern. To address this, ground settlement models were built to simulate how the interaction would behave.

A lightweight feature stair design involved cantilevering in both directions from a single pair of columns – these were modelled to ensure they would respond appropriately to vibrations.



New staircase ©Jonathan Davis – Sheppard Robson

Contemporary study spaces ©Jonathan Davis – Sheppard Robson

Building Services Engineering Interventions

New demand-led variable volume ventilation systems have been introduced, including efficient heat recovery systems and automatic controls that cut energy use by reducing the supply of external air when not required.

The new Art Gallery and Exhibition spaces were provided with close control ventilation systems that achieve environmental conditions to Tate specifications.

A rainwater harvesting system has been introduced into the existing system. This allows rainwater to be reintroduced to the building for use in WC flushing.

A new energy efficient lighting control system enables extended hours of use by automatically disabling lighting within unoccupied spaces.

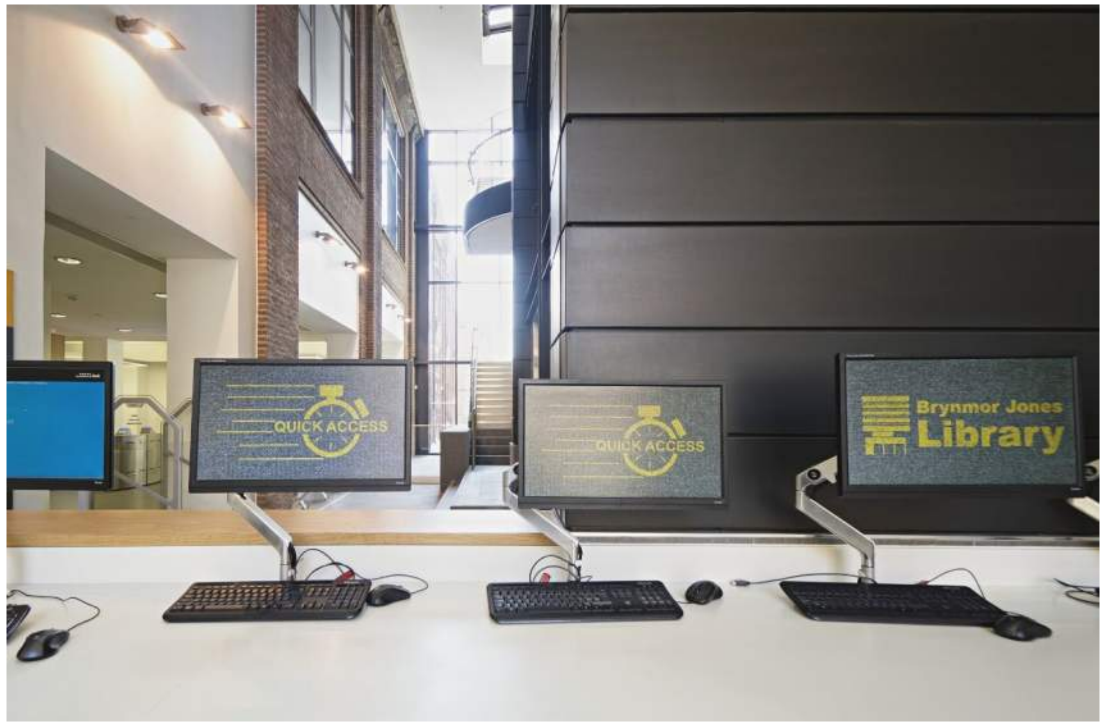
Brynmor Jones Library – University of Hull
Commercial considerations & key learning points

Cost & Finance

It was vital that the library remained fully functional throughout the programme. This reduced overheads associated with relocating the library or temporarily housing stock, staff and students.

However, keeping the building live was a major challenge. Surveying and works would have been much easier if the building could have been shut. It prolonged the programme and added complexity; the costs and difficulties associated with this were initially underestimated.

New income streams were created from the café ©Jonathan Davis – Sheppard Robson



A library fit for modern study methods ©Jonathan Davis – Sheppard Robson

Benefits & Lessons Learnt

Good communication ensured that disruption was minimised, and each individual phase was handed over on time, to a high standard for immediate use by the library. This was all achieved whilst keeping the library fully operational, with no book or resource unavailable throughout the entire construction phase of the project.

By demolishing very little of the existing building, the embodied carbon of the project was kept to a minimum.

The design team found that greater time could have been spent on surveying the building at the beginning, to ensure disciplines were aligned and risks minimised. It was harder to survey a live building.

Regional Award, RIBA
Yorkshire Awards (2016)

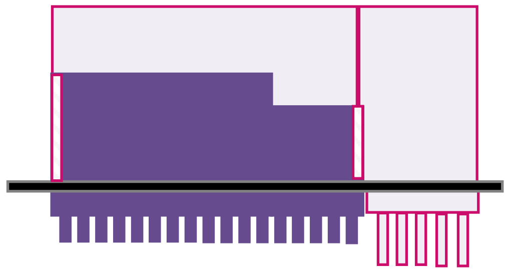
Good Mark – Hull Civic Society

BREEAM Very Good

Image:
Brynmor Jones Library
University of Hull
©Jonathan Davis –
Sheppard Robson

George Green Library – University of Nottingham

Project Overview



Major retrofit including significant extension

Architecture

Facade

Structure

Building Services

Overview

In 2017, the University of Nottingham's George Green Library was refurbished and extended, transforming a tired 1960s building into a modern, light-filled space at the heart of the University Park campus.

This £16m project saw the library double in capacity, greatly improving library services for students and enhancing the appearance of the science and engineering departments. It has since become a hub for students and staff across a wide range of disciplines.

Client:	University of Nottingham
Extent of Retrofit:	Architecture, Façade, Structure & Services
Building Age:	1960s
Year of Retrofit Completion:	2017
Cost of Retrofit:	£16m
Original Building Size:	3700m^2
New Building Size:	7400m^2
Architect:	Hopkins Architects
Structural Engineer	Arup
Building Services Engineer:	Arup
Façade Engineer:	Billings Design Associates
Main Contractor:	Galliford Try
Project Manager:	Faithful and Gould

Image:
George Green Library
University of Nottingham
©Martine Hamilton Knight/Builtvision

Image:
George Green Library
University of Nottingham
©Martine Hamilton Knight/Builtvision

George Green Library – University of Nottingham
Project Considerations

Previous Condition/Issues & Main Drivers for Project

The three-storey concrete building was used as a library primarily serving science and engineering students. The available spaces felt cramped, and there was insufficient capacity to accommodate the growing departments. Areas within the building were relatively cellular, with limited flexibility for use other than private study.

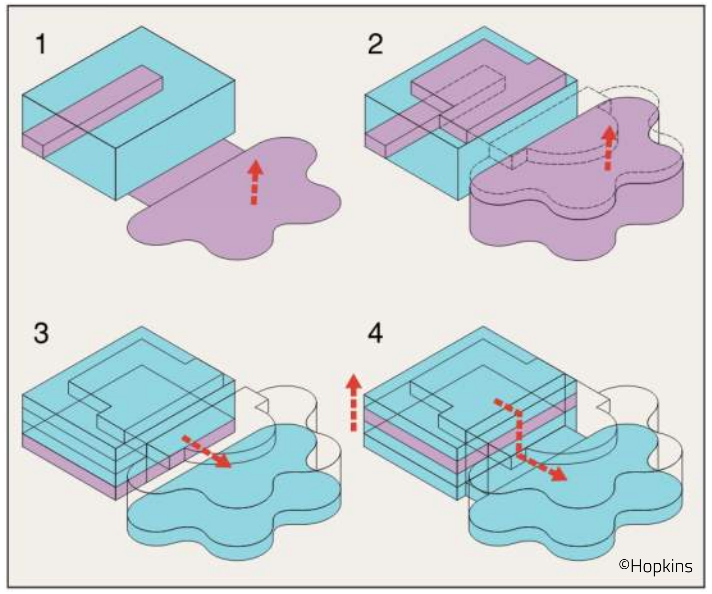
The building looked unimaginative and unappealing from the outside, at odds with the surrounding newer buildings on the campus. Internally the spaces were not very student friendly, and looked tired and uninviting, with students often preferring to use spaces in other buildings instead.

The useable spaces felt poor quality, with limited floor to ceiling heights and poor lighting and ventilation.

The circulation routes through the building were poor, often indirect and unintuitive, meaning some spaces were rarely used.

The building was around 50-60 years old, with minor defects and maintenance issues starting to be more prevalent.

The original building looked boring and unappealing from the outside ©Arup



Developing a phasing strategy to keep the library in operation was critical in the decision-making process. The active library is shown in blue and construction and refurbishment in purple.

Considerations in the Decision-Making Process

A design competition was run to determine the next steps. Shortlisted bids included both retrofit and new build options. The winning bid demonstrated the brief could be achieved through retrofit to create a larger modern facility, containing high quality flexible spaces, while keeping the library open and operational throughout construction.

The cost of the scheme was a key factor in the decision making, with the ability to re-use the majority of the existing foundations and structure being a significant cost saving measure.

It was vital the building could remain operational throughout the construction as there were no alternative locations to temporarily relocate the library. A phased retrofit solution offered this scenario.

As the original structural engineer, Arup had copies of the initial 1960's drawings in their archives, which reduced the cost of investigations that would have been required to understand the original structural design intent.

George Green Library – University of Nottingham
Interventions

Architecture Interventions

As well as the existing building undergoing a retrofit, a new 5-storey extension was added, doubling the capacity to meet the requirements of the growing departments. A variety of learning areas were incorporated including new flexible spaces located in the extension, while the required cellular spaces were retained in the original building.

A new façade was installed on the existing building to create a modern unifying aesthetic across old and new. Internally the original spaces were stripped out and re-furnished to create a consistent modern aesthetic across the whole building.

An atrium was used to connect the existing building with the extension, maximising natural daylight in both. This formed an airy, welcoming foyer for the library and enhanced visibility between floors. Book stacks were located centrally within floorplates, with a "free flowing" perimeter area designed for open plan study to achieve good lighting. Double height spaces were created in both the extension and original building to create a light airy environment.

Two new entrances were created, improving connectivity between different sides of the campus. New DDA compliant lifts were added to improve accessibility, and the circulation routes around the building simplified.

A new café was included as well as social spaces to create an environment where students could relax, enabling them to spend longer continuous periods in the building. As well as the café, spaces were designed with the flexibility required to host conferences and external talks, opening up new revenue streams.

The free flowing areas around the perimeter created well lit open plan study spaces ©Martine Hamilton Knight/Builtvision

The upgrade from the old façade to the new improved the external appearance, internal lighting and thermal performance ©Martine Hamilton Knight/Builtvision

Facade Interventions

A new aluminium façade was installed which wraps around the entire perimeter of both the extension and original building. The curved profile uses vertical mullions and straight double-glazed panels, with recessed curved aluminium spandrel panels that help express the floor levels.

Vertical fins mimic the original form of the façade, whilst also providing solar shading to control internal temperature gains.

A new thermal envelope includes high performance insulation which has significantly improved operational energy efficiency and comfort levels.

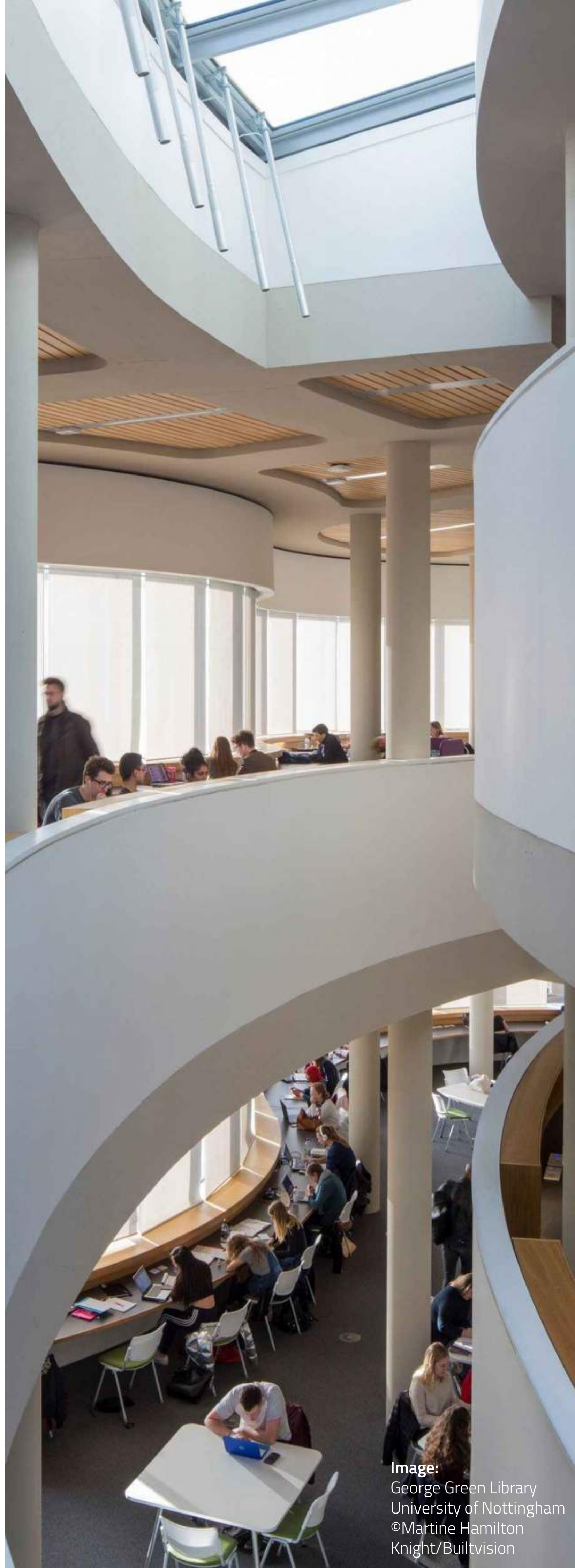


Image:
George Green Library
University of Nottingham
©Martine Hamilton Knight/Builtvision

