Buro Happold

Patterns

Specialist Consulting

Foreword

I have the privilege of crossing the threshold of Buro Happold's offices regularly. My remit is to challenge the engineers I meet to articulate their technical expertise so that I can transmit it to a wider audience. What is most striking about Buro Happold, apart from the range of projects and depth of knowledge, is the common-sense approach which means, for example, that sophisticated computational tools are used to validate human judgments, rather than vice versa.

The two years since the publication of Patterns 14 in March 2005 has been a period of remarkable growth for Buro Happold. It now has 19 offices – up from 12 in 2005 – and the number of employees has grown from 1000 to 1800 worldwide. The new Specialist Consulting group helps to maintain joined-up thinking in this increasingly globalised way of working, so that the scope and timing of technical input from various disciplines to a given project can be carefully controlled by a multi-disciplinary team.

The most successful collaborations are those of integrated design, where the design team works together from the outset in an iterative process to meet a client's objectives. Time and time again, I have found that Buro Happold is involved on projects from the competition stage, be it for the Grand Museum in Cairo with Heneghan Peng, on academy projects with Foster + Partners, or on a small housing project in Suffolk with Riches Hawley Mikhail Architects. Equally important is the follow-through period during the commissioning and first years of building occupancy. Here, too, Buro Happold is pushing the agenda forward to offer clients a comprehensive approach to building operation, including post-occupancy evaluation of buildings in use.

This collection of 10 essays serves as a litmus test of the issues that are at the top of the built environment agenda in 2007. Not surprisingly, half of the essays touch on sustainability, and three more are concerned with 'smart' buildings and digital technologies. The other two deal with acoustics and inclusive design.
A common theme runs through all these essays, perhaps best articulated by David Dropkin, who describes inclusive design as much more than ensuring compliance with a checklist of building regulations, but rather as 'environmental marriage counseling to ensure best outcomes for all'.

The strength of the multi-disciplinary approach of Specialist Consulting is that it can challenge conventional ways of doing things and incorporate new technologies. This requires a sensitivity to and understanding of design intentions; lateral thinking by all members of the project team; and effective communication. The following essays are a testament to these skills and to the fact that when engineering innovation is translated into practice, the end result is better design.

By Hattie Hartman, Technical Editor, Architects' Journal.

PatternsSpecialistConsulting

The rise of the specialist

From the earliest days of construction, specialists have been required to make buildings work for their occupants. As building materials and methods available today are so much greater, engineering consultancies have to provide expertise on an expanding range of disciplines, which led Buro Happold to create the Specialist Consulting group. Here discipline directors Mick Green and Peter Moseley chart its origins and ethos while Andy Nicholson and Mark Whitaker examine what factors are driving its growth today.

A large part of the skill set of the great cathedral builders and military engineers who pioneered early construction methods was based around practical and empirical knowledge. There is no doubt that they achieved great things and that they were the specialists of their day.

Over the subsequent years, particularly following the Great Fire of London and the increasing influence of the emerging profession of civil engineering, there has been a steady transition to the codification of knowledge. However, this knowledge was highly prescriptive as the research base was relatively immature.

It is only in relatively recent times, thanks to advances in technical research supported by dramatic increases in computational capacity, that we are now able to better predict the performance of the built environment. This has given us great flexibility and a wonderful opportunity to create and be comfortable at the boundaries of the possible.

In many ways, modern day engineers have picked up the philosophy of those early builders and broadened and strengthened it with an ever-widening spectrum of advanced technologies. Most important among these is the ability to predict, which presents great opportunities for creating dynamic buildings that incorporate quality spaces and places; that are adaptable and sustainable.

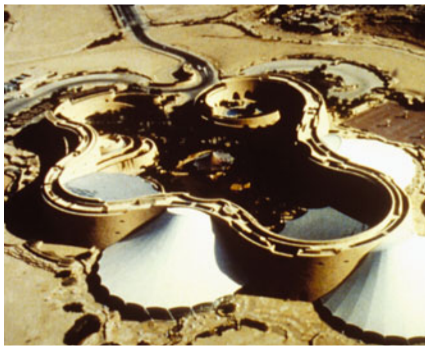
But this also creates a risk of fragmentation of understanding, compounded by increasing challenges of complying with legislation on safety and, even more recently, politically influenced or client-imposed restrictions on carbon dioxide emissions.

This is as much a challenge for the engineer as it is for the architect and so the ability to bring these skills together, by identifying synergies, scale of service and timing are all absolutely critical. Clients will only get real value when skilled designers offer a total solution, not just a collection of fragments.

This style of working was a key part of Buro Happold's approach to design from its earliest days. Practice founder Ted Happold believed passionately in integrating disciplines to create better designs. While teaching as a visiting professor at the University of Bath, he restructured courses so that students from different fields studied together. This created multi-disciplinary groups combining their knowledge to produce integrated design solutions.

Ted Happold also encouraged staff to have hobbies in disciplines aside from their own, which saw engineers developing expertise in new areas, all of which helped the multi-disciplinary capability of project teams and the practice as a whole.

As these capabilities grew, to include disciplines such as facade and fire engineering in the 1980s, so it was possible to give clients greater flexibility to drive value and performance as well as the essentials of signature projects. Key projects in that development, of what would become the Specialist Consulting group, are detailed here.



The Diplomatic Club.

The Diplomatic Club

An innovative building incorporating a series of 50m diameter PTFE roofs built around a 13m high, 600m long wall in Riyadh, perfectly in tune with the styles of the Nomadic and heavy masonry traditions of Saudi Arabia. The project saw great collaboration between Buro Happold's fire, lighting, acoustics and environmental teams to integrate their work with the challenging structural and building services engineering design.

58° North New Town.

58° North New Town

This project comprised a very large, free span enclosure to cover a town planned for the Arctic wastes of northern Canada, providing protection for workers and their families from the extremes of weather at this latitude. Although never built, the project had a significant influence on our early approach to interdisciplinary design as well as helping develop the use of foils and grid weaves in roof construction. The enclosure consisted of an air supported cable net roof approximately 600m by 1,000m and 60m high at its central point, with 40m high walls at its perimeter. The design work, completed in 1984, was a great example of Buro Happold's earliest specialist services, in lightweight structures, fire and environmental engineering.

Basildon Town Square

Design of this radical 400m by 40m cover to the town centre represented a landmark in the integrated approach of the design and engineering team. A lightweight membrane roof, suspended from a set of twin masts, was designed to cover the public space and a new mezzanine, without impinging on the existing, surrounding buildings. Although the design, developed in close collaboration with Hopkins Architects, was approved and procurement started, the project was not completed due to changes in the local development corporation.

Buckingham Gate

This project to create an atrium supported on three separate buildings, one of which was Grade one listed, incorporated many specialist skills and was an early example of an approved atrium design in London. As well as providing an enclosure that allows in as much daylight as possible, the roof had to be optimised to cope with differential movements between the various buildings and engineered for safety in the event of a fire, preventing excessive smoke build up in the new atrium. This was an unusual commission at the time (1983) as we were appointed as atrium engineers and provided all the disciplines necessary to deliver this task.

The Millennium Dome.

Millennium Dome

A tour de force for Buro Happold's multi-disciplinary team, the success of the design relied heavily on the interdisciplinary work by all of our engineers and specialists. The Dome's 320m-diameter cable net roof earned Buro Happold the prestigious MacRobert Award for innovative engineering in 1999. A great team effort!

Ascot Racecourse Redevelopment

The centrepiece of this redevelopment has been the construction of a new grandstand providing much improved facilities for race goers and includes a 300m-long internal galleria, extending the length of the grandstand. The galleria is an exceptional space requiring a close synergy between the architecture and structural solution, guided by the wind engineering and a very close alignment between the fire and environmental solutions. People movement also formed an integral part of the input and helped create a first for a sports building.

The Emirates Stadium.
Image: Simon Warren

Emirates Stadium

This landmark development, on a crowded urban site for Arsenal Football Club, represents a pinnacle for Buro Happold, not least in the breadth of services supplied. Structural, building services and civil engineers were joined by the Specialist Consulting team contributing: fire engineering to ensure safe exit in the event of an emergency; inclusive design services to ensure access, egress and passage around the whole stadium for all 60,000 spectators regardless of their mobility; lighting, facade and security design.

External influences driving Specialist Consulting

Increasingly for today's complex projects, specialist knowledge is required to allow the realisation of the design. And increasingly, clients expect a practitioner with appropriate qualifications and field experience.

The numerous specialist disciplines Buro Happold has gained in its 31 years, as illustrated in the timeline on the right, have been largely down to external drivers.

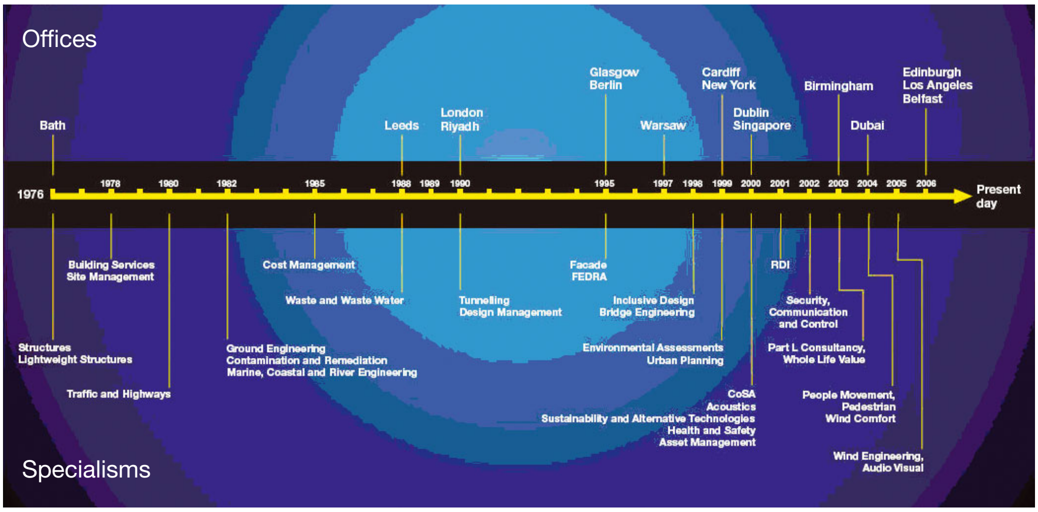


Figure 1 Timeline showing introduction of Specialist Consulting disciplines within Buro Happold.

Through analysing the external environment, we can see clearly the drivers for change that influence the services that Buro Happold is being called upon to provide. This STEEP analysis highlights the demands being made of the practice, much of which feeds into the continuing growth of the Specialist Consulting group.