Image:
George Green Library
University of Nottingham
©Martine Hamilton Knight/Builtvision

George Green Library – University of Nottingham
Interventions

Structural Engineering Interventions

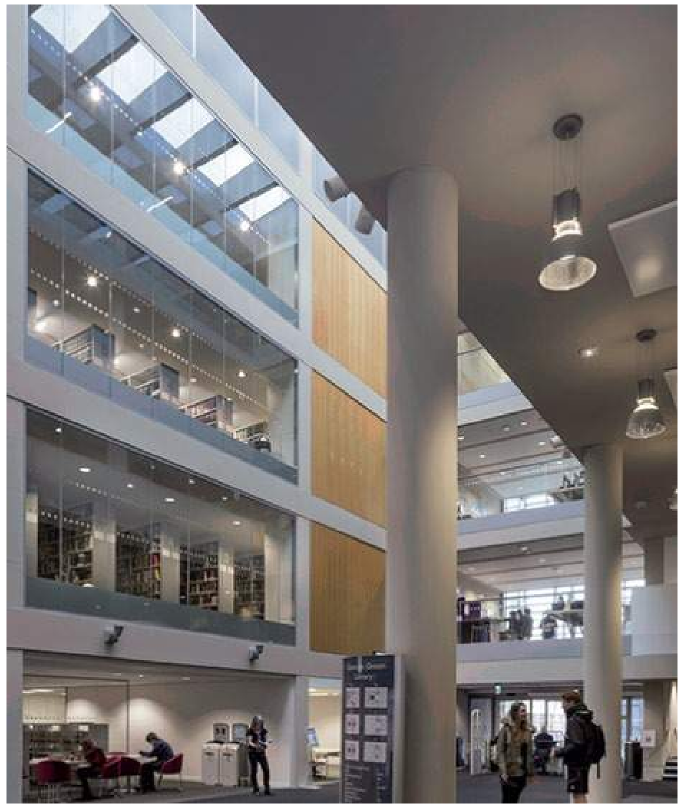
The basic design philosophy was to minimise alterations to the existing structure to limit the required enhancement of the building. To avoid strengthening works, the space planning took account of the original design loads to ensure the new loading did not exceed these.

In one or two locations this was not possible, including the library roof which needed to accommodate heavy mechanical plant. Following concrete sampling and detailed structural assessments the columns were shown to have just enough capacity. A new steel support frame was therefore installed on the roof to support new plant.

The existing basement had a constrained floor to ceiling height which did not meet modern building regulations for headroom, daylight or accessibility. It was therefore decided the floor and foundations needed to be lowered to create a more usable floor. Lowering the foundations and increasing the column lengths posed a significant design challenge, but an innovative temporary works scheme made this possible.

After the existing building was vacated, the finishes were removed exposing major defects that affected the structural strength of the building. Following detailed testing a repair strategy was developed that managed to offer significant programme and cost savings with minimal area loss.

The floor level was lowered in the basement to meet modern standards ©Arup



The new central atrium helped improve circulation and lighting ©Martine Hamilton Knight/Builtvision

Building Services Engineering Interventions

A completely new building servicing system was installed which included a closed loop ground source heat pump system. Solar gains were utilised where possible and solar shading used where required. A mixed-mode ventilation system was used, utilising the energy saving and user adjustability benefits of natural ventilation. Concrete surfaces were deliberately left exposed to use the thermal mass to limit internal temperature fluctuations.

New plant equipment consisting of air-handling and chiller units was located at roof level over the existing building, to serve both the existing building and extension.

The electrics and lighting were stripped out and replaced, ensuring up to date safety and lighting requirements were met as well as providing ample power and data connections to serve all the different spaces.

Water consumption was minimised through a rainwater harvesting system. The lower-level roof of the extension contained a sedum roof as part of a sustainable drainage strategy to minimise flood risk and protect against climate change. This was particularly important given the sunk basement structure.

To reduce operational carbon emissions, photovoltaic panels were installed on the roof of the existing building as well as the upper roof of the extension.

Together, these features helped the building achieve a BREEAM rating of "Excellent" upon completion, with a 25% improvement to energy efficiency.

George Green Library – University of Nottingham

Commercial considerations & key learning points

Cost & Finance

It was important to the university that the building remained open and operational throughout construction. This enabled the library to continue to function and service the needs of the many science and engineering students and staff, without additional costs incurred from temporary accommodation. Library facilities could continue to run effectively by being contained in the existing half of the building whilst the extension was constructed, before transferring into the new half during the refurbishment phase.

The main financial driver was to ensure the building remained operational during construction to prevent additional costs incurred from temporary accommodation. While the upgrade had an up-front cost of approximately £16m, the improved thermal envelope, more efficient heating, ventilation, water and lighting systems as well as the installation of renewable energy sources, have collectively reduced the operational and maintenance costs, as well as extending the design life and insurance premiums of the building. New spaces created, such as the cafe and areas available for hire, have also brought in new revenue streams. This project is therefore a great demonstration of the significant financial and environmental benefits a successful retrofit can have.

A few unexpected costs arose on the project from structural repair work for hidden defects uncovered during the construction. These costs were slightly larger than had been anticipated for contingency, resulting in the project being slightly over budget.

The completed building has been considered a major success
©Martine Hamilton Knight/Builtvision

The project won several design awards
©Martine Hamilton Knight/Builtvision

Benefits & Lessons Learnt

The project has been considered a major success for the university, with utilisation of the building seeing a significant improvement. Students love working and spending time in the different spaces in the building, including the social areas and café. While the budget was slightly exceeded, the building delivered above expectations. The university has since applied the experience and confidence gained from George Green Library to other retrofit projects on campus.

The main lesson learnt was the time required for up front detailed surveys. Had this been greater, some of the additional costs and delays to programme might have been reduced or avoided.

The project achieved BREEAM Excellent rating.

The project won the RIBA East Midlands Award and the Sustainability Award in 2017, the Concrete Society Award in 2018

"George Green Library has become one of the campus's most popular buildings, this is primarily due to its layout and interesting spaces that have been created by retrofitting a historic building with modern interventions. The university has a real passion for refurbishment projects and ensuring buildings within our estate are given a new lease of life for generations to come."

James Hale, Senior Capital Projects Officer, The University of Nottingham

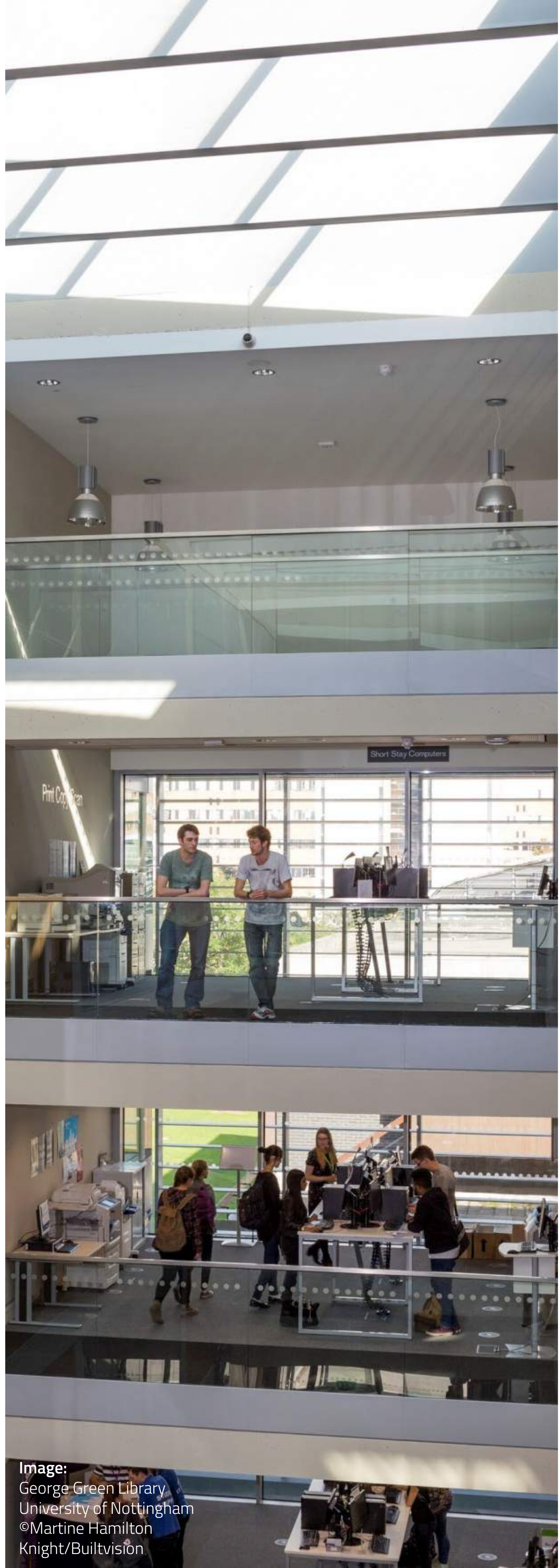
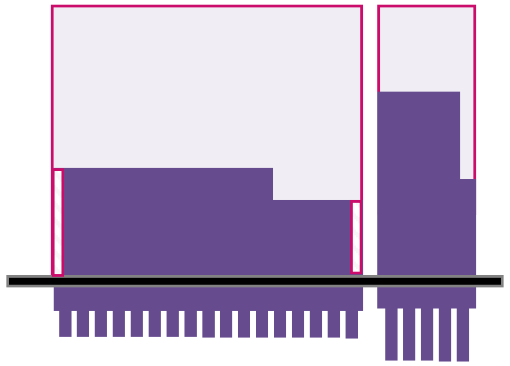


Image:
George Green Library
University of Nottingham
©Martine Hamilton Knight/Builtvision

Engineering Building – University of Leicester
Project Overview



Major retrofit

Overview

The Engineering Building is an architecturally significant Grade II listed mid-century tower on the University of Leicester's campus. This project involved the refurbishment of the iconic glazed roof structure, and the upgrade of the internal services. Named among the 10 best post-war buildings in Britain by Historic England in 2015, it was vital that the building's appearance was preserved, but that it perform to 21st Century standards.

Client:	University of Leicester
Extent of Retrofit:	Façade, Structure & Services
Building Age:	1960s
Year of Retrofit Completion:	2017
Cost of Retrofit:	£19.5m
Original Building Size:	-
New Building Size:	-
Architect:	Arup
Structural Engineer	Arup
Building Services Engineer:	Arup
Façade Engineer:	Arup
Main Contractor:	Lendlease
Project Manager:	Pulse