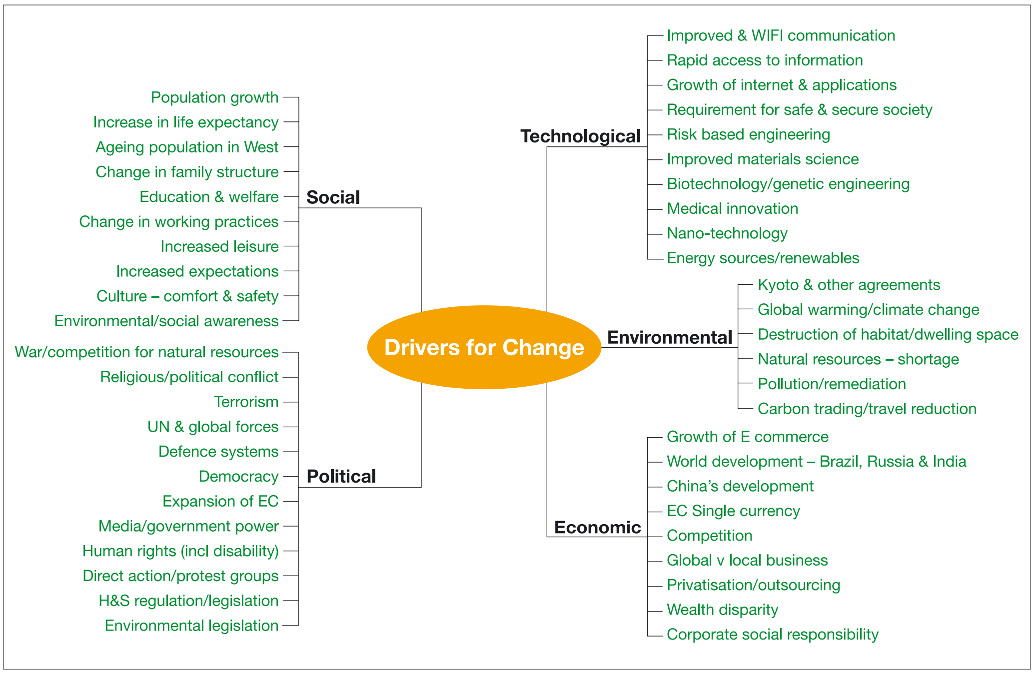


Figure 2 Analysis of key external drivers for Specialist Consulting.

The team works

A well-judged inter-disciplinary overview of a project is invaluable, allowing an early understanding of the risks – and opportunities – within the work.

This requires establishing the involvement of the key disciplines, the timing of each input and the scale of the contribution, without the need to carry out a significant amount of in-depth work. The key to this is having the right people who appreciate the value of not reinventing the wheel, understand commercial value, while allowing the right amount of innovation and flexibility. This process is designed to be a relatively short task, giving the client and design team a very effective strategic overview of their project which highlights the most important constraints, needs and opportunities.

Working in an industry affected so heavily by ever changing legislation and technological advances means increasingly complex choices have to be made on even the smallest project. Within Specialist Consulting we deal with this complexity through developing our skills in a series of related interdisciplinary themes. These are:

1. Quality Spaces and Places
2. Safe and Secure
3. Whole Life Value
4. Future Technology

Many of the ideas, projects and designs presented in this publication used these basic themes to support the thinking and processes that were deployed to achieve the client's objectives in each case. Each has been selected to give a flavour of the work Specialist Consulting carries out in these fields, illustrating the breadth of skills Buro Happold now offers.

There will always be a need for true specialists, but if we, as engineers, are to deliver best value to clients, there is an essential need for specialists to understand the values and constraints of others. The best projects do demonstrate this very effectively and provide a compelling argument to collaborate, communicate and deliver sustainable solutions in what is still very much a commercially-driven world.

There are a range of drivers that lead to the introduction of each specialist discipline. Some of these are below.

Guidance documents and legislation

Buro Happold has a long history of delivering bold and complex projects in which guidance and legislation provide a backdrop to, rather than a driving force for, the design. While obviously conforming to legislation, in the case of these signature projects the practice often comes up with alternative ways of working to reach the same ends.

One example of where the legislation provides guidance but requires expert advice to achieve best practice is in the field of inclusive design. The Disability Discrimination Act (DDA) makes it unlawful to discriminate against people on the basis of their disabilities. Detailed guidance within the act applies to the built environment but, as it focuses on the rights of individuals rather than prescriptive solutions, does not necessarily ensure the aims of the DDA are achieved. Inclusive Design consultants within Specialist Consulting provide the necessary strategic guidance to demonstrate compliance to the DDA. Buro Happold created this specialism, as the Disability Design Consultancy, in 1997, formally renaming it Inclusive Design in recognition of the growing breadth of services being called for, in 2007.

Environmental considerations

Care for the environment has been one of the driving forces within Buro Happold since its very earliest days and is something for which the practice is renowned. Innovative use of timber, for example, is a recurring theme, going back to the practice's projects of the 1980s.

Today, however, a slew of targets and protocols aimed at reducing carbon dioxide emissions are in place on regional, national and international levels, with the Kyoto Protocol perhaps the most famous of them all.

Inclusion of renewable energy in projects and measures to boost sustainability and energy efficiency have long been fields of expertise in Buro Happold but they were formally amalgamated into the Sustainability and Alternative Technologies group in 2000.

Progress and knowledge gaps

Buro Happold has always been heavily involved in research of new technologies and adoption of new materials and products. This approach has formed a sound basis for our progress over the years and, in many cases, has seen the practice lead the way in the use of certain construction methods. Consistent involvement with academia also means that the practice has long been seen as one of the industry thought leaders.

A good example of application of this developing body of knowledge is in facade engineering. This started out with assisting the architect to leverage their creative skills by adding technical knowledge of what was a fairly straightforward specialism. But over the years, as materials and processes have advanced, facade engineering has become ever more complex and now includes, among many other elements, aspects of acoustics, building services strategy (in terms of allowing in light and heat) and blast protection.

Buro Happold’s facade engineers take all of these issues into account to ensure a fully co-ordinated and value added design is produced.

Comfort, safety and productivity

Buildings have always been required to provide safety and comfort to their occupants, but in recent times we have been more able to identify what these issues mean in more detail, and how to deliver that. It means being able to cope with extremes of temperatures year in, year out; from the bitter cold of 58° North to the sweltering heat of the Middle East. More detailed knowledge is also being applied to making buildings not only comfortable, but more conducive to effective work, which also affects the productivity of occupants as well as creating better conditions for them.

The study and simulation of people movement is another detailed area of expertise that can affect the architectural design. Understanding people movement in circulation areas can identify congestion, which could make people feel unsafe, or highlight space in a building that could be used better. The use of these services has been instrumental in unlocking the value of circulation space in public buildings, providing confidence for the client that the design will be safe and operationally manageable. These areas of expertise, which are becoming more broadly recognised in the wider building community, are examples of how Buro Happold is moving towards delivering what can be seen as a human experience, or service for the occupant. Rather than simply designing beams and decks and walls, engineers now have to think in terms of meeting the demands of human behaviour to create a product that meets the many criteria of the client.

Mick Green and Peter Moseley are co-leaders of the Specialist Consulting group.

Andy Nicholson is an associate in the Fire Engineering group within Specialist Consulting.

Mark Whitaker is head of Happold Safe and Secure within Specialist Consulting.

All wrapped up

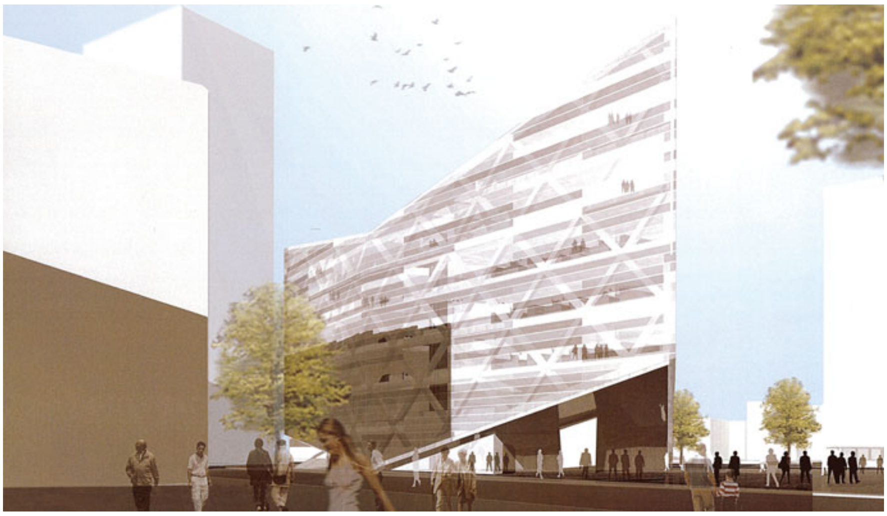
A building's facade plays a key role in reducing its energy consumption. Francesca Madeo describes exactly how the 1m zone around a building can achieve class-leading energy performance, while contributing to its look and structure.

The facade engineer has become an accepted element of many design teams, particularly where the envelope of the building is required to perform beyond normal parameters. They give clarity to the role of assisting the architect and design team to mediate successfully between the external environment and what some call the building's metabolism within.

As our experience in the Nykredit project highlights, facade engineers address a distinct zone of influence and in Buro Happold we have described this in terms of a 1m zone. However, it might be more accurate to define the zone as starting at the sun and finishing the five or so metres inside the building where the benefits of natural light begin to diminish. Of course, the influence also extends deep into the servicing systems but, suffice to say, it is not simply confined to the shell of a building.

The design of the facade for the Nykredit building in Copenhagen, Denmark is leading edge in comparison with most projects and is a great exemplar of the latest thinking in this field. On this project the multi-layered facade is fundamental to the strategy of producing a high performance and transparent building.

The building will be the new headquarters for Nykredit, one of the largest mortgage and finance companies in Denmark and so the brief calls for a building symbolising the company's status and capability. In conjunction with the high quality architecture, it also had to have the best performance in terms of energy efficiency.



The architect's intention to create a precious diamond-like structure is clear in this visualisation of the Nykredit building.

Image: Schmidt Hammer and Lassen

The full name of the project, Nykredit Sky and Crystal, emphasises the aspirations of the client for a building as precious as a diamond. The brief was interpreted by the architect, Schmidt Hammer Lassen, into a multifaceted crystalline form that stands alone from its surrounding urban context.

The aim of the design team in relation to the facade was to reflect these high architectural aspirations, partly through the expression of an elegant substructure but also through a very high degree of transparency – and at the same time provide exemplary solar-thermal performance. Therefore the underlying philosophy adopted was to create an ambitious polyvalent 'skin' to perform efficiently and effectively.

The performance requirements of the facade were set during early design work by the architects and Buro Happold's building services and structural engineers.

The external facade features a stiff primary structure (a lattice grid) and supports the roof which, in turn, supports the inner floor plates from hangers. The structure appears to touch the ground lightly and this 'light touch' is reflected in the building service strategy, which uses natural ventilation with high levels of glazing to produce a well-lit environment.

In tandem with this was the ambitious target for an overall U-value for the facade of 1.0 W/m2K. This was particularly challenging as a standard curtain wall system, with low-E double glazed units, can achieve around 1.6 W/m2K, while statutory obligations in the UK (under Part L 2006) only call for an average facade U-value of 2.2 W/m2K. Other well-performing examples of double skin facades with a naturally ventilated cavity can get the U-value no lower then 1.3 or 1.4 W/m2K.