Image:
Engineering Building
©University of Leicester / Simon Kennedy

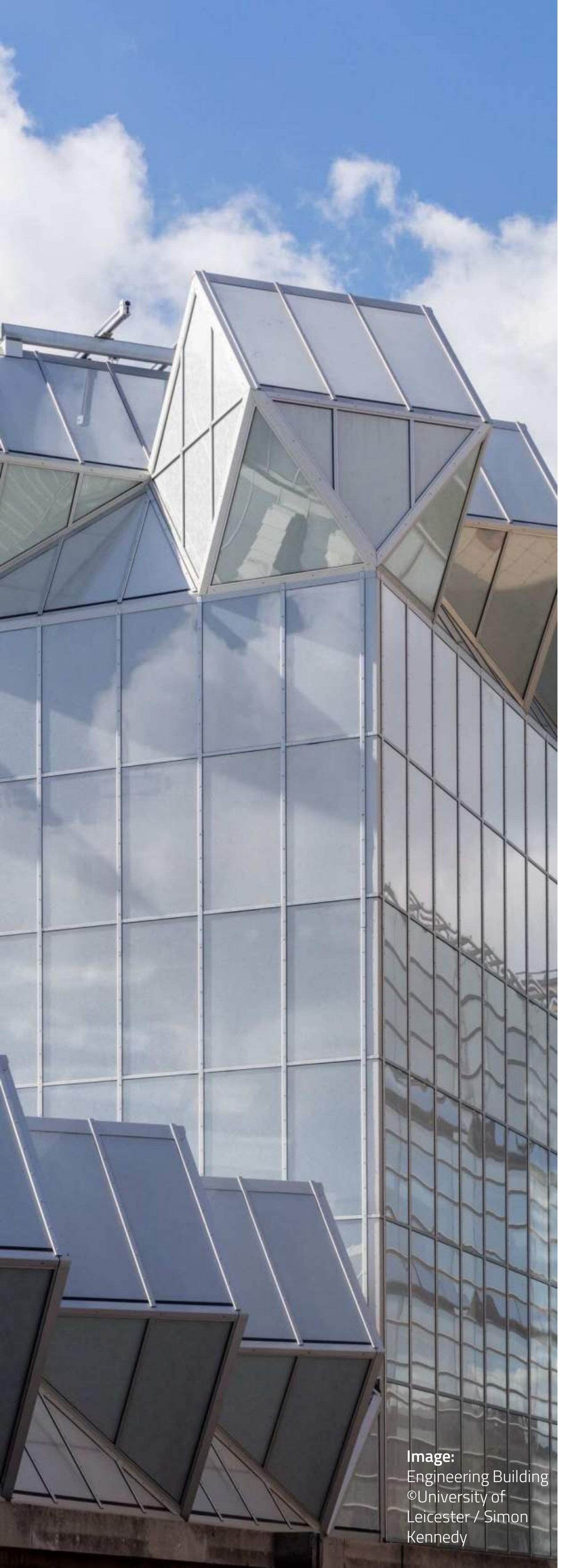


Image:
Engineering Building ©University of Leicester / Simon Kennedy

Engineering Building – University of Leicester
Project Considerations

Previous Condition/Issues & Main Drivers for Project

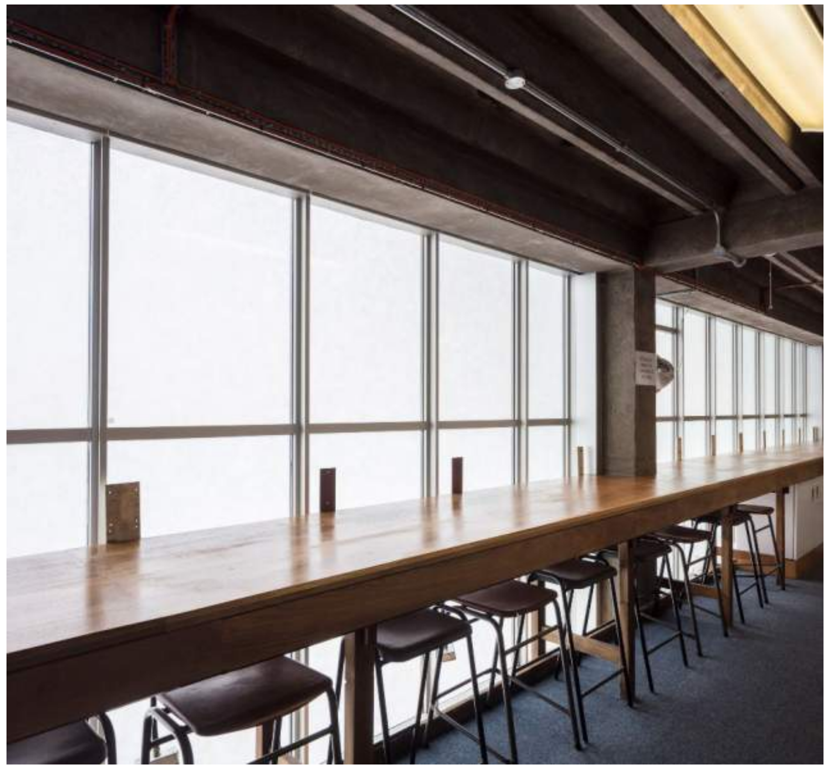
The building is architecturally significant, being a Grade II* listed example of 20th Century architecture. The university and other heritage stakeholders wanted to extend the life of the building in its current form.

Thermal and occupant comfort was noticeably bad in winter and summer. The building also leaked and suffered drafts.

The thin glass roof structure made access for cleaning and repairs impossible – by 2011 it was completely out of bounds. The roof was unmaintainable, which was shortening its life and could have led to safety concerns.

Some fixings were coming out of the vertical glazing, which had the potential to cause a stability issue.

Inside the workshops ©University of Leicester/Simon Kennedy



Work benches and study spaces ©University of Leicester/Simon Kennedy

Considerations in the Decision-Making Process

As a listed building, all decisions had to be made to the satisfaction of the local authority conservation officer, Historic England and the Twentieth Century Society. A Project Charter was signed by the university, project team and stakeholders as a basis for everyone to co-operate in preserving the historic status of the building.

Previous attempts (by a different design team) to improve comfort in the building by raising the glazed roof had provoked strong push back in the heritage community, so the university were keen to find a solution that preserved the architectural form in its entirety.

Challenges had to be overcome, such as how to access the glazed structure without causing further damage. The framing of the façade was bespoke and needed careful consideration from all parties to ensure the new system worked.

The main aims of the project included achieving drainage and temperature control, the provision of safe access systems for future maintenance, a fifty-year life expectancy, and minimal disruption of the department. The final point required the building to remain operational throughout the works.

In all, it took four and a half years of surveys, analysis, design and negotiation before the dismantling of the glazing began in 2015. Practical completion was in 2017.

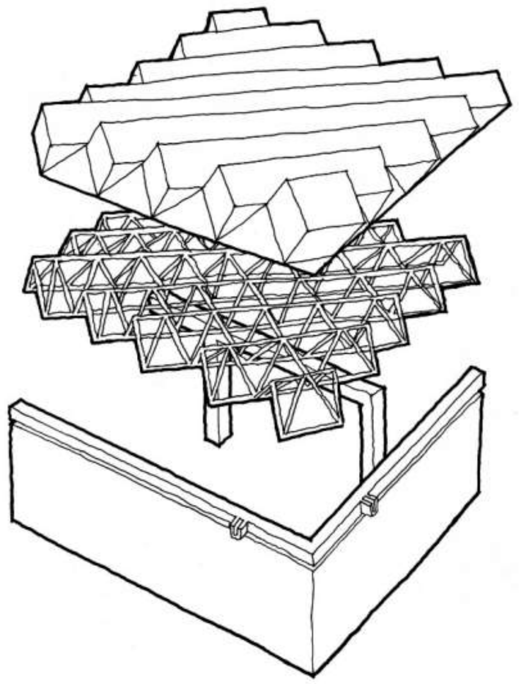
Engineering Building – University of Leicester
Interventions

Architecture Interventions

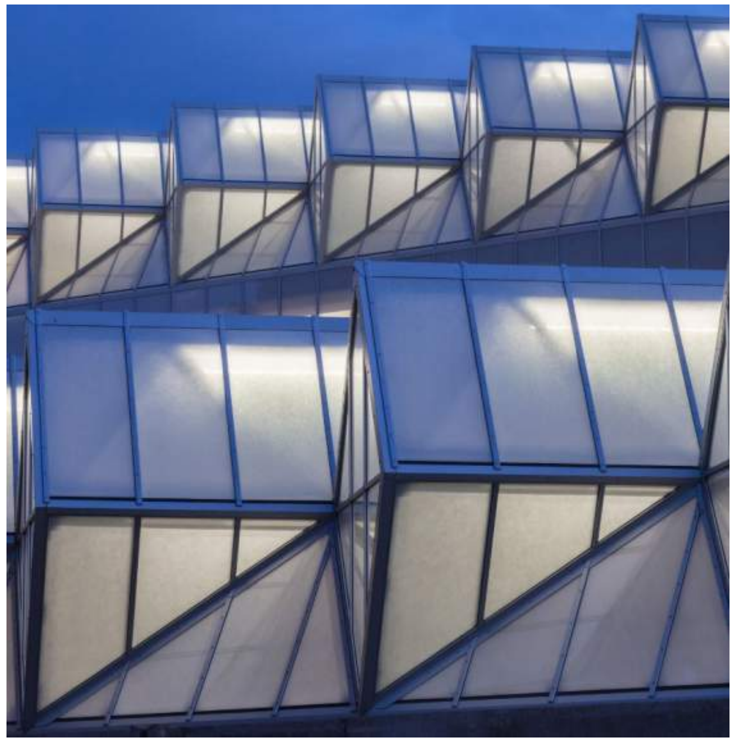
Since the building is Grade II* listed, and of significant architectural importance, it was not the intention of the project to alter the appearance of the building. Therefore, no extensions or remodelling were included in the scheme.

Instead, the project focused on retaining the architectural features, whilst modernising the façade and MEP to bring the building up to modern efficiency and comfort levels. This in turn extended the life of the building, and helped resolve some maintenance issues associated with the highly fragile glazed roof structure.

Great thought was put into the replacement of all glazed elements, to ensure the visual weight remained similar to the original, whilst achieving the modern-day strength and comfort requirements.



A sketch showing the glazing and truss layers making up the workshop ©Thomas Pearson @ Arup



The glazing at night ©University of Leicester/Simon Kennedy

Facade Interventions

The appearance of the façade was retained in line with heritage guidance, but its functionality was improved to bring comfort and efficiency up to 21st Century standards. In its original form, the glazed roof acted as a giant greenhouse, which was not conducive to learning or work. Building physics modelling including occupant comfort analysis was carried out to compare glazing options.

2500 glass panels on the roof were replaced with double glazed units. Each glazing unit had to be unique to fit with the existing warped structure.

The new envelope is watertight and airtight, with natural ventilation openings to relieve high temperatures during summer.

In addition to having poor functionality, the previous glazing was highly fragile and impossible to maintain. Replacing it with more robust units will prolong the unique building's life. To ensure maintenance of the new roof, slim rails and moving trolley units were installed.

Image:
Engineering Building ©University of Leicester / Simon Kennedy

Image: Engineering Building ©University of Leicester / Simon Kennedy

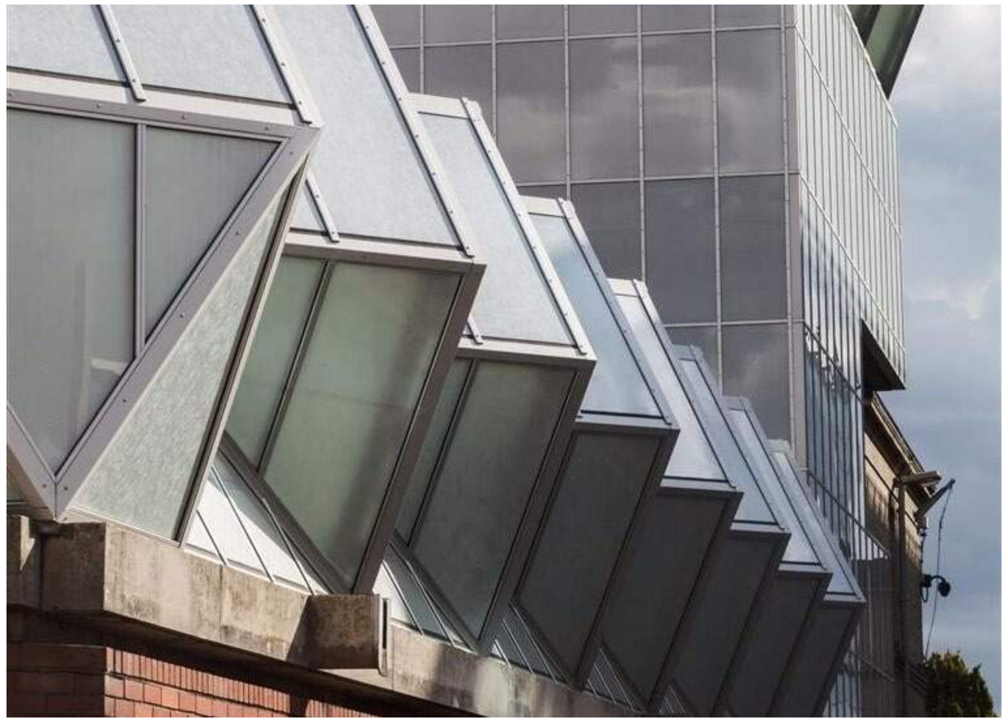
Engineering Building – University of Leicester
Interventions

Structural Engineering Interventions

The form of the building was not changed, so there were no new structural elements to create extensions or new architectural forms on this project. Below the roof, it was concluded that the primary concrete and steel structure could be preserved, whilst the glass and aluminium would be fully replaced.

However, structural consideration was still required, as the new double-glazed units were twice as heavy as the original single-glazed ones.

Furthermore, modern standards suggested that the original roof structure might not be able to withstand snow loading as it is determined today. Arup retrieved the 1950s codes, reconciled modern loading with 1950s material strengths and proved the structure could withstand the loading, minimising the need for major structural intervention, a great example of undertaking engineering to implement a 'do nothing' approach.



The glazing in daytime ©University of Leicester/Simon Kennedy

Globe fan ventilation features ©University of Leicester/Simon Kennedy

Building Services Engineering Interventions

A significant number of original building services were replaced to meet modern standards and needs. The new elements were hidden in floor trenches or bespoke-made to complement the functional aesthetic of the interior spaces., whilst the new plant was located in a discrete area at the rear of the building.

Where possible, the original components were refurbished and refitted. This included under-desk convector units and globe-shaped through-wall fans. 19 No. additional replica globe fans were produced to provide additional ventilation.

Natural ventilation and cooling systems were fitted to relieve high temperatures in summer. Various options were considered, including openings in the new roof structure itself, but these were discounted as they were not authentic to the original aesthetics. This was offset by major savings on heating during winter.

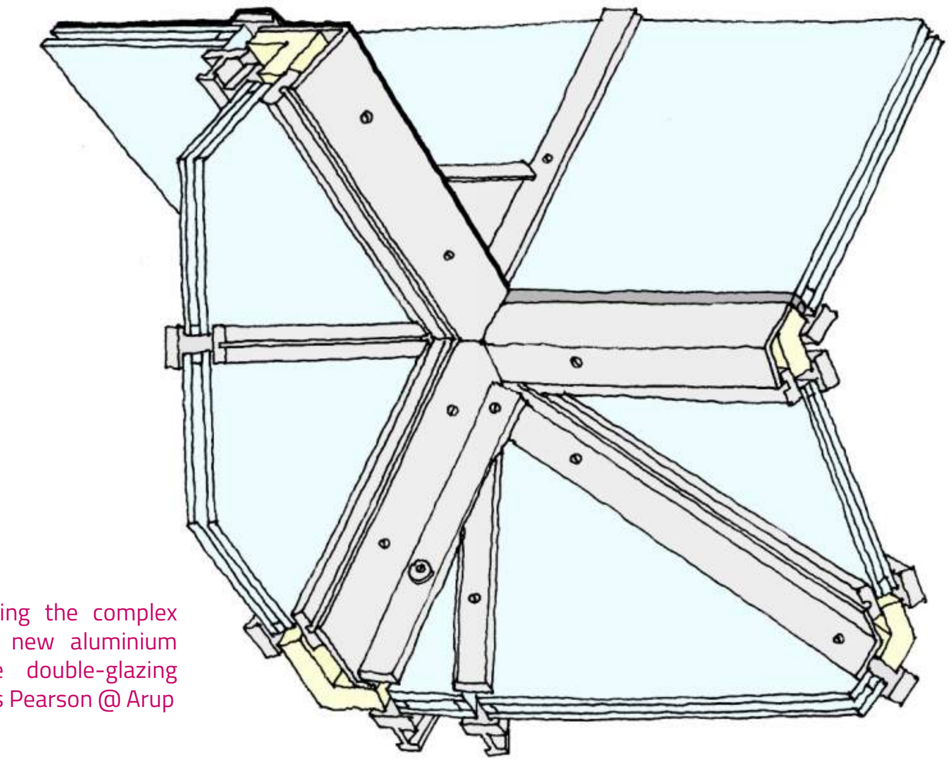
Zonal controls allow for different climatic responses in each area and reduce system conflict.

Engineering Building – University of Leicester
Commercial considerations & key learning points

Cost & Finance

Estimated costs rose in the initial stages of the project, leading to a standstill of approximately 18 months.

During the dismantling and reconstruction phase, relocation costs were avoided by keeping the department open throughout. This was achieved by the erection of tension nets directly beneath the roof glazing, which avoided the need for crash-deck scaffolding. Large scaffold roofs were erected above the building.



A sketch showing the complex buildup of the new aluminium frame for the double-glazing panels ©Thomas Pearson @ Arup

The Engineering Building from afar ©University of Leicester/Simon Kennedy

Benefits & Lessons Learnt

The new interventions to both the services and façade have created a comfortable environment with functional heating, cooling and ventilation.

The winter energy savings have been extensive, thanks to the modernised façade system. An unfortunate side effect of being true to the original glazed design is that it does heat in summer, as it now effectively acts as a double-glazed greenhouse. These effects are likely to worsen with climate change. However, on balance, it is preferable that savings are made in winter, when the building is most highly occupied. As with many university buildings, occupancy is lower in summer, so the negative impacts are felt less.

More surveys of greater quality might have made the project run more smoothly. This is a common thread across many case studies, and reinforces the importance of accurate data gathering at an early stage in a refurbishment project..

East Midlands Property Dinner Awards 2017 – Construction Project of the Year

SFE Façade of the Year 2018 – Refurbishment

AJ Retrofit Awards 2017 - Listed Building over £5m - Shortlist

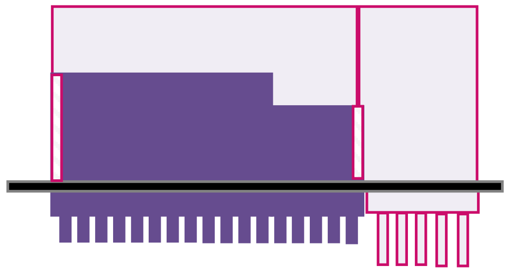
'The Engineering Building is significant to the history and heritage of the University and at the centre of our estate. The building is exceptional and presents unique challenges which were embodied in the restoration of the glass roof over the engineering workshops. Throughout this undertaking the collaboration and solution finding across the project team was excellent. The successful completion of the project is a tribute to the original work by Stirling and Gowan and has enabled the continued use of the building by future generations of engineering staff and students.'

Richard Thomas, Deputy Director of Estates, University of Leicester

Image:
Engineering Building ©University of Leicester / Simon Kennedy

Learning and Teaching Building – University of Strathclyde

Project Overview



Major retrofit including significant extension

Architecture

Facade

Structure

Building Services

Overview

The University of Strathclyde's aim was to bring diverse facilities together under one roof to enhance the student experience. The final scheme joined two buildings (the Colville Building and the Grade B listed Architecture Building), refurbishing as much of the existing structures as possible and adding a new hub to join the two. Adaptive reuse created a sustainable new home for the student union, student support services as well as Strathclyde Doctoral School, along with a 400-seat lecture theatre and breakout spaces.

Client:	University of Strathclyde
Extent of Retrofit:	Architecture, Façade, Structure & Services
Building Age:	1960s
Year of Retrofit Completion:	2021
Cost of Retrofit:	£40m
Original Building Size:	-
New Building Size:	20,000m2
Architect:	BDP
Structural Engineer	Arup
Building Services Engineer:	Hulley and Kirkwood
Façade Engineer:	Hansen
Main Contractor:	Balfour Beatty PLC
Project Manager:	-

Image:
Learning and Teaching Building
University of Strathclyde
© David Barbour

Image:
Learning and Teaching Building
University of Strathclyde
© David Barbour

Learning and Teaching Building – University of Strathclyde
Project Considerations

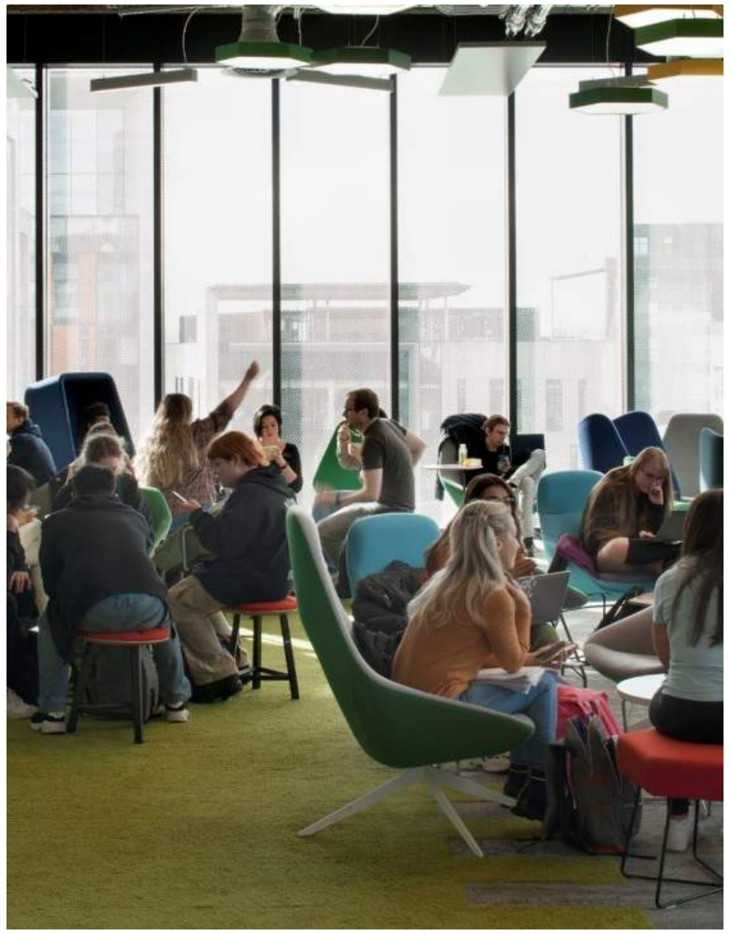
Previous Condition/Issues & Main Drivers for Project

The existing buildings were outdated and disjointed, with poor circulation and facilities not suitable for modern learning.

The university wanted a flagship building that could bring together multiple facilities – the SU, student support services, the Doctoral School, and various teaching and learning zones.

This project was much more about reconfiguring space than dealing with dilapidated buildings – the Colville building, for instance, was actually in a reasonable condition structurally, and very few repairs were required.

The buildings were closed throughout the works.



Students enjoying the breakout study spaces ©David Barbour

The original Colville Building ©Arup

Considerations in the Decision-Making Process

The University of Strathclyde wanted to ensure that the building design enabled both staff and students to have seamless access to essential resources, fostering a sense of community and collaboration.

Cost was a big driver in the decision-making process. Demolition and new build options were considered. A comparison study showed that by retaining both buildings, extending them and joining them together, the university could save significant amounts of money.

Sustainability and energy efficiency were key parts of the client brief. The university was looking to achieve a design that reflected its commitment to sustainability. It was determined that retaining the buildings would result in a 67% CO_2e reduction compared with an equivalent new build.

Given that Arup were the original structural engineer, and therefore owned the archived building drawings, it was much easier to plan a refurbishment project and minimise unknowns.

The Architecture Building is Grade B listed, and therefore required thoughtful preservation.

Learning and Teaching Building – University of Strathclyde

Interventions

Architecture Interventions

The Learning & Teaching Building is designed to cater to modern learning needs, with intimate breakout areas, tutorial rooms, expansive meeting spaces, and a 400-seat lecture theatre. Furthermore, the building serves as a centralised hub, containing student support services and the Student Union.

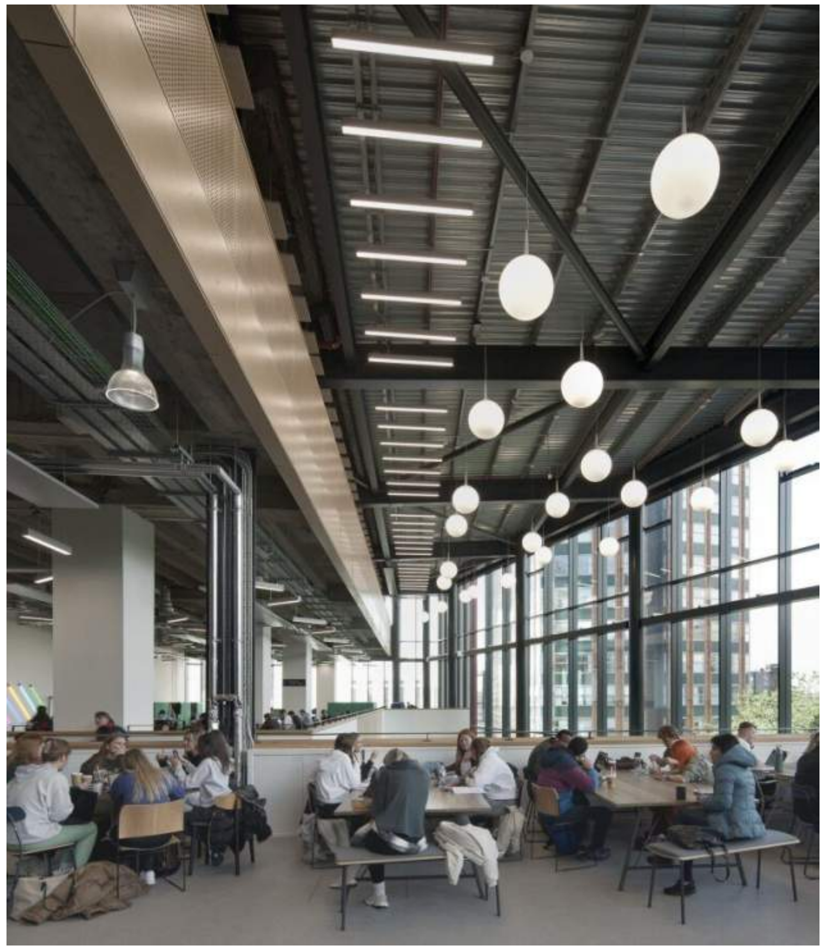
In the Colville Building, the structural frame was stripped back, resulting in more voluminous spaces.

The redundant concrete water tanks from the Engineering Hydraulics Lab were reconfigured to provide seating spaces and meeting rooms. The new Student Union was formerly an undercroft car park and laboratory.

The Architecture Building, which is Grade B listed, underwent a more sensitive upgrade, preserving its history while introducing modern functionality.

A triple height extension was added to create the new galleria circulation space connecting the two buildings. This space includes a lightwell and green sedum roof.

Acoustic specialists ensured that all modifications contributed to a comfortable aural experience for users.



The atrium is light-filled and airy ©David Barbour

Students have multiple social spaces ©David Barbour

Facade Interventions

The whole of the Colville building was reclad to improve the building's appearance and performance.

On the Architecture building, a softer approach was used, opting to retain the existing brickwork and only adding new copper cladding to the extrusions.

A sedum green roof was added to the extension to enhance biodiversity and improve aesthetics.