Our response to these design parameters was to consider the layering of the facade zone carefully and to assess where maximum performance can be gained through the application of leading edge technology and materials. However, the final design did not wholly rely on new technologies as this was

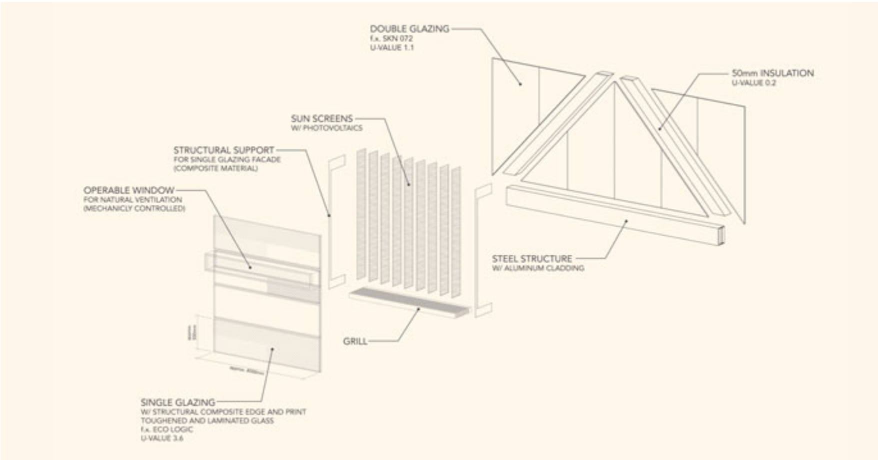


Figure 1 This diagram shows the key strategy of the facade design: the multi-layering of the zone. Great care has been taken in the choice of material and systems for each layer in order to optimise final performance.

Image: Schmidt Hammer and Lassen

not an experimental scheme with a limitless budget. Material selection was tempered by such issues as durability, buildability, the effectiveness of precedents and, of course, cost.

The initial facade scheme was a proposal for a double skin system with a non-conventional, wide ventilated cavity of 800mm which acts as buffer zone to improve thermal performance. The successful application of a double skin scheme relies on the accurate design of each layer and in the interaction between the layers, with the cavity itself acting as a layer.

It is in the careful examination of these layers and interfaces that the facade engineers have worked hard to validate, and help specify, the final design.

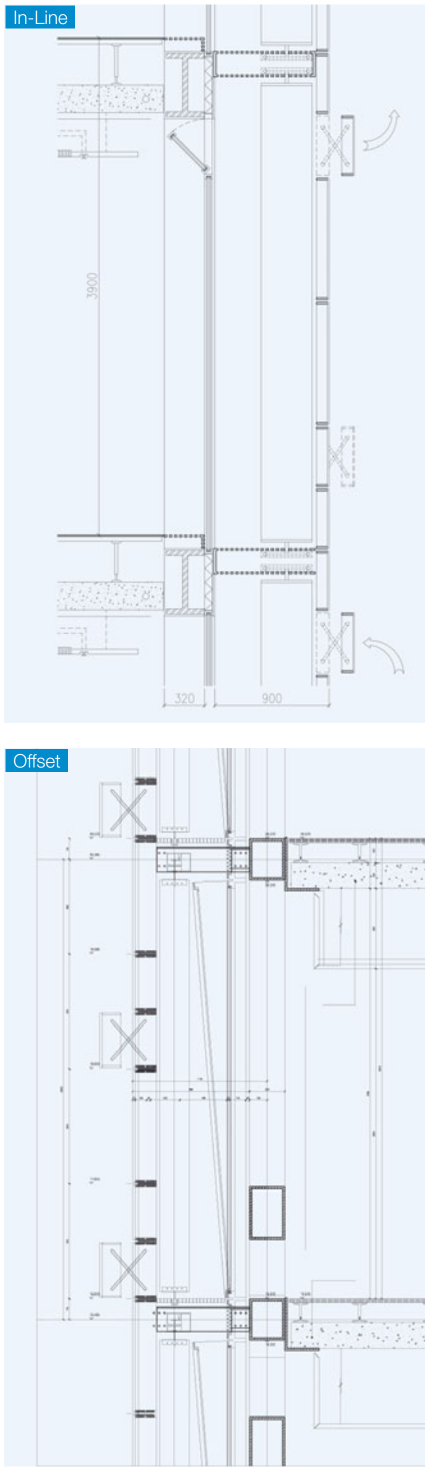
The geometry of the facade follows the plan grid of the structure, with modules 3m wide by 3.9m high for the outer skin, which corresponds to a double module of the inner skin (1.5m wide by 3.9m high). The scheme is based around a naturally ventilated cavity with single glass to the outer skin and double glazed unit to the inner skin.

The inner facade forms the sealed boundary to the external environment and is the weatherline of the building. The second skin (that is, the inner facade) is closed during the winter, acting as a barrier against the extreme external conditions, which reach -14°C in winter and 28° in summer. Therefore, there is control to the air coming through and into the cavity, and control of the temperature of the air in the cavity and close to the inner skin. This enhances the benefit to the internal environment while reducing the overall energy consumption of the building.

Inside story

The inner facade needs to provide the majority of the thermal performance of the overall envelope build up. To design it as an effective, high performance barrier, an in-depth investigation into low-emissive, innovative glazed products was carried out.

The design team concluded that an argon filled double glazed unit (with a U-value of 1.1 W/m2K) would have advantages in terms of performance as well as a proven track record with a number of suppliers.



Figures 2 & 3 Comparison of the cross sections through the facade to show the two options for the structural layout.

The next decision was to decide the location of the inner layer in relation to the superstructure. There were three options: within the zone of the superstructure, outside the superstructure but aligned with it and inside the cavity.

The third option was discarded due to space requirements inside the cavity for the shading louvers and for access to the cavity. Both the other options were considered valid and analysed according to the effect on the thermal performance of the inner skin. Initially it was thought that placing the inner skin in line with the superstructure, thereby reducing the overall glazing area, would prove most efficient. However, even with the insulated line wrapped around the superstructure, the result of increased linear transmittance and greater air leakage meant that the simple double glazed facade system placed at the edge of the superstructure performed better.

The frame of the inner skin was carefully considered as it represents the weak element in terms of thermal performance. It also had to meet the architect's desire for a slender sub-frame, which was in conflict with the load-carrying capacity required for awkwardly shaped and relatively heavy units. Furthermore, the system required opening lights and needed to be cost effective.

Cavity and shading

In addition to the inner and outer skin, the cavity plays a large part in the overall performance of the facades zone. On the one hand it acts as a buffer zone between inside and outside, with enhanced thermal resistance due to the large width. But it also provides enclosure and protection to the shading system of vertical adjustable louvers. The GRP (Glass Fibre Reinforced Polycarbonate) louvers provide protection from solar gain in the hot season and from glare when the angle of the sun is low. They are double storey in height (approximately 8m tall), are top hung and controlled primarily through the Building Management System.

A mock up of the shading system, produced by manufacturer Ars Andersen.

Outer skin

A particularly challenging aspect of the design has been the development of a GRP fin support system directly bonded to the glass of the outer skin. The GRP fin system was previously used by the architect on another project and was developed together with the Danish facade contractor Sirius Façades.

The choice of this innovative system was made by the architect, primarily on aesthetic grounds, as the GRP fins are thinner and lighter than a glass equivalent. It also has enhanced thermal properties with a very low U-value of around 0.2 W/m2K.

As a consequence of these light fins, the large outer facade modules (which measure 3m by 3.9m) can be cantilevered from the main structure by nearly a metre.

The facade engineer played a key role in the evaluation of design options for the GRP fin system by assessing the most efficient solution in terms of assembly and inclusion of an openable sub module made entirely of GRP components.

But does it work?

After such a sophisticated design process, the evaluation of it had to consider all the thermal layers as the facade zone and whether it could achieve its target. The conclusion was that the sealed facade units in winter conditions achieved a U-value of 0.97 W/m2K, a figure since verified by the client's peer review team.

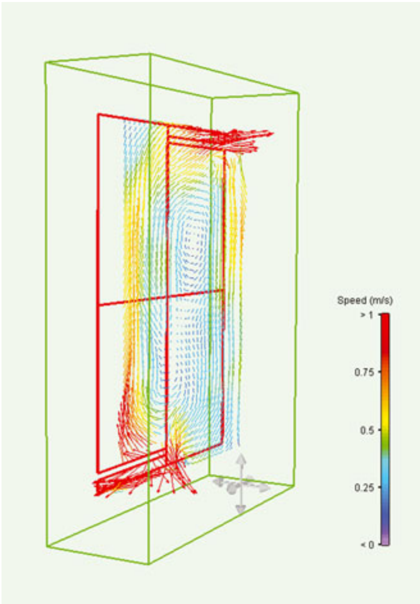
The first stage of the evaluation was to calculate the U-value according to the European standard EN10077. This presented a major technical challenge as there are no specific guidelines on the calculation of U-value for multi-layered facades with such wide cavities. As such, Buro Happold's facade engineers had to propose a methodology essentially from first principles, drawing on experience within the team and also analysis of precedents.

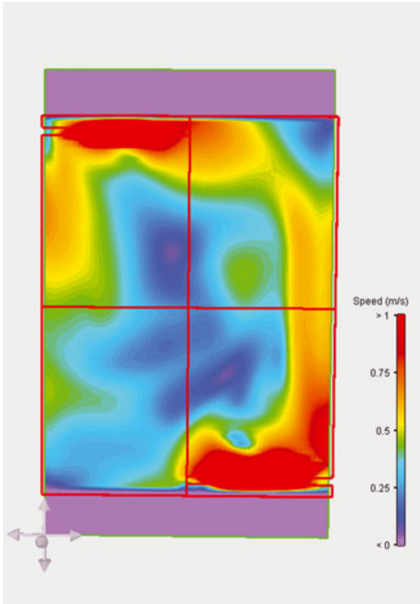
Although the initial proposal resulted in a high performance facade module with a U-value close to the target of 1.0 W/m2K, this was not considered good enough by the design team. Therefore, the whole design team had to work closely together to find an accurate rearrangement of the facade to further reduce the U-value. The solution was to extend the solid area of the inner skin to the overall upper part of the module, above the opening lights.

A confirmation of the U-value of the revised module came through Computational Fluid Dynamic (CFD) analysis, which provided proof of the value of the work done by the facade engineer.

The thermal models developed through computer analysis were fundamental to validation of the facade design. A number of thermal models were created, in addition to the CFD analyses used in the U-value investigations, to study the thermal characteristics of the facade module and the resulting comfort condition.

The studies focused on the potential for overheating in the cavity during summer, so the aim was to establish the required amount of ventilation through the facade module to avoid this and thus the size of free area to be specified. This in-depth study included investigations of compartment size, the impact of Venetian blinds and the vent positions. The final output of the study was a





Figures 4 & 5 The computational fluid dynamics analysis was undertaken to examine the ventilation and overheating in the cavity so as to determine the strategy for design and distribution of vents.

detailed guide for the distribution of the openings and an optimised facade module pattern that created the desired visual effect of a semi-random geometry on the facade.

Conclusion

The design process on this project makes clear that the facade can not be designed in isolation from the rest of the building, and nor should it be seen as being just the outer covering to the structure. The facade engineer works hard to control the effects of this zone, beyond the thickness of the facades, both inside and outside.

The designing of a high quality and innovative facade requires the reconciliation of architectural aspirations with technical performance demands. This calls for an integrated approach from the design team, involving close collaboration with other design disciplines, as well as other parties such as manufacturers and contractors, to ensure materials and technologies, be they conventional or innovative, are consistent when interfacing with other subsystems.

The Nykredit project exemplifies how facade engineers and other designers can approach leading edge technologies to produce radical and well performing envelopes. The difficult part has been defining carefully the physical boundaries of the facade zone and, at the same time, making this zone work in an integrated way with the rest of the building – by considering the envelope as a multi-functional skin influencing the metabolism of the entire building.