Image:
Learning and Teaching Building
University of Strathclyde
©BDP

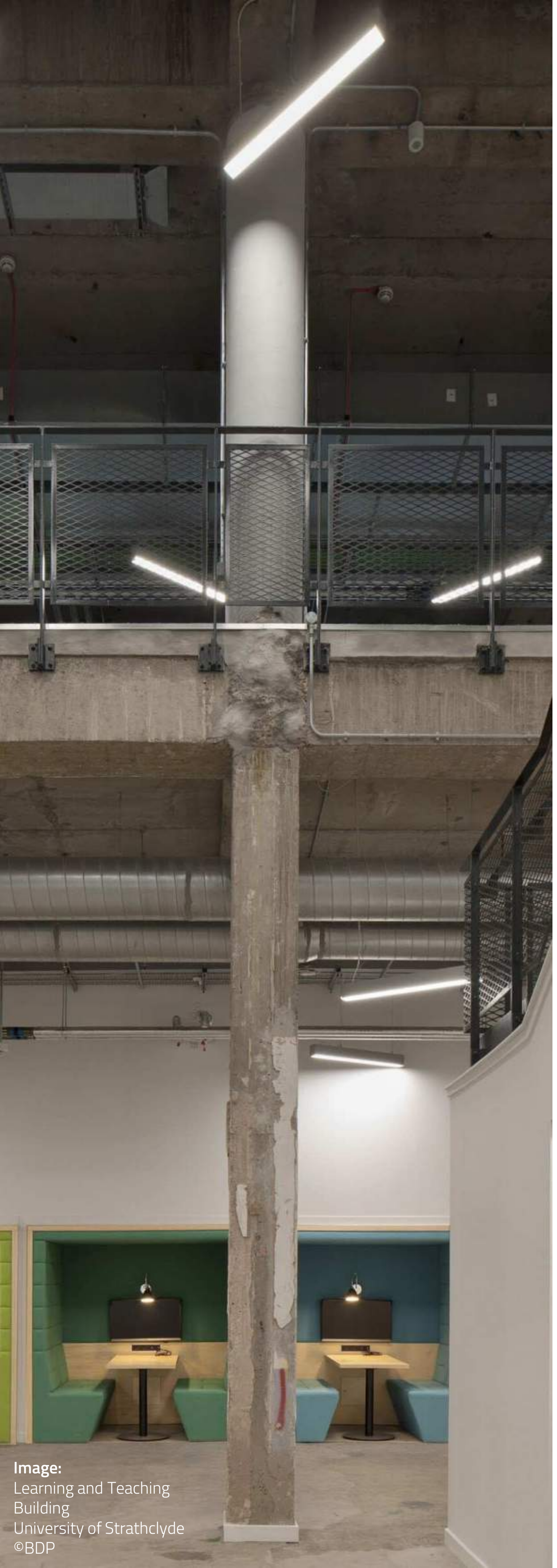


Image:
Learning and Teaching Building
University of Strathclyde
©BDP

Learning and Teaching Building – University of Strathclyde

Interventions

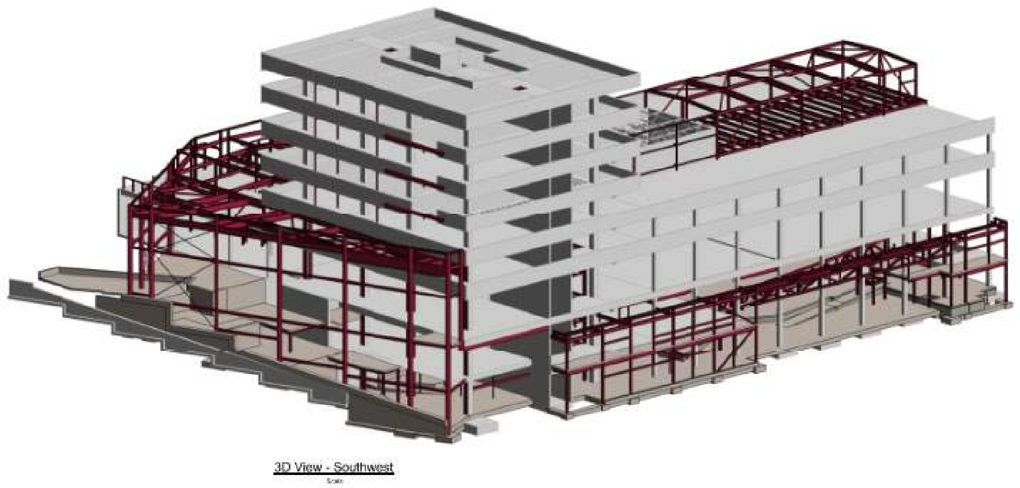
Structural Engineering Interventions

Most of the structural interventions were carried out on the Colville Building. Although few structural defects were identified, initial assessments revealed that some elements were working overly hard. Some strengthening was therefore required to bring the building up to modern standards.

A new feature stair was erected, and a double-height space was created to establish a new entrance by installing a 25m long steel truss. This has become a striking focal point. Where floor plates were removed, columns that had become double-height were strengthened. A cantilevered steel frame was added to the roof to increase plant area, and a triple height extension was built to connect the two buildings.

The construction of the new entrance presented significant challenges on the demanding sloping site. Foundations were strategically positioned to avoid interference with the underground train tunnels.

In the basement, tanks were broken out, and lintels put in, to create new rooms.



Southwest view showing the structural additions in red ©Arup

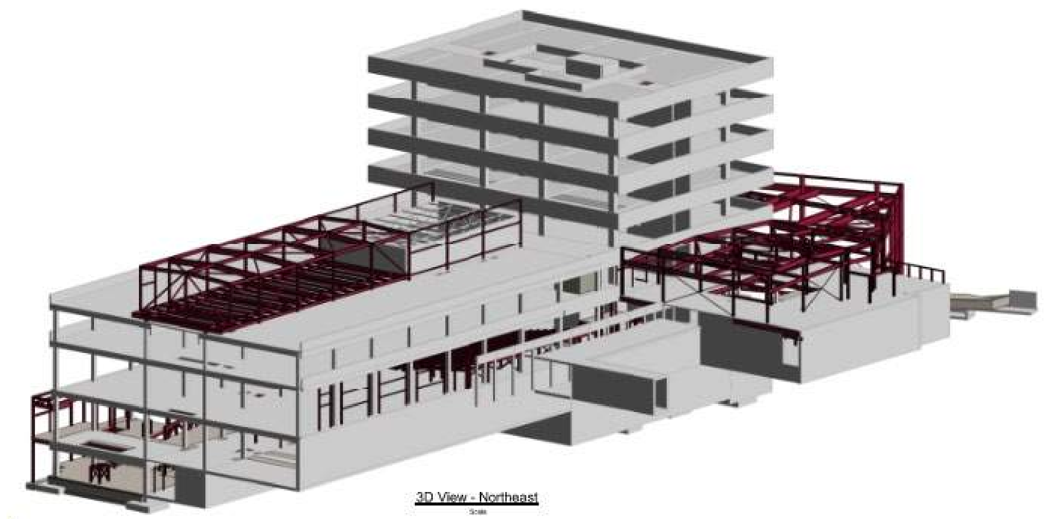
Building Services Engineering Interventions

The strategy for the building services upgrades targeted low carbon emissions and energy reductions. For instance, ventilation plant was chosen for low specific fan powers (SPFs) and high efficiency heat recovery. Comprehensive HVAC controls were added to give the users full flexibility and comfort.

An air-cooled chiller plant with heat recovery and transfer was added to serve the domestic hot water.

The building was connected into the university's new district energy network.

Automatic lighting controls were added, with high efficiency LED lighting throughout.



Northeast view showing the structural additions in red ©Arup

Learning and Teaching Building – University of Strathclyde

Commercial considerations & key learning points

Cost & Finance

This £40m project represented a significant part of the university's £1 billion investment initiative.

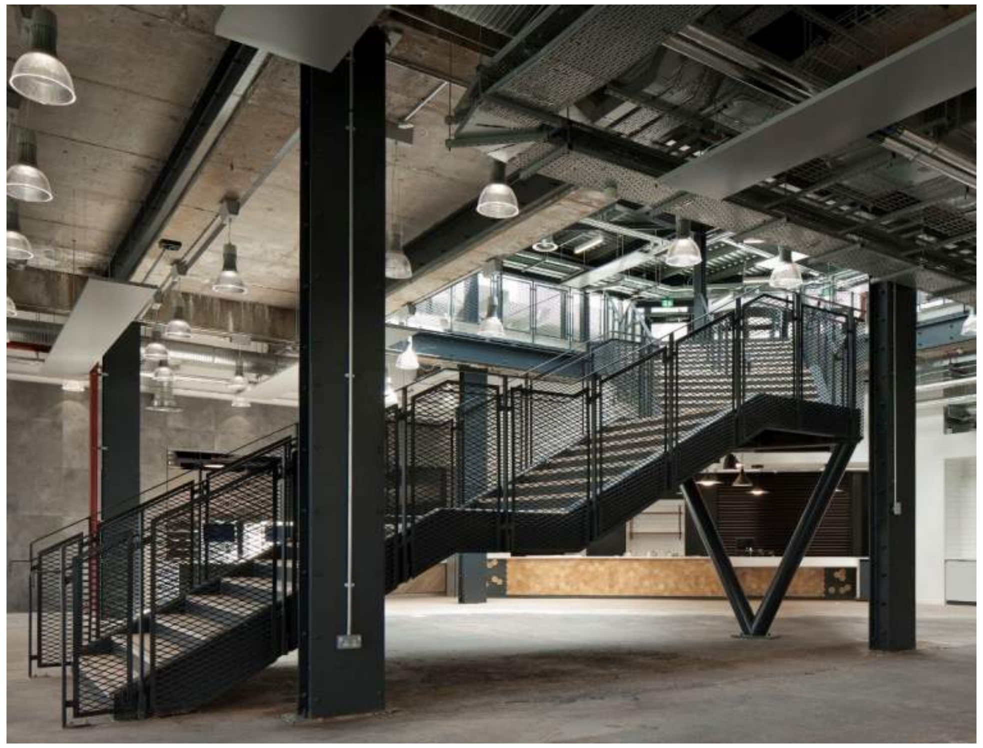
As the central hub of the university, the Learning and Teaching Building will appeal to prospective students and staff, bringing in income for years into the future.

As the original Colville and Architecture buildings were quite large, a new build on such a scale would have cost significantly more than this refurbishment solution.

A variety of quality catering facilities were provided in the facility. The aim of the project was to provide a "one-stop shop" for students and promote a "sticky campus" where students have no need to leave to use alternative facilities.

There were challenges, such as Covid-related delays and the associated cost implications. Furthermore, a long period of time elapsed between the initial briefing period and construction. A revisit of the initial end user briefings could have reduced a number of issues which arose later in the project.

New feature stairwell ©David Barbour



New feature stairwell ©David Barbour

Benefits & Lessons Learnt

The project has been very successful in providing a centralised space where students can access any assistance they require from student services. The completed facility has been very well received and acts as a hub for students; it provides student services, high quality formal and informal study and learning space.

The carbon emissions saved by repurposing the two buildings are equivalent to those produced by 3,350 Scottish homes in a single year. The project is expected to achieve BREEAM Very Good rating.

Best Modern (Post 1960s) Building Refurbishment Project (IStructE Scottish Structural Awards (2022))

Architect's Journal Retrofit Award 2022 in the Higher Education and Campus Category

Winner in the Innovation in Delivering a Sustainable Learning Space Category at the Learning Places Scotland Awards

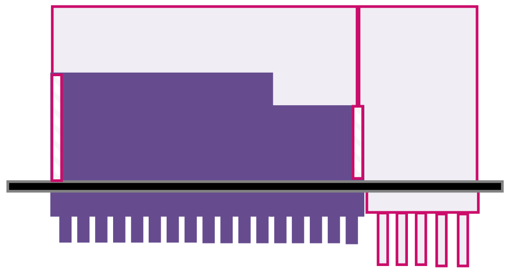
Best Regeneration Project – Commercial Category at the Herald Property Awards.

'The University of Strathclyde has transformed its campus with the new Learning & Teaching Building. This modern and multi award winning facility repurposed two existing buildings and contributes to the University's carbon reduction targets and sustainability goals. The facility has been open since 2021 and is proving to be extremely popular and well used by students.'

Graeme Currie, Assistant Director – Project Delivery, Estates Services, The University of Strathclyde

Image:
Learning and Teaching Building
University of Strathclyde
© David Barbour

Old Gym – University of Birmingham
Project Overview



Major retrofit including significant extension

Architecture

Facade

Structure

Building Services

Overview

The Old Gym is an innovative re-purposing of the University of Birmingham's 1940s gymnasium. In 2018 it was converted into offices and teaching spaces, with a variety of lecture halls and seminar rooms to suit modern needs.

The previously underutilised building was originally earmarked for demolition but increasing demand for new student spaces drove a rethink, and the decision was instead made to retrofit and extend.