Francesca Madeo is a senior engineer in the facade engineering group within Specialist Consulting.Francesca gratefully acknowledges the support of Ian Maddocks, head of facade engineering, without whose help and encouragement this article would not have been possible.

Valuing green

The pressure on building designers to go green continues to grow for a whole range of reasons, but is there a financial argument among them? Henrietta Cooke examines work being done to find out whether building in an environmentally friendly way really does add value.

The headquarters of biotechnology company Genzyme, in Massachusetts, USA was one of the first to receive a platinum certification from the US Green Building Council under the Leadership in Energy and Environmental Design system. Just 12 other buildings had been awarded this at the time of the award, in 2005.

Putting a value on 'green solutions' is critical in increasing the use of the energy saving techniques and renewable technologies required to meet targets for cutting carbon dioxide emissions. If the extra value of these eco-friendly measures can be demonstrated and accurately quantified, it will be more likely that a developer will invest in going green.

Establishing a link between green and value, however, is not always an easy task. The terms themselves are broad in scope and are often used imprecisely. This, combined with the great diversity of the professions and trades involved in construction, is leading to a range of different approaches being taken.

It is illuminating to consider two very different industries that feed into the built environment – those of real estate and power generation – to look at ways in which the concepts of green and value are being used and assessed.

Keeping it real

Putting a value on green in the real estate sector has proved to be difficult. It is a sector in which the subjective issues of aesthetics, usability – and now sustainability – mix with the objective, quantitative world of finance. Those who are investing and developing want evidence in the form of numbers from those who are designing; people who are more used to speaking in terms of quality of life and visual impact.

One way of viewing the matter is as a hierarchy, with legislation driving sustainable building at the bottom, rational/logical analysis such as productivity studies taking it forward and what could be termed moral values being the ultimate arbiter at the top – see figure 1 right.

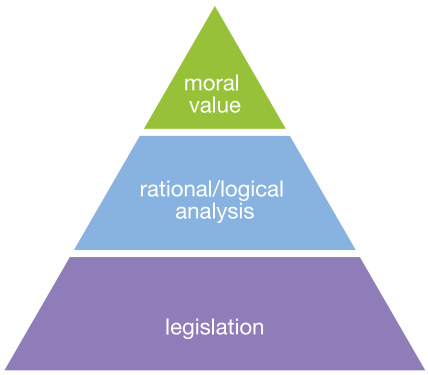


Figure 1 Adaptation of US psychologist Abraham Maslow's hierarchy of needs, which represents more primitive needs at the bottom of the pyramid.

On the legislative side, aside from the targets for reduction of CO_2 emissions through energy efficiency measures and the use of renewable energy, a particular piece of legislation that is likely to have a significant impact on the value of green real estate is the Energy Performance of Buildings Directive (EPBD) soon to come into effect throughout Europe.

This Directive requires all new buildings to be given an energy rating akin to the ABC energy performance ratings that have long been attached to white goods. Buildings will be required to display their ratings publicly and they will be assessed not just at the build stage but also once occupied. It is inevitable that this will impact on property values with owners not wishing to be associated with low rated buildings and tenants preferring to occupy high rated ones.

Moving up the hierarchy to rational/logical analysis, considerable research effort has been put into establishing, in financial terms, the relationship between green design and asset value. Figures are becoming available, thanks to studies of existing buildings, particularly those certified under green rating systems such as LEED (Leadership in Energy and Environmental Design, a scheme run by the US Green Building Council to certify buildings according to a range of environmentally friendly design criteria) in the USA. These studies demonstrate that it is the impact on occupants that is critical in driving up asset value.

Solar reflectors on the roof help direct the sun's rays down into occupied areas.

The excellent levels of daylight that penetrate the offices of Genzyme helped it to achieve great results in terms of occupant satisfaction. An employees survey found 58% said they were more productive than in the company's former home; absenteeism was 5% lower than the average for all its offices in the state and energy usage was estimated to be down 42% compared to a conventional building; water usage by 34%.

The positive experience of tenants of a green building means that they are prepared to pay higher rents, there are more of them wanting to move in and they stay longer - all things that have a positive impact on the financial yield accruing to the building owner and hence on the building's value. A 2006 report from financial analysts McGraw-Hill, called SmartMarket Report, states that buildings in the USA renovated to meet green standards can bring 3% higher occupancy rates and a 7.5% increase in a building's value compared to their conventional equivalent.

These figures are based on detailed work into such things as productivity gains, recruitment and retention. Examples include a post office in the US that upgraded its lighting and altered ceilings to minimise energy use and improve light quality – a refit costing around $22,000. The consequence was a 6% increase in processing rates, so a productivity gain that far outweighed the cost. Similarly, anecdotal evidence from companies in well designed green buildings suggests that people apply to work there because of the quality of the office environment and once there, they want to stay.

Such research is being fed back into valuation models to enable financial organisations to offer more innovative funding mechanisms such as dedicated green building investment funds or green mortgages.

Saving energy

Another key area is, of course, the energy savings associated with a green building. Buro Happold recently undertook a major energy audit into a portfolio of buildings in New York. The owners were aware that the carbon footprint of their buildings was higher than it should be. They wanted to understand why this was in order to develop a strategy to reduce it. Part of what they were interested in was understanding how any investment that might be required would feed back into higher returns. They were also aware that implementing energy efficiency measures would positively impact on their company profile in the eyes of the planning authorities and enable them to access a wider range of development sites within the city.

The study was successful in determining where the building was inefficient and how this could be addressed. It also assessed the cost of each necessary measure and the potential payback in terms of energy savings so that options could be ranked and a plan for implementation drawn up.

But what became clear was that the additional costs and potential energy savings were not significant when considered in the light of the owner's overall capital and development plans. Instead, what was significant was the potential for higher rents that they could charge and the impact this would have on yield and building value.

Finally, at the top of the hierarchy is the complex issue of moral value, where the word moral is used in a broad sense to include social and environmental ethics. In the end, real estate value is determined by market mechanisms and the market's perception of what value is. There is some evidence to suggest that this perception is changing and expanding to include this broad moral sense where quality of life, a sense of community, resilient energy systems, water conservation and ecology are all important. It could be said that these values – or morals – within the market place will ultimately be what puts a value on green.

Powering up

At the other end of the spectrum is the power generation industry. One of the developments within the sustainable construction movement is towards urban masterplanning, moving on from designing specific buildings to tackling the complex relationships between them: the water and energy provision, the transport links, access and security – things that have an impact on quality of life and may feed back into individual building design.

For a developer examining the supply of energy to a site, the drivers influencing value are different and in some respects lead to more quantifiable results than those of green building design. Aesthetics play less of a role and hard numbers are easier to come by.

Financial modelling has become more complex in a carbon-constrained world. The interplay between cost, benefit and risk now needs to consider issues such as tax credits, new technology risk, the availability (or not) of capital subsidy and a whole range of different forms of revenue, such as politically influenced green energy tariffs and carbon credits. However, the basic concept of project finance is broadly the same as it has always been. As such, valuing green is an easier and arguably more meaningful process.

An example of where Buro Happold has used such analysis to assess the value of going green has been at a development in Egypt, on the coast of the Red Sea. The client was keen to examine ways of making the development more sustainable and reducing its carbon footprint. One idea considered was wind power as the area has good wind speeds and the government has already commissioned a number of wind farms nearby. The question was, given the economics of the power industry in Egypt, could such a project be directly viable? And if not, how much more would a developer have to invest to make it so?

The economics of a wind farm depend primarily on the unit cost of electricity produced by the farm, compared to the unit cost of electricity available from the national grid. Egypt's grid is heavily subsidised making the economics of this project difficult to justify without thinking more broadly around the subject. Review and further analysis suggested there were a number of ways in which the economics could be improved. These included:

1. Broadening the revenue streams available to the wind farm through mechanisms such as carbon credits, potentially available to renewable energy projects in developing countries.

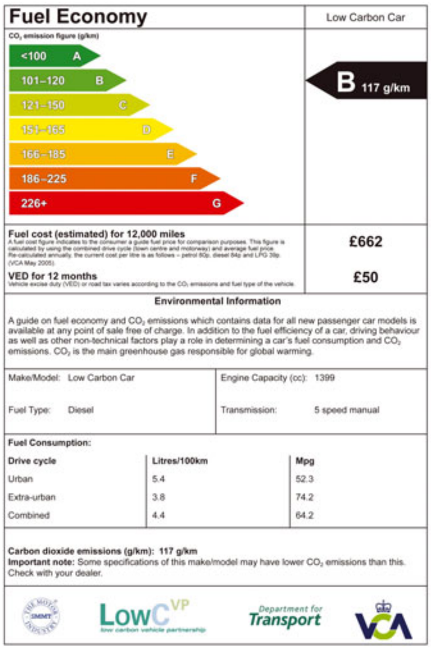
2. Involving the right investment partner, for example a governmental body that could provide access to cheaper finance and easier permitting and grid connection.

3. Attracting sustainable development funding from international bodies, by way of grants.

4. Self-financing the project on the basis that softer commercial returns, such as the enhanced branding of the development by being seen to be green, are possible and recognised as an investment in a licence to operate.

Financial modelling in this case showed that a value could be put on green as the additional, up-front funding the developer would have to inject, but on which it would not expect to get a return, could be quantified. On a mega-project of this size, such an investment of $4m to $5m was not an unreasonable figure. And through assigning this funding to a separate budget or considering it a licence to operate, it can be seen as simply a cost associated with being permitted to build.

This concept has long been present in the UK construction industry, through Section 106 agreements, whereby



As well as white goods, energy efficiency labels are attached to new cars, detailing carbon dioxide emissions per kilometre travelled.

planning permission is given on the condition that the developer also builds, for example, a community centre.

So can we actually make any claims about putting a value on going green? Each sector within the industry is starting to do so using different approaches relevant to their specific economic and business models. As engineers examining this issue in depth, it is our job to understand all the various complexities and how they relate to sustainable construction. If we can put a value on green it will make the implementation of sustainable designs both easier and more likely and, as such, it is in all our interests to continue developing this important field of research.

Henrietta Cooke is a consultant in the Sustainability and Alternative Technologies group within Specialist Consulting.

Breaking down the barriers

Greater use of alternative energy technologies in buildings is being hampered by a whole range of issues within construction. In order to more precisely define – and so tackle – these issues, Rob Cooke took a long, hard look at how the industry needs to change to implement low carbon energy technologies.

The UK Government has set the target of reducing CO_2 emissions by 60% by 2050, compared to 1990's level. Energy used by buildings is responsible for around half of the CO_2 emissions in the UK. There are many established methods for reducing such emissions from buildings but these opportunities are not being fully realised. One of these methods is the use of Alternative Energy Technologies (AETs) integrated into the built environment.

It is clear that engineering consultants have a key role in the design of buildings, their energy consumption and the consideration of AETs. In order to find out what barriers are in place preventing AETs becoming more broadly established, Buro Happold undertook some research. The aim was to examine the process of delivery of AETs in building projects, the key factors that influence the viability of these technologies and how engineers can increase their rate of uptake.

While there are many well known incentives and restrictions to using these technologies, there has been little research into their impact in a practical context. This report includes evidence from design teams directly involved in projects using AETs, finding significant variations in the drivers and barriers to using AETs.

These experiences were investigated in detail through focus groups, which led to the development of a structured interview programme held in two phases. The first interviews investigated the experiences of 41 participants drawn from the full range of building project stakeholders. Phase two looks at 24 relevant projects, from the perspective of the engineering consultant, investigating the decision making and design processes in more detail.

The first phase of 41 interviews was a qualitative and partly quantitative investigation of all the building project stakeholders in the UK, conducted between October 2003 and May 2004.

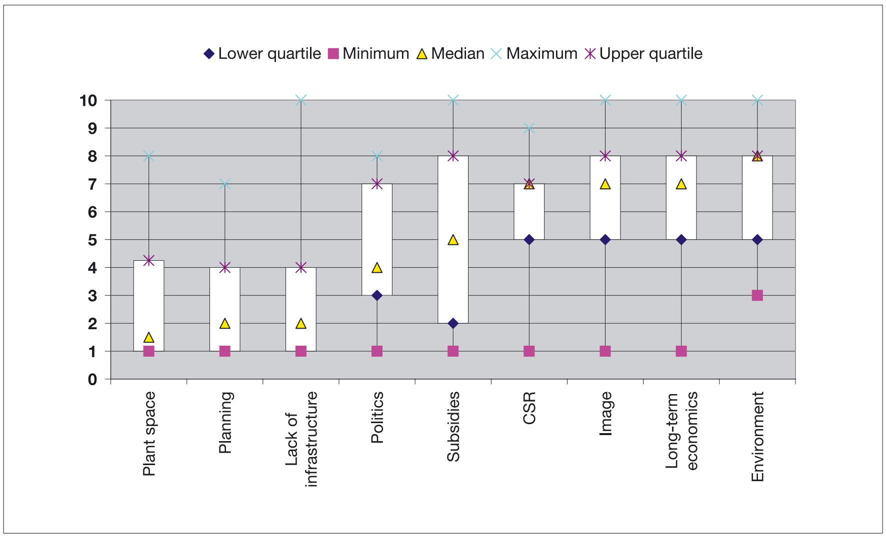


Figure 1 The perceived importance of drivers for the use of alternative energy technologies in buildings.

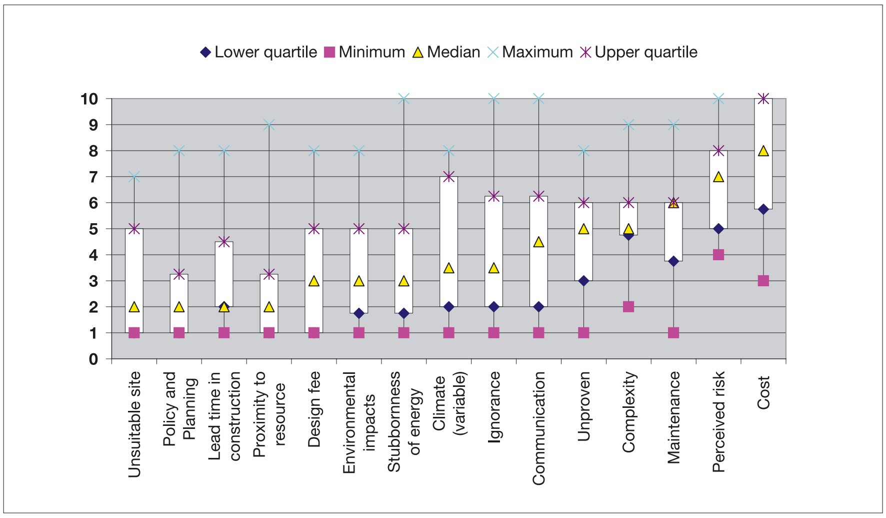


Figure 2 The perceived importance of barriers to the use of alternative energy technologies in buildings.

Drivers vs. barriers

A list of important drivers and barriers to using AETs in building projects was produced through the research and during each interview scores were attributed to each heading in terms of their importance. From these scores a hierarchy of drivers and barriers to the use of AETs has been developed. The building project stakeholders interviewed said each project has its own hierarchy of drivers and barriers.

The conclusions from this study were:

- There is a lack of experience of installing AETs in buildings in the UK, and the understanding of these technologies is variable.
- The high capital cost and subsequently long payback period is seen as the most significant barrier and is the main focus of existing assessment approaches.
- No structured approaches to assessment that specifically address AETs and the drivers and barriers to implementation are being used in the industry. Further education and new approaches to assessment are required, to move the emphasis away from capital cost and toward the benefits provided by AETs.
- Building services engineers play a key role in the technology selection process and also in raising awareness of AETs in the industry.
- There are a number of drivers and barriers to the use of AETs in buildings, and the relevance of each of these varies between projects, with time and with the technology.
- There are a number of key factors that affect the viability of implementing AETs in building projects.

The second phase of interviews looked specifically at 24 projects, which led to the creation of case studies that can be compared against the more general insights and conclusions generated in Phase I. This project-specific study investigated in more detail the decision-making processes and the influence of various factors throughout the design process.

Results of this study are subject to much less variation than in Phase I for several reasons. Only building services engineers were interviewed, so removing the differing perspectives of the different stakeholders. Also, as each project was assessed in detail, answers are specific rather than general observations, which makes recognition of cause and effect easier. And as some of these projects only considered a small number of

The Sustainability and Alternative Technologies group advised on all aspects of energy use at the Academy of St Francis of Assisi in Kensington, Liverpool, which opened in September 2005.

Image: Daniel Hopkinson

AETs – and in some cases, only one in depth – specific technology drivers or barriers were brought out more clearly.

The Phase II interviews highlighted the importance of recognising opportunities for using AETs very early in the project and gaining a commitment from the client to consider them as part of the building design.

The factors affecting the viability of AETs are highly project variable and there is no essential formula for success. But in projects where AETs were maintained in the project through to construction, many of the barriers were considered as less important than in other projects. In particular, there was further evidence of the importance of reducing ignorance and improving communication within the design team to increase the chance of integrating AETs into building projects.

These interviews also reinforced the understanding that simple financial payback calculations are the most common form of technology assessment, and that other considerations are often presented within a written technical report summarising technical pros and cons. This emphasises the absence of refined and structured decision tools that can accommodate qualitative and quantitative considerations in a holistic and transparent manner.

These results suggest that in successful projects, ways have been found to reduce barriers and to allow positive drivers to overcome them. The role the consulting engineer has to play here and the impact they can have on reducing ignorance, through obtaining and disseminating accurate information, has been shown to be key.

Even in winter these solar panels help supply hot water (above) and electricity (below) for use in the school.

There are a number of key factors that influence the viability of the various AETs, including the client type, project location, building purpose, construction timescale. These natural project variations are a hindrance to the integration of AETs as they add complexity to the assessment and selection process.

There is a lack of suitable operational examples in the UK that cover the extents of project variations and in enough detail. Such case studies are useful in the design process; they reduce the level of uncertainty and the perception of risk within the design team by demonstrating that the technology has been applied in a similar case before and is a success.

The lack of case studies available to engineers adds to the overall lack of detailed awareness, design experience and understanding of the principles of using AETs, which is common throughout the building industry. This, combined with a perception of undue risk and complexity, restricts the use of AETs in UK building projects. But through the project experience gained during this research project, information has been obtained and put into practice; spreadsheets and assessment approaches have been developed and refined and eventually technologies have been designed into buildings and built. With each project this process becomes easier and quicker and the technologies are considered in more detail and then installed more frequently.

Despite the varied nature of the projects, high capital costs stand out consistently as a major barrier in nearly all the projects reviewed – a factor not directly influenced through the role of engineer.

Beyond the capital cost and technical constraints that cannot be influenced through the role of the building services engineer, other significant barriers include ignorance and perceived risks.

It is essential for further development of AETs that, for each project, the key drivers and barriers are recognised. This is reliant on technical developments, political decisions and influencing human perception within the project team. The exploitation of drivers is reliant on better understanding and effective modes of communication of the potential benefits.

Regardless of the variety of projects, capital cost is the major barrier to using AETs because the approach to decision making is often based on monetary and then technical considerations. This research has highlighted that there are no commonly used methods for comparing quantitative factors, such as cost, with less tangible factors such as environmental benefits. In the Phase II interviews, the environment and long-term economics were the highest rated drivers and capital cost the highest rated barrier.

However, no method is used for comparing these important factors in a holistic manner. Without methods that can openly compare qualitative and quantitative considerations, particularly as many of the drivers are difficult to quantify, it will be difficult to justify using AETs in building projects.

Key factors for integrating AETs into building projects have been shown to be:

- High levels of awareness and understanding of AETs.`
- A high level of importance attributed to the environment and to green image benefits.
- An early and sustained commitment from the client.
- The client having an ongoing interest in the building.

Other factors affecting successful integration of AETs in buildings were highlighted through experiences gained during the specific projects. These are:

- The availability of reliable energy consumption data and technology design, cost and performance data. To do this, a large database of projects needs to be amassed and the details made publicly available.
- Co-ordination with the design process to keep one stage ahead of the main design but being prepared to provide the right level of information at the right time.
- Agreed project priorities and objectives from an early stage. The use of a decision matrix can help to inform this process.
- Ensuring that the client is aware of potential additional risks, design time and costs, but also of the external benefits such as identity, local economy and local energy awareness. This includes providing an insight into the risk and sensitivity of fuel prices.
- Necessary involvement of other stakeholders such as renewable energy suppliers, local residents, funding bodies, etc, who can have a significant influence on the viability of AETs at the later project design stages.

These approaches must be based on a better understanding of qualitative and quantitative aspects such as whole life financial, environmental and social impacts and clearly defined client value criteria. They must also guide the engineer through the decision process and be designed to provide the right level of information at the right time. Such methods will help to improve the chances of integrating AETs into building projects, beyond the use of subsidies and legislation to reduce the up-front financial burden of investment.

Solar photovoltaic cells to generate electricity and rainwater harvesting are among the key sustainability features of the Core educational facility at the Eden Project in Cornwall.

Image: Mandy Reynolds

The Royal Mills complex contains 178 apartments as well as bars, restaurants, retail and business spaces in a series of new buildings alongside redeveloped cotton mills in the Ancoats area of Manchester.

Image: Daniel Hopkinson

A further challenge is the need to make buildings future-ready so that, where AETs are not considered viable in the present climate, the building should be able to accommodate them in the future without significant alterations. This approach should account for changes in energy prices and technology developments.

In short, to address the issue of integrating AETs into building in the UK, engineers need to be better informed and to embrace holistic technology assessments of AETs, which account for both qualitative and quantitative considerations.

Rob Cooke is a senior consultant in the Sustainability and Alternative Technologies group within Specialist Consulting.

The changing metabolism of buildings

Looking at the evolution of the built environment and how heat is transferred in the natural world offers some useful insights into building design. Salmaan Craig tracks recent trends in building envelope technology and finds that reducing environmental impact is all about resolving contradictions.

The buildings we live and work in today are the offspring of the insulated, locally sourced biomass-heated, hunter-gatherer shelters of yesteryear. The biggest changes to housing since then have arguably occurred not in the building technology we employ to manage heat, but in the way we deliver it.

As population and urban centres have grown, society has organised itself into increasingly complex forms. The fuel and energy we use to heat and cool our buildings is now distributed on a national scale. This is only a problem because the natural fuels we use are limited resources and electricity, an energy carrier, is mostly generated in a carbon-intensive manner. We seem to be locked in to this particular form of comfort delivery and talk of energy efficiency is usually limited to making this mode better, while failing to consider others.