Client:	University of Birmingham
Extent of Retrofit:	Architecture, Structure, Facade & Services
Building Age:	1940s
Year of Retrofit Completion:	2018
Cost of Retrofit:	£7.5m
Original Building Size:	1523m^2
New Building Size:	2172m^2
Architect:	Associated Architects
Structural Engineer	Arup
Building Services Engineer:	Arup
Façade Engineer:	-
Main Contractor:	Willmott Dixon
Project Manager:	University of Birmingham

Image:
Old Gym
University of Birmingham
©Associated Architects

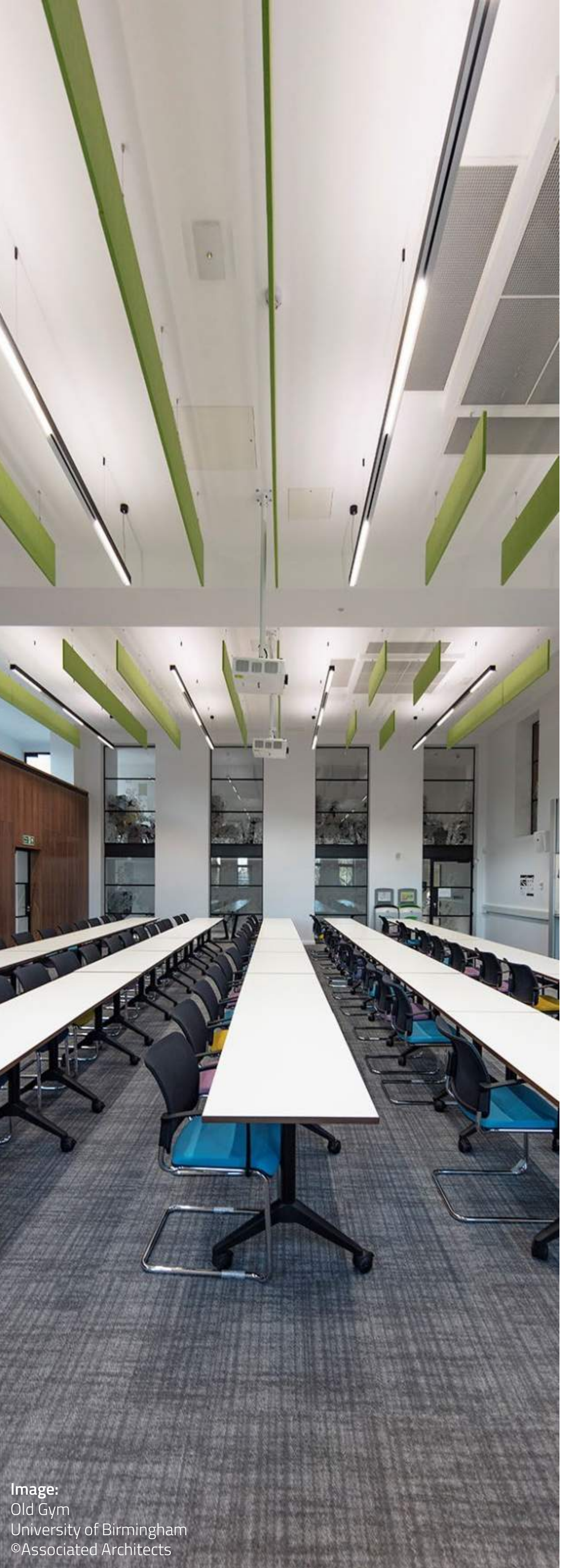


Image:
Old Gym
University of Birmingham
©Associated Architects

Old Gym – University of Birmingham
Project Considerations

Previous Condition/Issues & Main Drivers for Project

The building was previously a gym and squash hall. The university had recently built a large sports facility, rendering the Old Gym surplus to requirements.

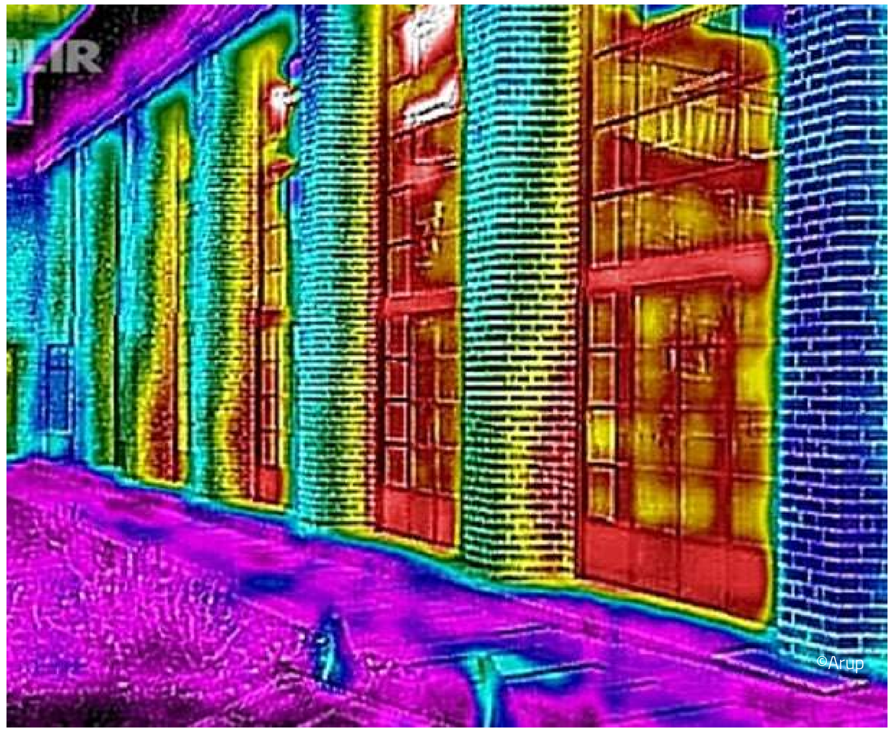
Some staff were using temporary accommodation, driving the need for more offices and teaching spaces. Despite being underutilised, the building was centrally located, making it a strong candidate for refurbishment or replacement.

The internal layout was incoherent for present day uses.

The services were outdated and the environmental conditions in the building were poor. The existing façade was poorly insulated and not up to modern requirements.

The building contained various structural defects, and there was water ingress on the east façade at ground and lower ground levels. Asbestos was present across the building.

The original gym ©Arup



Thermal image of original façade showing poor performance ©Arup

Considerations in the Decision-Making Process

The brief required increased office and teaching space under one roof. Demolition, new build and refurbishment were all considered.

The benefits of a new build included the option to pursue Passivhaus standards for insulation and airtightness, which would not be achievable with a refurbishment, However, refurbishment offered a chance to save a significant amount of embodied carbon through material reuse.

The site was heavily constrained by roads and other buildings, with a level change across the site. A nearby tunnel would also require costly diversion if a new build was selected.

A feasibility study was undertaken to assess the viability of refurbishing and extending the building. This looked at a range of factors across structural, MEP and facade specialities. It was decided that a refurbishment and extension upwards would avoid many of the challenging site constraints that a new build would face.

Old Gym – University of Birmingham

Interventions

Architecture Interventions

The architectural solution capitalised on the existing building's assets to create tall, airy spaces for teaching and group work, with a modern roof extension to house office space. The building design maximises daylight in occupied spaces, creating excellent learning and working environments. Conversely, focus desks for personal study were located in the deeper plan areas of the building, where access to daylight is a premium.

The interior of the building was reorganised and remodelled to suit contemporary expectations and requirements. A two-storey roof-level extension was added to the building, enabling the addition of significant floor area within the existing building footprint.

Grade A offices were introduced, with 90 open plan desks. These were located in the new roof extension, where bespoke open floorplates could be achieved with modern floor to ceiling heights and raised access floors for varied workspace arrangements. New teaching spaces were added, including an 81-seater tiered lecture theatre in the former squash hall, utilising the double height space. 265 student spaces were added for personal study.

Acoustic baffles were added to improve the internal environment.

The roof extension created a modern light filled office area ©Associated Architects

Elevation showcasing new and old elements ©Associated Architects

Facade Interventions

The single glazed Crittal windows were replaced with high-performance double-glazed units with a similar appearance.

The existing solid brick façade was internally lined with high-performance insulation panels. This had a limited impact on appearance, whilst reducing heat loss by 75% on average. Meanwhile, the new build roof extension allows cross ventilation with large openable sliding windows in the façade.

Sedum green roofs were introduced to enhance biodiversity.

Image:
Old Gym
University of Birmingham
©Associated Architects

Image:
Old Gym
University of Birmingham
©Associated Architects

Old Gym – University of Birmingham
Interventions & commercial considerations

Structural Engineering Interventions

Prior to design, intrusive surveys were conducted on the building to understand the existing structure and the extent of defects and repairs required.

The gymnasium roof was strengthened, and additional columns were added. The capacity of some foundations were also increased.

A steel and concrete roof level extension was added to the building, enabling the addition of significant floor area within the existing building footprint. Small-span floors were used in the extension to minimise the weight.

Through re-use of the building structure approximately 350 tonnes of embodied carbon has been avoided when compared to a similar new build scheme

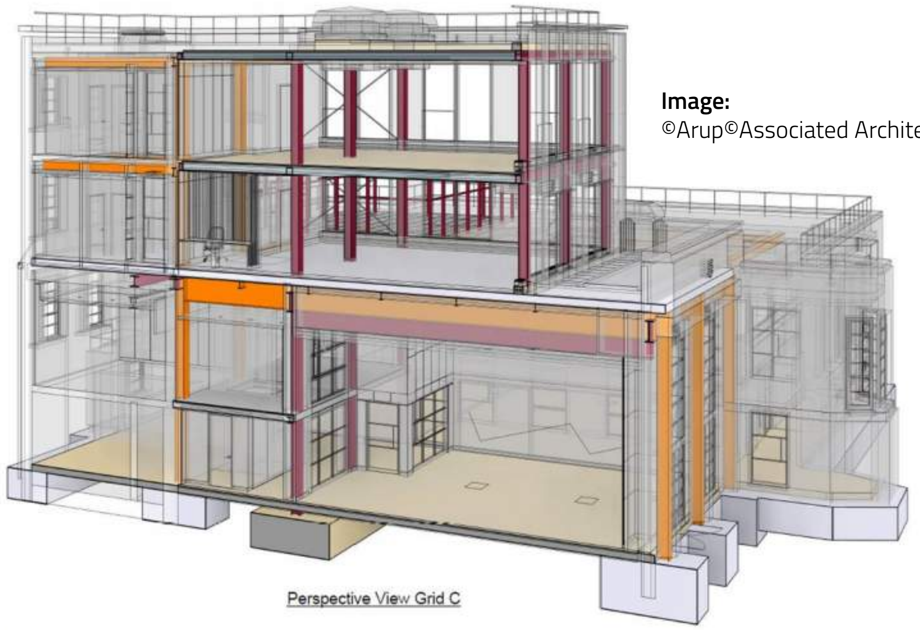


Image:
©Arup©Associated Architects

Retained structure shown in orange, new structure shown in red

Building Services Engineering Interventions

A natural ventilation system was introduced to all teaching and office space, with intelligent automation. An innovative heat recovery system was integrated into the façade to monitor and control internal temperature and CO2 levels, varying ventilation rates to match demands. Thermal mass in the structure was exposed, and nighttime cooling introduced.

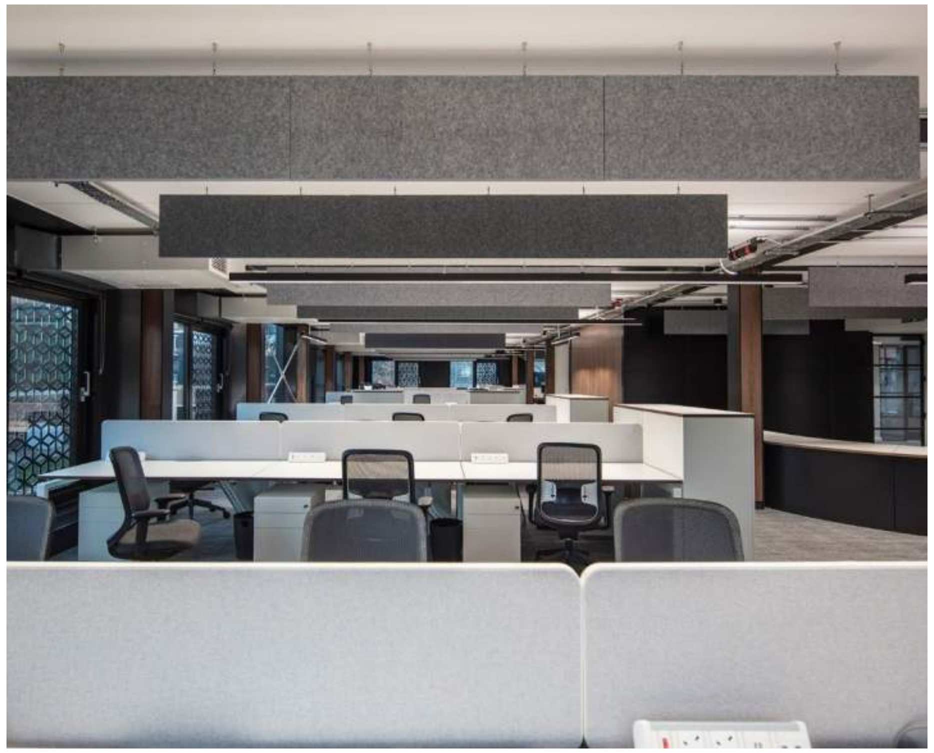
Raised access floors were added for future servicing flexibility. LED lighting was introduced with an automated control system.

Cost & Finance

This refurbishment project arose out of a need to make use of a building that was surplus to requirements. By retaining the structure and extending and improving it, the university increased student and teaching capacity without having to demolish and rebuild.

Staff were able to move out of temporary accommodation and into the Old Gym, presumably reducing overheads associated with renting temporary buildings.

Refurbishment projects do sometimes bring unknowns and associated costs – for instance, the presence of bats in the building presented an unexpected financial cost and time delay.



Acoustic baffles were added to improve the internal environment ©Associated Architects

Old Gym – University of Birmingham

Key learning points

Benefits & Lessons Learnt

The re-use of the existing building structure and façade greatly reduced the embodied carbon of the project. A significant amount of material was saved, including 1300 tonnes of brickwork, 2200 tonnes of concrete, 90 tonnes of steel reinforcement and 80 tonnes of steelwork.

An embodied carbon calculation was carried out, which demonstrated that the reuse and extension of the building resulted in a project with a SCORS rating of A+ (56kgCO2e/m^2 across new and existing). This fairs much better than a new build equivalent, which would have required a large amount of new material (a typical new build results in 200-250 kgCO2e/m^2 or SCORS C).

As a result of the building refurbishment, the regulated energy intensity is expected to be reduced by 50%, at 22.5kgCO2/m^2 down from 47kgCO2/m^2.