The dominant thermal comfort strategy can be thought of as 'plug-in and close-off' – insulate as much as is practical and let active systems provide internal heat or coolth using energy and fuel distributed on a national scale. It is not entirely unnatural to insulate and turn up the thermostat as mammals do the same, with insulation in the form of fur or blubber and metabolic rate as a thermostat.

But for energy *efficacy*, buildings are increasingly being asked to flip between different heat management strategies depending on the time of year or day. And this is often about the design of the building envelope, before active systems come into play. When it is hot, it makes sense to have a building that will, passively, cool down faster than it heats up. When it is cold, it should heat up faster than it cools down.

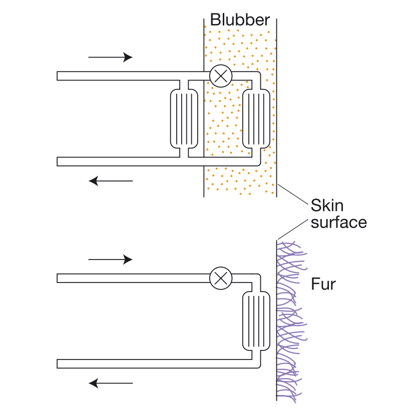


Figure 1 Unlike furry mammals and many of our buildings, dolphins are able to bypass their insulation when they need to cool off. Counter current heat exchangers mean that they can transport blood without losing heat. Heat recovery systems in buildings employ the same principle to decouple ventilation from heat loss. Some biologists think Dolphin blubber may be a phase change material (pcm).

Biology has captured many such successful strategies where buildings struggle. Can our buildings bypass their insulation when the need for heat dissipation increases, as dolphins do? (see figure 1) Or can they adapt, like a swarm of bees? (figure 4) Can they respond to the live orchestra of radiation, sensible heat, latent heat, air, moisture and water flows that they find themselves in? Within the interloping strands of building envelope evolution are responsive strategies that have difficulty gaining a competitive foothold, largely because the status quo works and is widespread.

But the building technology repertoire to tackle these issues is growing, and while it is nowhere near the depth and range seen in biological systems, exciting developments are taking place.

The important developments are those that resolve recurring bottlenecks or technological conflicts. A technological contradiction occurs when two features or parameters of a system are in conflict with one another (for example, the ever-present strength versus weight conflict). Here are some technological contradictions that are important drivers in the development of building envelope technology.

Harmful sunlight vs. useful sunlight – from variable transmission to splitting the solar spectrum

On a cold winter's day, sunlight is useful as both light and heat. But during the summer, the heat component is harmful because it contributes toward overheating. Socrates recognised this and designed buildings that would flood with low level, warming winter sun whilst avoiding high, overheating summer sun. He did this through form and orientation. Other static ploys include shading devices and prismatic glazing.

Dynamic ploys start with louvers, blinds and clever placement of deciduous trees. Recent advances in building management systems and chromogenic (switchable) glazing allow automatic variable transmission.

Correctly employed, these are all valid forms of annual temperature adaptation. But there is still room for development. The materials currently used in chromogenic glazing absorb the solar spectrum when darkened. To avoid overheating, it would be better if they switched to a reflective state. 'Switchable mirrors' are in development, but not yet available.

Incoming solar radiation consists of three components: ultraviolet (9%), visible (40%) and infrared (51%). Unlike chromogenic glazing, which is becoming well known, spectrally selective films in functional terms have no historical precedent. The development of very thin, virtually transparent, metal oxide films means that the need for natural light and views outside need not be such a thermal drain. In hot climates, selective glazing can let in only the visible component,

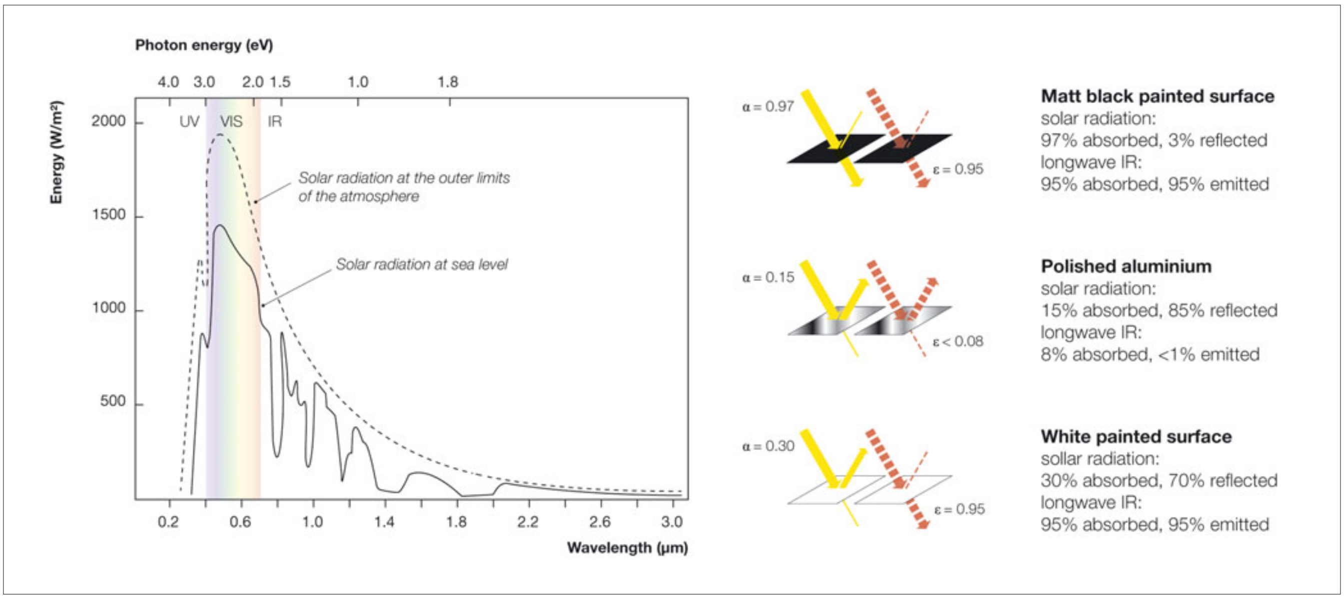


Figure 2 Solar radiation received by buildings is 9% UV, 40% visible and 51% near infrared. We feel infrared as heat. The earth keeps heat balance by rejecting longwave infrared into space via the atmosphere. Buildings are painted white in hot countries because it reflects solar but emits longwave infrared. This simple spectral selectivity can bring about free thermal mass cooling on clear still nights.

while reflecting the infrared (thermal) part. In cold climates, the entire solar spectrum can be transmitted, and the infrared reflected internally to begin a warming greenhouse effect.

Perhaps at some point soon there will be convergence of the spectrally selective and variable transmission strands of glazing technology. This would allow natural light to be used whenever it is available, solar heat to be used when it is available and useful, or avoided when it is harmful.

Visible light transmission vs. retaining heat

Allowing in natural light has traditionally been a thermal sore point in cool climates. Glazing lost more heat than walls, but at least it kept out the wind and rain. Emphasising this point, the word window originates from the Old Norse *vindauga* – *vindr* meant 'wind' and auga 'eye'. The idea of double glazing is, surprisingly, two millennia old, but not until recently have the transparent parts of the building envelope started to compete thermally with the opaque parts. This has come about with the introduction of several glazing layers, gases with lower conductivity than air, spectrally selective films and manufacturing control. Vacuum glazing is yet to take off, but is commercially available.

Transparent insulations, like solar selective coatings, have their origins in solar collector development. Air-inflated cushions of clear ETFE film offer lightness, transparency and low thermal conductivity as an alternative to the conventional, glazed curtain wall.

Sensible heat storage vs. charging & discharging: 'unlocking' thermal mass

Concrete, or 'liquid stone', has played a significant role in the history of construction, mainly because it is strong in compression, cheap and formable. But its capacity to store heat has come more into focus recently. Flat slab construction, invented as a fast and cheap way of erecting multi-storey buildings, can now be used as Fabric Energy Storage (FES) systems. Exposed slabs with an internal structure use either flowing air or water as a heat exchange medium, to 'unlock' the temperature regulating potential of the building structure.

The significance of this development is easily overlooked. Thermal mass is useful, but its efficacy can be compromised by insulation. In order for thermal mass to work, it needs to be thermally coupled to the appropriate heat source and heat sink so it can charge and discharge accordingly. Internal and external insulation can hinder this process.

Similarly, on a more fundamental, material level, increasing the conductivity of, say, concrete so it is able to charge and discharge more effectively, will compromise its ability to store heat. This conflict also extends to the new generation of latent storage materials, or phase change materials. FES systems show how this conflict can be resolved by introducing heat transporting structures into previously monolithic elements.

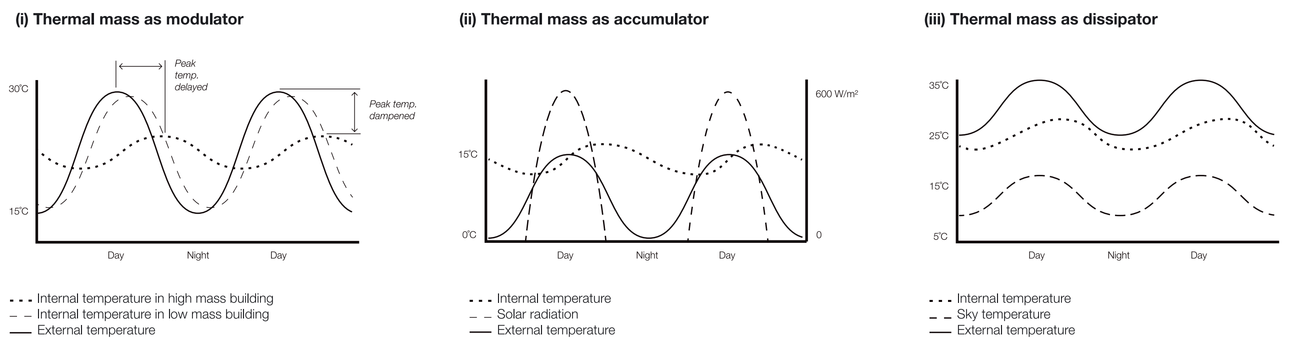


Figure 3 Three types of thermal mass effects (capacitive insulation). In temperate climates, the trick is getting the mass to modulate temperature swings (i). In cold climates, you want your mass to heat up faster than it cools down (ii). The opposite is true in hot climates (iii). Hence thermal mass design is about coupling and decoupling to the right heat sources and heat sinks.

Retaining heat vs. ventilation

Sealing off buildings from their environment by super insulating does have very real limits, not least in that the people inside have to be able to breathe! The problem is that ventilating a room introduces a convective link between the warm inside and the cold outside. But this convective link need not transfer heat. Counter-flow (also known as counter-current) heat exchangers decouple mass flow (in this case, fresh air) from heat flow (leaking heat). The trick is to have one flow running counter to another so that heat that would otherwise escape is transferred axially to the incoming flow. Highly effective counter-current heat exchangers have been found in many animals. Such devices in the flippers of dolphins and the legs of wading birds mean that no matter how cold the water gets, blood can still be transported to the extremities.

Of course, counter-current heat exchangers are widely used in engineering and they provide the basis for the heat recovery ventilation systems used in buildings. One engineering trick that has not yet been found in biological systems is counter-convection. In the building industry, this is called dynamic insulation. Outgoing heat conducting through a porous envelope is recaptured by incoming air. Practically all the heat that would otherwise be lost can be transferred to the air being forced through the porous envelope. Fresh air is heated almost for free by controlling the pressure drop between inside and out.