The project achieved BREEAM Very Good rating, an EPC rating B and SCORS rating A+.

A 3D render showing the internal and external improvements to the building © Arup ©Associated Architects

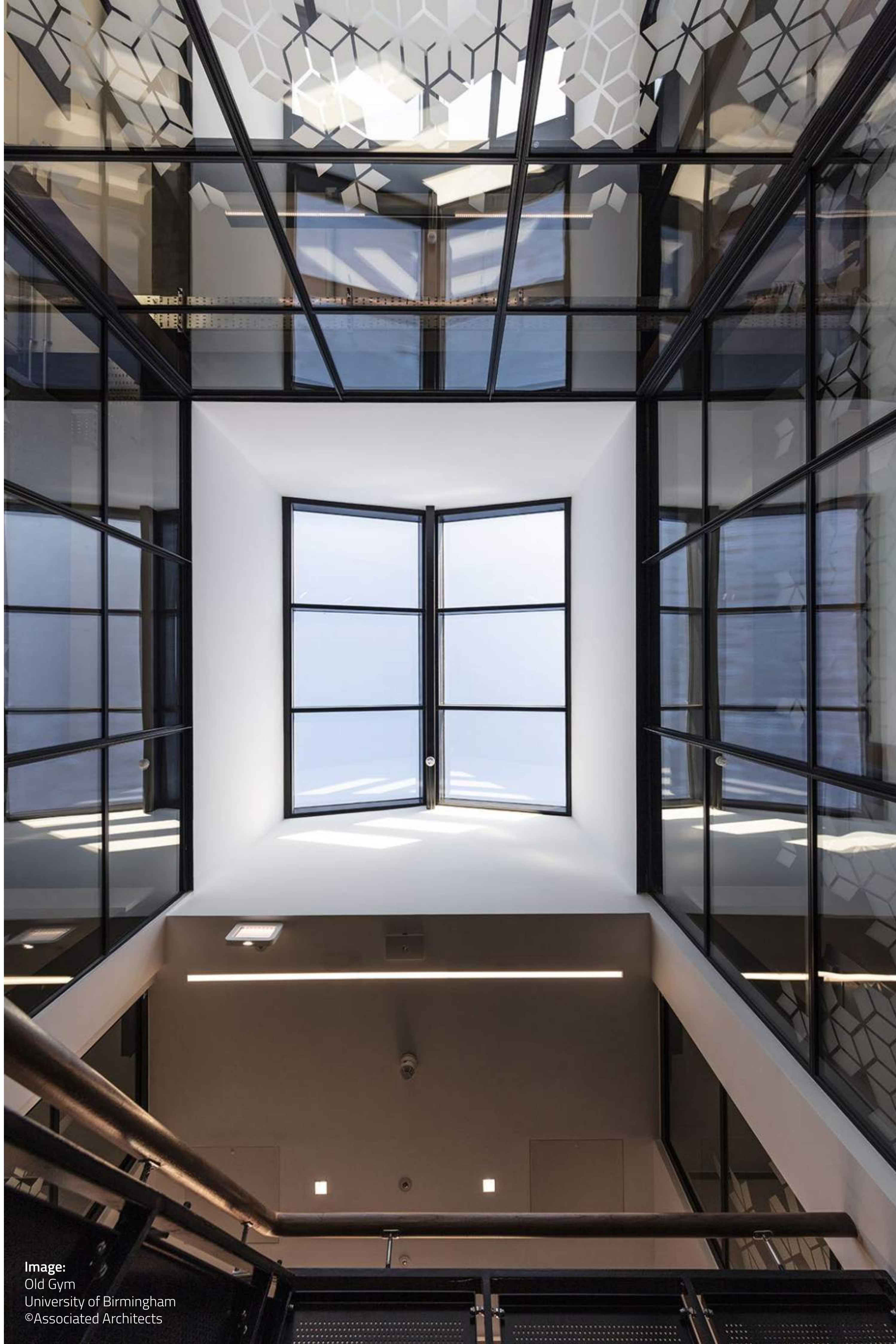


Image:
Old Gym
University of Birmingham
©Associated Architects

Park House – Technological University Dublin

Project Overview

Light/medium retrofit

Architecture

Facade

Structure

Building Services

Overview

With the University moving onto the Grangegorman Campus in 2020, they needed a library to provide services to the 10,000 students migrating from 4 of their Dublin city centre sites. Delays to the start of construction of their new library building in Grangegorman meant that it would not be ready in time for this move. They therefore needed an interim solution, a temporary library that could provide services to the students and staff moving into the new Campus. As the Park House building was designed to be used as office space, a complete retro-fit of 3 ½ floors was required to make it suitable for use by students and as a library space.

Client:	Technological University Dublin
Extent of Retrofit:	Architecture, Façade, Structure & Services
Building Age:	1970s
Year of Retrofit Completion:	2020
Cost of Retrofit:	€12m
Original Building Size:	10,000m^2
New Building Size:	10,000m^2
Architect:	Mahoney Architects
Structural Engineer	EirEng
Building Services Engineer:	Hayes Higgins Partnership
Façade Engineer:	-
Main Contractor:	Flynn Construction
Project Manager:	Mahoney Architects

Image:
Park House
Technological University Dublin
©Associated Architects

Image:
Park House
Technological University Dublin
©Associated Architects

Park House – Technological University Dublin
Project Considerations

Previous Condition/Issues & Main Drivers for Project

The Park House Refurbishment Project is a dedicated project focused on relocating the current cohort of libraries from existing buildings around the Greater Dublin Area to a single site temporarily until the academic hub build is complete. The project is also dedicated to giving TU Dublin office space for its own use and for commercial use.

Energy efficiency was not a key driver, however as the existing services were over 35 years old, the installation of new boilers, TRV controlled radiators, internal shaft wall, PIR controlled LED lighting, the energy performance of the building was improved.

The floors to be used by the library would need to be made accessible to all students. Accessible showers were added along with WC provision where they were missing on 2 floors.

The ground floor lobby (the main reception space for the building) was dark and uninviting. The WC facilities needed to be modernized and accessible. All spaces needed to be improved to be inviting to students, to make them less like an office block and more like an open learning space.

Previous office space with suspended ceilings and internal partitions ©Associated Architects

New open plan office spaces with exposed services ©Associated Architects

Considerations in the Decision-Making Process

The retrofit was always going to be temporary, but it needed to be fully functional as library. The successful brief provided the number of study spaces, adequate shelving space for the library collections, and the requisite upgrades needed to meet the change in use.

The libraries that were relocating into this building could stay where they were until the project was completed and the building was ready for occupancy. The COVID-19 pandemic meant that all libraries were closed to students. Relocations happened during these closures; this lessened the effect of the move on students.

Park House was designed in the late 60's/early 70's and designed originally as a hotel but halfway through construction this use was changed to office accommodation. There was an existing AutoCAD file for the building that was issued in the design team tender for information purposes only as layouts had changed over several years. Part of the scope for the design team was to produce existing Architectural Plans including elevations, sections, details, site plan, structural plan, MEP, & schedules and specifications.

Image:
Park House
Technological University Dublin
©Associated Architects

Park House – Technological University Dublin
Interventions

Architecture Interventions

The southern block was completely opened up and remodelled on the lower 3 floors to convert from office to library use. Other types of study spaces were added for group learning, reading and browsing. Student and staff support spaces were added to the 'northern' block which were more cellular, including careers offices, math's learning centre, counselling rooms, meeting rooms and staff offices.

A new, accessible ramp was added from the adjacent public pavement to the front door and these doors were upgraded by adding a lobby space with automatically activated, sliding doors. Accessible toilets were added to all floors along with a first aid and breastfeeding room.

Internally, the original spaces were stripped out and re-furnished to create a consistent, appealing and appropriate spaces for the new building users. New floor finishes were applied throughout and visually appealing, as well as practical, acoustic treatment panels were used on ceilings, wall finishes and to re-clad columns. Services were left exposed, new showers and lockers were added as well as upgraded and enlarged toilet provisions.

New external stairwell to allow for the increase in occupancy required. ©Associated Architects

Facade Interventions

An internal shaft wall was constructed for thermal insulation and for aesthetic purposes. The existing heating system was a single pipe sill line attached to a block wall adjacent to the internal cladding system. The existing heating system was removed and upgraded. The decision was made to construct an internal shaft wall that would help with the thermal performance of the building and that when the cladding system was to be replaced in the future, the shaft wall would stay in place that would allow for the floors to be still occupied.

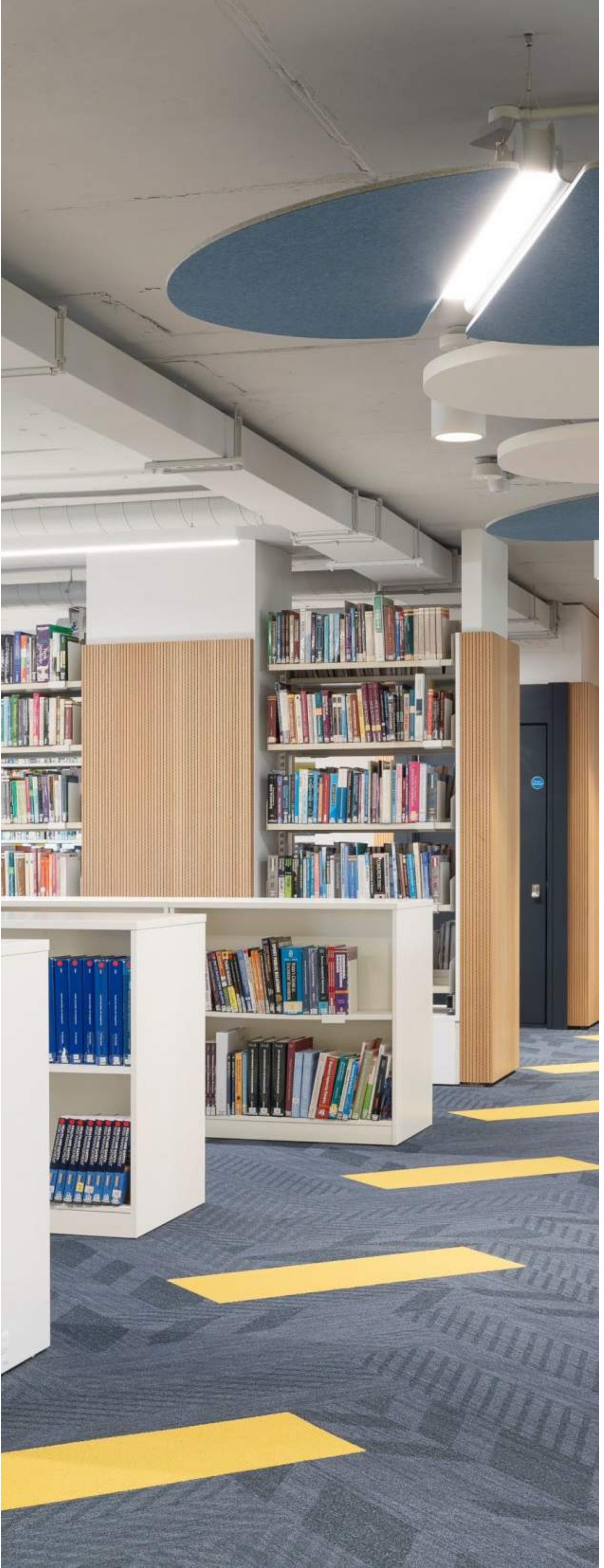
Localised structural strengthening to allow increased load from previous use ©Associated Architects

Structural Engineering Interventions

The existing structural columns were reinforced with steel beams to take the additional load of the new bookshelves on the lower ground 3 floors. These are mechanically fixed on top of the slab and are therefore removeable when the building reverts to office use.

New stairwells were constructed at both the east and west elevations, these stairwells were constructed to allow for the higher occupancy on the library floors and was a condition of the planning/fire certification application.

Image:
Park House
Technological University Dublin
©Associated Architects



Park House – Technological University Dublin

Interventions, commercial consideration & key learning points

Building Services Engineering Interventions

It is estimated that the efficiency of the building has seen an improvement of 22% overall.

The existing single pipe sill line heating system was replaced with a two-pipe heating system with TRV controlled radiators to improve temperature control, enhanced comfort, increase energy efficiency and a reduction in noise of the heating system. The existing Dansk Stoker boilers that were 35 years old and 60% efficient were replaced with high efficiency boilers that provided a 40% reduction in annual fuel consumption.

All lighting was replaced from T8 fittings to LED PIR controlled lighting. All power and data were stripped out and replaced.

Cost & Finance

The objective of the project was to refurbish the building so that we could temporarily house the existing libraries and support staff from TU Dublin in Kevin Street, Rathmines, Cathal Brugha Street, Rathdown House and Mountjoy Square in Park House prior to their move to the academic hub. Another purpose of the project was to provide additional office space for TU Dublin and prospective tenants. This project ran in parallel with other new building projects that were to accommodate the teaching of students that were moving from the buildings above. The buildings above were sold so the new owners wanted occupation on the date agreed. The library needed to function both pre and post move without the financial impact of either staying over a lease or being penalised by a new owner of a building for staying past the handover date.

The funding stream was taken from funds realised from the sale of existing TU Dublin building stock.