The technological repertoire is widening and is making buildings that better utilise the resources present in their immediate environment more likely. But we should be warned against introducing new technology for the sake of it. There are several approaches to resolving heat management conflicts: some are simple and old, some are complex and new. High technology, complex monsters will consume more energy than simple dinosaurs. At least framing design issues in the form of technological contradictions is a useful starting point. It might also help us avoid settling for compromises and to look past stock responses like optimising the glazing ratio, for instance.

Does building technology evolve?

The analogy of buildings having a metabolism in or out of tune with their immediate environment is one of the more recent drawn between biology and building design. Re-emerging now is the ecological analogy, which sees the appropriateness of designed objects for their functional purposes as being equivalent to the fitness of animals and plants for their environment. And of course there is the Darwinian or evolutionary analogy, which explains the design of useful objects and buildings in terms of a sequence of repeated copies, with changes made at each stage.

These analogies can be helpful but they can also be misleading. The evolutionary analogy is a case in point as even the theory of evolution itself has evolved since Darwin. For instance, while survival of the fittest suggests that only the very best will do, creatures can survive perfectly well even though other creatures could occupy their niche more effectively. The superior characters that, in principle, ought to displace the inferior, do not because they can not get started while the inferior character is present.

A technological example of this is the QWERTY keyboard. Nearly all of the world's keyboards are QWERTY yet it is very ineffective and all records for speed typing were achieved on the Dvorak simplified keyboard. QWERTY couldn't slow down typists more effectively if it were designed to do so, and in fact, it was. On the earliest typewriters, rapid typing caused keys to jam and so QWERTY emerged as the most efficient from a host of rival keyboard designs toward the end of the 19th Century.

For a technology to occupy a niche it doesn't have to be the best possible, it just has to be good enough and widespread enough to stop competitors from gaining a foothold. Many existing technologies possess enormous market inertia. In order to displace one of them, a new technology must not just be better; it must be so much better that it can overcome all of the difficulties of being a latecomer.

That the building technologies being specified by engineers every day are unlikely to be the best possible is good news for innovators as it implies there is plenty left to invent. And it is worth remembering that evolution goes in directions where there are most benefits for least costs. This often means that new functions piggyback on to others. One example of this is FES systems which are gaining a foothold partly because many buildings are going to be made out of concrete anyway, despite there being many materials better at storing heat.

This provides food for thought to those who want to break the 'plug-in and close-off' status quo. We should stop limiting the conversation to energy efficiency, and instead talk about resolving contradictions to achieve energy efficacy.

Salmaan Craig is a research engineer in the Sustainability and Alternative Technologies group within Specialist Consulting.

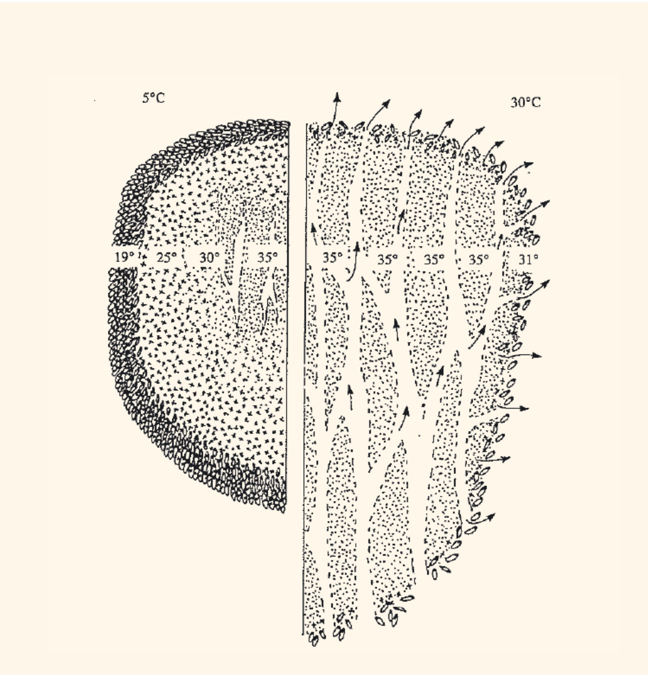


Figure 4 Honeybees regulate the temperature of their swarm cluster by huddling up when it is cold and creating ventilation structures when it is hot [Adrian Bejan (2000) Shape & Structure from Engineering to Nature].

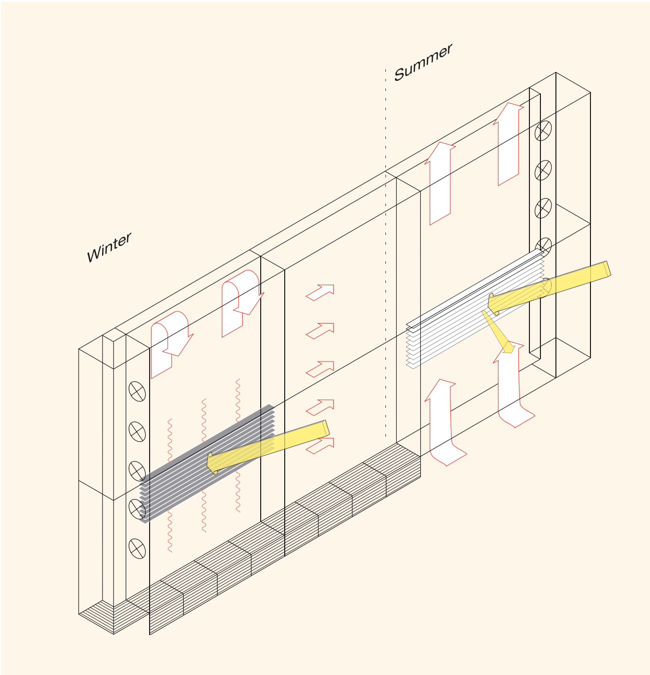


Figure 5 Double skin facades aren't as clever as honeybees, but they are an example of passive temperature adaptation. They use solar radiation as either free heat or to induce natural ventilation, depending on whether it is winter or summer.

Enabling everyone

All too often, inclusivity is considered as an afterthought to a project's design, brought in to tick regulatory boxes. David Dropkin explains what the Inclusive Design team really does and how it not only ensures accessibility, but also positively effects and encourages opportunities for all.

The term inclusive design is often misunderstood. Its detractors often mistake it as a euphemism for designing for the disabled, that is: designing environments, products or systems for a small minority. Another misinterpretation is that inclusive design seeks to find a utopian solution, a kind of 'one size fits all' to suit all types of users.

Literary examinations of utopian societies, such as Thomas More's Utopia, portray societies organised to overcome the flaws of human nature; where individual appetites are controlled and balanced against the needs of the community as a whole. Compare this to the inclusive approach to design, which positively recognises diversity and turns away from homogeneity.

This process, when successfully applied, delivers environments where all members of society can access and benefit from a full range of opportunities. By removing barriers that create undue effort, separation or special treatment, we enable everyone – regardless of disability, age or gender – to participate equally, confidently and independently in mainstream activities with choice and dignity.

The adoption of inclusive design principles therefore ensures that the project, whether it be the built environment, a product or organisational policy, will be designed to be:

- Inclusive – so everyone can use it safely, easily and with dignity.
- Responsive – taking account of what people say they need and want.
- Flexible – so different people can use it in different ways.
- Convenient – so everyone can use it without too much effort or separation.
- Accommodating for all people, regardless of their age, gender, mobility, ethnicity or circumstances.
- Welcoming – with no disabling barriers that might exclude some people.
- Realistic – offering more than one solution to help balance everyone's needs and recognising that one solution may not work for all.

Inside the Scottish Parliament debating chamber, great effort was made by the Inclusive Design team to ensure accessibility for all although these measures are not immediately visible. Measures include: providing step-free access to around half the seats in the chamber; provision of specially designated seats for wheelchair users in the public gallery; specification of carpet with a short, dense pile that allows wheelchairs to run smoothly over it and use of induction loops and infra-red sound enhancement systems throughout the building to help those with hearing difficulties.

Image: © Scottish Parliamentary Corporate Body – 2007

Inclusive Design: what is it really?

Simply said, people need to be at the heart of the design process. Developing exciting concepts for public realm projects and building striking and innovative structures does not preclude this. Too often, our role as access consultants is seen to ensure compliances against checklists extracted from Building Regulations or British Standards.

One of the voting consoles with tactile interface, which sits alongside a microphone and speakers on each MSP's desk.

Image: © Scottish Parliamentary Corporate Body – 2007

The Inclusive Design group worked closely with the architect and design team on every aspect of the Parliament buildings, to ensure physical accessibility throughout.

Image: © Scottish Parliamentary Corporate Body – 2007

However, our actual role is to have a watching brief, encouraging dialogue and discussion within project teams to ensure there is an understanding of how the issues that form access and inclusion are addressed across all disciplines.

At the same time, our guidance has to be balanced against the very real physical constraints of the site or financial restrictions. One of the greatest threats to the delivery of inclusion is value engineering, which reduces access to physical features and their relative value within the project. That process really is about minimum compliances.

Accessibility does not lend itself to this approach of evaluation. Meeting the Requirements of Part M of the Building Regulations does not ensure that duties under the Disability Discrimination Act (DDA) will be met. The DDA describes barriers that can be removed, but as it does not describe exactly how they should be removed there is, therefore, nothing to comply to.

Our role is to allow designers and architects to create their vision in a way that is accessible and inclusive. For the design teams that we work within, it is a continuous process of education. At times it feels as if we are providing environmental marriage counselling, whereby all parties share their requirements with the aim of achieving the best possible solutions.

The scope and breadth of our work is changing. Access consultancy and inclusive design are very much part and parcel of a long, continuing process that has moved disability from the realms of a medical model (in which barriers are the medical condition) to a social model of disability (we create barriers – whether in terms of employment, physical access or interpretation).

Increasingly, in order to begin to deliver the broader requirements of Diversity and Equality Strategies that public authorities are aiming to deliver, we are

Full accessibility has not hampered the architectural aspirations of Palestra, an exemplary office block in central London.

Image: Christian Richters

looking at how to provide appropriate and inclusive environments for all communities.

These may include provision of family rooms that allow quiet feeding time for babies and are accessible to both parents and spaces for ablution and prayer, paying particular attention to their orientation within the building. These are aspects not covered by the Building Regulations. Not everyone will immediately perceive these as accessibility issues, but they are part of the expertise that the Inclusive Design team is developing in order to meet the increasingly wider client briefs.

The environmental and societal requirements of delivering sustainable developments now require inclusive design strategies, particularly addressing the issues of changing need, flexibility and adaptation.

Although the content of the May 2004 Part M is similar to BS 8300: 2001 *Design of buildings and their approaches to meet the needs of disabled people — Code of practice*, there is a significant and major shift. It is no longer ‘Access to and facilities for disabled people’, but rather ‘Access to and use of buildings’.

With its publication, a statutory inclusive approach was established in England and Wales. The key requirement is that ‘reasonable provision shall be made for people to gain access to and use the building and its facilities.’ Its author, the chief architect David Petherwick, clearly intended that it was to be an educative document. It is set out with objectives and design considerations as well as specific provisions. These sections in particular encourage a process of lateral thinking when problem solving, particularly as every building type and element cannot be described nor anticipated in terms of required solutions.

This great achievement, however, is still a long way from being universally understood as both design team and clients continue to ask the Inclusive Design team to comment on ‘compliance and the disability regs.’