New canteen ©Associated Architects

'The Park House Library project is a fantastic example of adaptive re-use of an existing building. We are consistently delighted when visitors come to the building and realise the transformation from a very tired 1970's office building to a revitalised library and student support centre. It is an excellent embodiment of the Universities Sustainability ethos as well as a pathfinder project for the third level sector generally.'
Director of Estate

Contemporary office spaces ©Associated Architects

Benefits & Lessons Learnt

The project was a major success for both staff and students. The library spaces have been in use for over 3 years and feedback from a recent student survey has been very positive. Students are often surprised by the standard of the spaces considering it is a temporary library. The café space on the ground floor is very popular with students both as an informal study space and a social space. Library staff work in an open plan, light-filled space.

The main lesson learnt was the time required for upfront detailed design work. Had this been extended, some of the additional costs, re-design work and delays to programme might have been reduced or avoided.

Derwent P (CLASP Mark 3B)
University of York

Light/medium retrofit

Architecture

Facade

Structure

Building Services

Overview

In 2022, the University of York's Derwent P accommodation block underwent major refurbishment work. Derwent College is a CLASP structure constructed c.1967 and is Grade II listed due to its unique combination of teaching, social and residential facilities within a single college. Derwent is an early example of a wave of new universities that improved access to higher education and marked the highpoint of publicly-funded architecture in post-war Britain..

The £7m project saw the existing accommodation (4No. offices, 6No. communal kitchens & 54No. beds) being significantly overhauled to provide 57No. upgraded en-suite bedrooms and 6No. communal kitchens.

Client:	University of York
Extent of Retrofit:	Architecture, Structure & Services
Building Age:	1960s
Year of Retrofit Completion:	2023
Cost of Retrofit:	£7m
Original Building Size:	1,350m^2
New Building Size:	1,350m^2
Architect:	Fuse-Studios
Structural Engineer	BWB Consulting Ltd
Building Services Engineer:	CPW
Façade Engineer:	-
Main Contractor:	Lindum
Project Manager:	Faithful+Gould

Image:
University of York
©Fuse-Studios

Image:
University of York
©Fuse-Studios

Derwent P (CLASP Mark 3B)
University of York

Previous Condition/Issues & Main Drivers for Project

The building was in a very poor condition and not fit for current student requirements in residential accommodation. In addition, the building was inaccessible for all users which was a major concern. The space functionality of the proposed layouts meant that better use of the space created additional rooms and larger kitchen/communal spaces. Better designed rooms also allowed the installation of en-suite shower facilities and more storage.

With finances being stretched in the higher education sector, operational costs were a main driver for the work. Improvements to the energy efficiency of the building were required to reduce operational costs and then in line with the quality of the refurbished accommodation would make the building economically sustainable whilst also helping the university achieve its NetZero targets.

The building's listing meant that longevity of life was a key driver for the refurbishment works. With the building being 60 years old, defects to its external fabric required attention to ensure the extension of the building's life expectancy.

During construction showing the CLASP bracing system and staircase ©Fuse-Studios

Stripped internals during construction ©Fuse-Studios

Considerations in the Decision-Making Process

As a Grade II listed building, a new-build option was not considered for the site, despite a significant number of benefits where a new-build would have been a preferred option.

The buildings listing, and its significance in CLASP architecture, meant that the block alongside our wider Derwent nucleus of buildings needed to be retrofitted to extend the lifecycle of the structure.

Derwent P (CLASP Mark 3B)

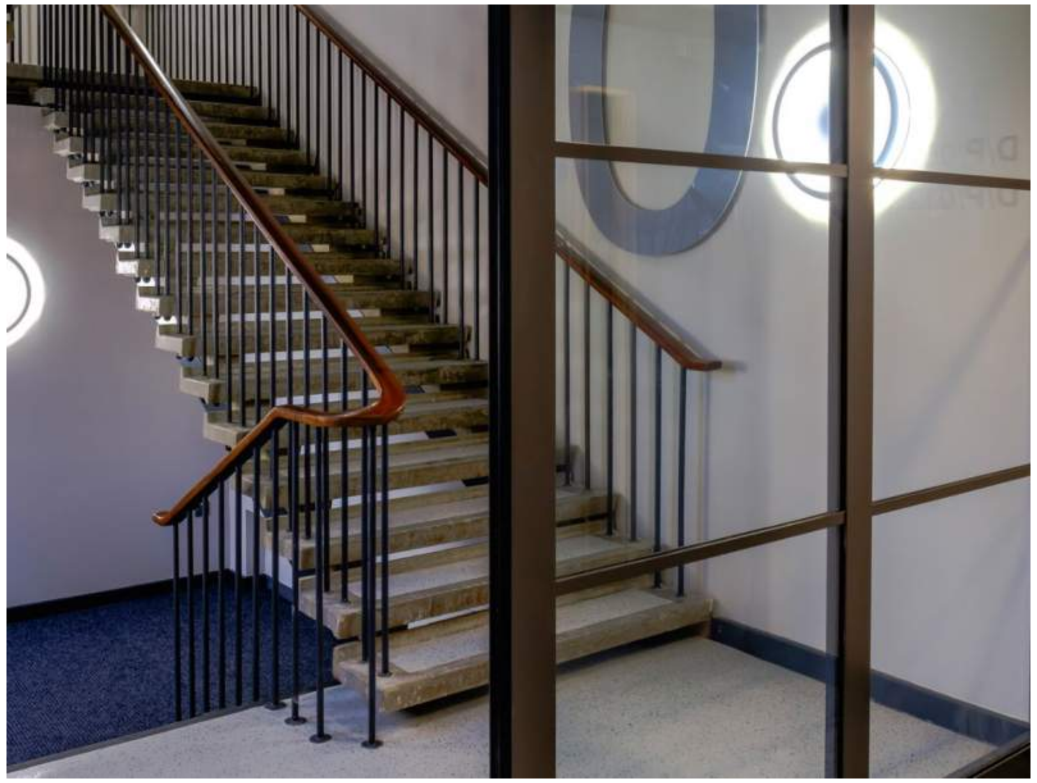
University of York

Architecture Interventions

The overall aim of the project was to update and modernise the look and feel of some of the existing old stock of residential accommodation on Heslington West which was in poor condition. Accommodation plays a key role in the decision-making process for students choosing York and the updated high-quality portfolio will support both home and overseas recruitment and conversion, particularly with the addition of en-suite facilities and upgraded communal kitchen/dining spaces.

The existing narrow corridors were also increased to provide greater sense of space within the building together with improving the buildings overall accessibility. Lift installation was not possible for structural and finance reasons.

Additional bedrooms, and the ability to increase the cost of the rooms due to improved facilities (en-suite) will provide further revenue to the residential block. The high quality of the spaces also allows the university to rent out the accommodation to non-students during the summer period to support their conference team.



Refurbished stairwell ©Fuse-Studios

New bedroom model ©Fuse-Studios

Facade Interventions

Glazing sizing was retained due to listing however overhaul of units allowed for improvements in natural ventilation and reduction in solar gains.

Improvements to insulation within the roof build-up and to the internal side of the existing external fabric to improve operational energy efficiency and comfort levels.

Improved insulation to the building fabric and replacement glazing to current standards improved acoustics.

No external changes, structural repairs to the listed CLASP envelop only.

Image:
University of York
©Fuse-Studios

Image:
University of York
©Fuse-Studios

Derwent P (CLASP Mark 3B)
University of York

Structural Interventions

The proposed loadings to the site for residential were deemed to be lower than the existing designed loads for the structure, as such no strengthening was required. Some internal walls were removed where bracing was not located, as with CLASP moving bracing and/or columns is difficult and in some cases impossible.

No changes in performance criteria from a structural perspective were required as part of the project. Additional service/drainage trenches needed to be installed to facilitate the student accommodation layout, which had to be carefully undertaken so as to not impact the integrity of the structural slab/pad bases.

During construction when the internal fabric was opened up cracking was evident to the CLASP concrete cladding facade panels. Due to the listing the preference was to repair/strengthen these elements as the work to remove sections within the CLASP structure would have been both difficult and time consuming. After reviewing the methodology and cost of various options, a stitching repair was undertaken to the panels to prolong their usable life.

Some of the internal walls were removed to make suitable space for communal kitchens which were required as part of the work.

New living space model ©Fuse-Studios

New living space ©Fuse-Studios

Building Services Interventions

To demonstrate the benefits of the refurbishment, allowances were made for a direct fed LTHW system from a central Plate Heat Exchanger which is supplied via the local district heating network. This provided the heating to the accommodation. The building design solution is based upon a highly insulated, air tight envelope, with mechanical ventilation throughout.

A plate heat exchanger was installed to ground floor reception ceiling void to connect to the Campus District Heating. Thereafter, distribution was taken through risers and into each of the rooms via the ceiling voids. Local control provided in each room in the form of TRV’s.

Existing lighting was replaced with high efficiency LED light fittings complete with high frequency control gear. Lighting controls improved to allow generally photocell control dimming and PIR absence/presence detection throughout.

Derwent P (CLASP Mark 3B)
University of York


New bedroom ©Fuse-Studios

Benefits & Lessons Learnt

Despite the economic disadvantages of the refurbishment in comparison to new-build alternatives, the project has been a great success in safeguarding the integrity of one of our listed CLASP structures and providing excellent accommodation for students/delegates. The increased revenue per bedroom, and the ability to utilise the facilities 12 months a year, will generate additional revenue and lower running costs. The projected reduction in energy usage not only assists the management of our estate in the current economic climate, but also goes some way in helping us drive towards our NetZero targets. Due to its completion date in 2024 the rooms have yet to be occupied fully by students on long term lease arrangements, and as such we will track success once the facility is in use.

In terms of building performance there have been no issues noted to date, noting the building has yet to be occupied over four seasons. There have been queries over sink provision to the ground floor communal kitchens based on the numbers of students that will occupy the building. These issues are being reviewed with the design team / contractor at present.

Cost & Finance

The existing accommodation was archaic and as such required an upgrade. The operational cost per m^2 for the block was extremely high in comparison to more modern accommodation. With financial viability being a key driver in the current financial market, together with the listed status meaning the building had to be retained, meant that any proposed retrofit needed to reduce energy usage. The redesign of the layout allowed for additional bedrooms within the block which had a direct positive impact on income generation. The higher quality of the accommodation as well as the introduction of en-suite facilities allowed for a greater rental income per bed.

A review of anticipated costs were undertaken at various stages and it was known that the cost of refurbishing the existing accommodation, due to its construction, would attract a higher cost/m^2 than a new-build alternative. Due to the buildings listing however, and the requirement to upgrade the facility generally, a new-build structure was not a factor in the decision to proceed with this project.


New bedroom model ©Fuse-Studios

"At University of York we are committed to preserving the essence of our heritage while embracing progress. Our unwavering commitment to sustainability means that through innovative design and eco-conscious practices we can shape a greener future for the public good. The refurbishment of Derwent P accommodation improves the overall student experience for its residents and ensures the long-term viability of a key building in the heart of our campus. "

Endnotes

1. Derwent London (2012) Sustainability Report. https://www.derwentlondon.com/uploads/downloads/Responsibility/DL_Sustainability_2012_v2_WEB.pdf
2. (UK Gov Net Zero Playbook).
3. HEPI (https://www.hepi.ac.uk/2023/01/20/the-majority-of-uk-universities-have-failed-their-carbon-reduction-targets-reducing-ambition-and-embracing-offsetting-is-not-the-solution/)
4. Net Zero Carbon Roadmap, UKGBC- https://ukgbc.org/wp-content/uploads/2021/11/UKGBC-Whole-Life-Carbon-Roadmap-A-Pathway-to-Net-Zero.pdf
5. London Plan Guidance – Whole Life-Cycle Carbon Assessments – March 2022 - https://www.london.gov.uk/sites/default/files/lpg_-_wlca_guidance.pdf
6. IStructE – Setting carbon targets: an introduction to the proposed SCORS rating scheme - 2020
7. One Click LCA - Embodied Carbon Benchmarks for European Buildings – 2021
8. https://ukgbc.org/wp-content/uploads/2023/12/Progress-Report-Roadmap-December.pdf
9. UKGBC – Net Zero Whole Life Carbon Roadmap Progress Report – 2023
10. Historic England – Adapting Historic Buildings for Energy and Carbon Efficiency – July 2024
11. GLA Circular Economy Statements (March 2022) - chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.london.gov.uk/sites/default/files/circular_economy_statements_lpg.pdf
12. What is a circular economy? | Ellen MacArthur Foundation
13. IStructE – Circular economy and reuse: guidance for designers – 2023
14. The Institution of Structural Engineers – Reinforced Autoclaved Aerated Concrete (RAAC) Panels Investigation and Assessment – Feb 2022
15. Department for Education - Reinforced Autoclaved Aerated Concrete (RAAC) identification guidance – April 2024
16. P. John Clarkson – History of Inclusive Design (2015)
17. Chris Watkins (Arup) - IStructE Inclusive Design Webinar
18. IStructE – Inclusive Design for Structural Engineers (2024)
19. Jane Simpson Access
20. Categories of design life
21. Average Service Life of Building Elements
22. Building layers and their indicative lifespans (taken from GLA Circular Economy Statements guide
23. https://www.rics.org/content/dam/ricsglobal/documents/standards/Cost_analysis_and_benchmarking_UK_ARCHIVED.pdf
24. How risk allowances compare on a retrofit vs. new build project (taken from CIRIA repurposing and reconfiguring buildings guide
25. The impact of common retrofit measures (taken from UKGBC building the case for net zero: retrofitting office buildings)

AUDE

This report has been produced by Arup for and in collaboration with AUDE.
It takes into account the particular instructions and requirements of our client. Whilst it includes current best practice, it is not intended for and should not be relied upon by any third party without undertaking due diligence. No responsibility is undertaken to any third party