The Hazelwood School in Glasgow will provide a sympathetic learning environment for children with severe sensory impairments and so has to provide the full range of cues to help them safely walk through the building and surrounding gardens.

While, importantly, physical provision forms a large part of the work that we advise on, almost all of the work that Inclusive Design are involved with has to be measured in terms of consequence relating to the Disability Discrimination Acts 1995 and 2005. A large part of our role is to bring an expertise and understanding to the duties owed under the Acts to the design teams and projects that we work on.

Consultation and Involvement

In his crusade to make the web more accessible, internet usability consultant Jakob Nielsen describes “the accessibility fallacy”, based on the assumption that accessibility exists in a vacuum and can be scored without considering users and their tasks. But even if you meet every high-priority checkpoint (and this is, unfortunately how many designers and architects still view access and disability), disabled users may still be completely incapable of using what is designed.

Depending on the size, nature and scale of the project, public consultation is increasingly required at various RIBA stages, particularly by public authorities, which now have a duty to consult and involve disabled people under the Disability Equality Duty.

The Inclusive Design team facilitates these consultations, assisting clients and project teams to understand, incorporate and implement what can often be perceived as quite negative input, and to distil it into constructive and positive information that benefits all.

Planning and building control process

Design and access statements came into force as a statutory requirement of the Planning and Compulsory Purchase Act in England in 2006 and in Wales in 2007. In order to prepare the access strategy, a design review is conducted which is then incorporated into the design and access statement. It represents the architect and client’s approach to creating and maintaining an inclusive environment.

The access strategy forms the core of the access portion of the design and access statement. It explains design principles and concepts and how the issues of access and inclusion have been addressed in the design development. It is essential that the approach to inclusive design is not just limited to the access section of the statement but is woven throughout the approach to the entire project.

The access strategy will inform an access statement (if required by the local authority) which follows at building control submission. The access statement is intended to be ‘living document’ and is revised as the project develops.

At project completion, the client should be presented with the two documents that chart the processes and decisions that make their facilities accessible. These, in turn, should provide the basis for the client’s formulation of policies, procedures and practices required for managing their facilities in an inclusive manner, to meet their duties under the Disability Discrimination Acts 1995 and 2005.

Shared experience

Ultimately, our aim is to ensure that everyone has the same equality of experience – the essence of what is enshrined in the Human Rights Act. But that does not necessarily imply that the mean and mode of the experience are absolutely identical.

If we are successful in our approach to inclusion, we create seamless experiences for all users to adapt to their specific requirements without people who choose a particular option drawing attention to themselves.

Too often, though, when we are asked what constitutes accessibility, the reply is a long list of physical features such as ramps, lifts and automated doors. There is no argument that these features, as individual elements, are essential. But how they fit into an overall package of service provision and employment, however, is very rarely mentioned. Our role is not only to ensure that minimum physical provision is addressed but to broaden the understanding of both the project team and client as to what constitutes well thought out, inclusive solutions that go well beyond a tick-box approach.

Our successes can be measured when all people can transact their day-to-day business without any special effort or thought.

David Dropkin is a senior access consultant in the Inclusive Design group within Specialist Consulting.

Learning from experience

Installing the latest building services equipment is not enough to ensure a quality, productive environment for building users – it needs someone to ask some hard questions. As Dave Beck and Ian Pegg discuss here, this is the only way to ensure all systems are working as they should be.

A new building always raises expectations in the minds of the people who are going to use it, whether it is as a working environment or a place to visit. All too often, in reality there is often a feeling of disappointment when they do so, thanks to a variety of reasons. The vast majority of these are to due to the internal environment that has been created. It is too cold, too hot, draughty, noisy or the lighting is poor – these are the most common complaints. Rarely does the architecture figure in the list of the top ten complaints. Why is this?

While there may be issues with the basic building design, these cases are in the minority. The cause of the occupiers' discomfort is, in most cases, down to building services systems that have not been fully or properly commissioned.

Building services designers are frequently called back to completed projects to investigate problems associated with heating, ventilation and controls. The development of IT in this field has led to requirements for greater integration of these increasingly complex systems, which theoretically should lead to more efficient services. However, even with this level of integration, which should simplify the control of services, it often presents inexperienced or poorly trained facilities managers and users with yet more problems.

A couple of fundamental requirements must be achieved if a building is to perform as the designers intended. Firstly, the building must be fully commissioned before opening and secondly, all facilities managers and users must be fully trained in how to operate their building.

The headquarters of Wessex Water in Bath was designed to be the latest in environmentally friendly technology when it opened, in 2000. While incorporating a host of sustainability features, such as solar thermal heating to heat water used on site, a post-occupancy evaluation provided some fine tuning of the building once in use.

During the post-occupancy evaluation, lighting levels in the Wessex Water building were found to be higher than necessary. Buro Happold engineers found that the same levels could be achieved with 70% of the power, so recommended a 30% reduction in maximum output, which resulted in energy savings for the client.

Allowing as much sunlight in as possible is a key part of the lighting strategy for Wessex Water.

Construction programmes always start with the good intention of allowing an adequate commissioning period. However, what invariably happens is that the construction process eats into this period and buildings end up being handed over only partially commissioned.

The importance of commissioning is widely recognised, not least in the Building Research Establishment Environmental Assessment Method (BREEAM) in which credits are awarded for the appointment of an independent commissioning manager and for seasonal commissioning once the building is occupied. It therefore becomes fundamentally important that a buildings performance is objectively assessed. Hence the need for Post Occupancy Evaluation (POE).

A POE is usually concerned with measuring energy use and the occupants' perception of their building. Certainly there are clear, tangible benefits in identifying areas of excessive energy consumption, rectifying faults and/or introducing controls to reduce it.

But this is only part of the picture and a full POE can give a detailed account of how a building is performing in all sorts of ways, not least in how the users are finding it. Taking this approach in schools can lead to better performing pupils. It is well documented that poor acoustics in a classroom will reduce the grades attained by pupils and the same can be applied to other environments. In the case of office buildings, tackling issues like this can lead to financial benefits for the employer.

Creating a really great working environment is good for business. Staff who are comfortable in their workplace will perform more efficiently and there will be less absenteeism thanks to their increased general well being. It is therefore in the employer's interests to create the right environment for workers and asking them to highlight concerns for a POE is a first step towards this. In most cases the issues would only ever come to light when the building is in regular use and could not have been foreseen at the design stage when, often, the nature of the resident's business would simply not be known.

It makes business sense for the building developer or owner to run a POE too. An occupier entering their new building to be very quickly greeted with these problems leads to a very poor initial perception. The resulting loss of occupier confidence can be very hard to recover.

Undertaking a comprehensive, structured approach to POE – to measure energy, acoustics, ventilation, lighting and operating procedures, among others – can produce clear benefits and will enable continuous improvement to working environments.

The most common outputs from a POE are:

1. System performance is monitored and faults are identified for correction.
2. How the building is actually used can lead to adjustment of systems operation.

The Lowry Centre in Manchester. All aspects of the building's performance, in the complex's many different spaces – which includes two theatres, cafes, bars and restaurant – were assessed in the post-occupancy evaluation. Particular attention was paid to the building's air conditioning system which uses water drawn from the adjacent canal for cooling the internal atmosphere.

3. Excessive energy consumption is identified and remedial measures can be put in place to reduce this.

However, there are a number of other factors that affect building and user efficiency to be considered and which should be part of a POE. These are:

1. How good are the building acoustics? Are there rooms with very hard surfaces that can lead to high background noise levels and cause people to raise their voices and so develop sore throats? Do partitions provide adequate acoustic separation, to create some privacy?
2. Is the building accessible for all users, irrespective of any disabilities? The need for wheel chair access is well recognised but, for example, certain colour schemes can make it very difficult for those with visual impairment to easily navigate their way around the building
3. Does the building give the occupiers a feeling of being safe and secure? Are the access controls effective and appropriate for the nature of the occupier's business?
4. Will the fire safety management procedures be effective in the event of an incident? Following the implementation of the Regulatory Reform (Fire Safety) Order, it is now a statutory requirement for building owners to ensure appropriate procedures are in place.
5. Can occupiers effectively move around the building? In schools, for example, does the timetable allow the efficient movement of pupils? For a sporting venue, can all the spectators leave safely at the same time?

To begin a POE there are two key sources of information that will start the process. Information from the Building Management System (BMS) is the first and will provide definitive data on the easily quantifiable factors such as room temperatures and electricity consumption. However, it is through the feedback from the building's users that the full story can be gained and which will identify weaknesses in a buildings performance.

Following a briefing session with the management team or building owners, a user questionnaire can be written which focuses on the building's particular mode of operation. This is distributed to all users as a confidential questionnaire.

Conducting POEs invariably leads to a number of positive outcomes. Buildings are optimised from an energy perspective and the system controls will be set up to meet the occupiers' expectations. It should not be underestimated the effect on staff morale of them seeing something tangible being undertaken to improve their working conditions.

Learning from schools

A recent Buro Happold study comparing the performance of five recently completed academies demonstrates the principles of POE and the benefits that can be achieved in terms of energy use.

Figure 1 shows the gas and electricity consumption and compares the schools to typical and good practice. In all five cases the school's gas consumption was better than good practice, an achievement that came as a consequence of using high efficiency condensing boilers, weather compensated heating circuits, optimised starting and shutdown controls and installing efficient insulation in the buildings.

But it is the data for electricity consumption which is alarming. This demanded a more in-depth study and figure 2 shows the breakdown of the typical uses around the schools.

A pair of key points stand out:

1 Lighting consumption in schools B and E was up to four times greater than schools C and D.
2 Power consumption by fans, pumps and controls in schools A, B and D was twice that of schools C and E.

The reasons why the above differences occurred are very revealing.

Simple and effective lighting controls can deliver major savings in electricity consumption. In school C each space was fitted with Passive Infra-Red (PIR) detectors which switch off lights when rooms are unoccupied. In schools C and D only manual control of lights was used. This lack of automatic control was particularly evident in the public spaces where no one had responsibility for switching. Figure 3 compares the energy consumption by lighting of manual switching in school B and with the automatic switching in school C. The effects and benefits are self-evident.

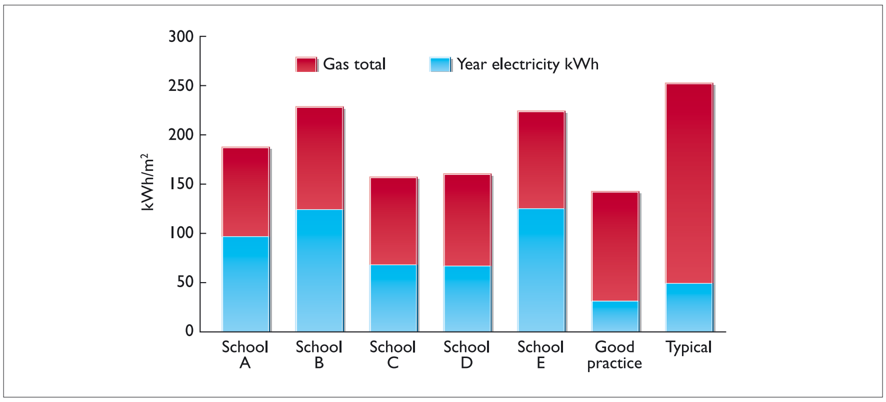


Figure 1 Headline gas and electricity consumption figures for five academies.

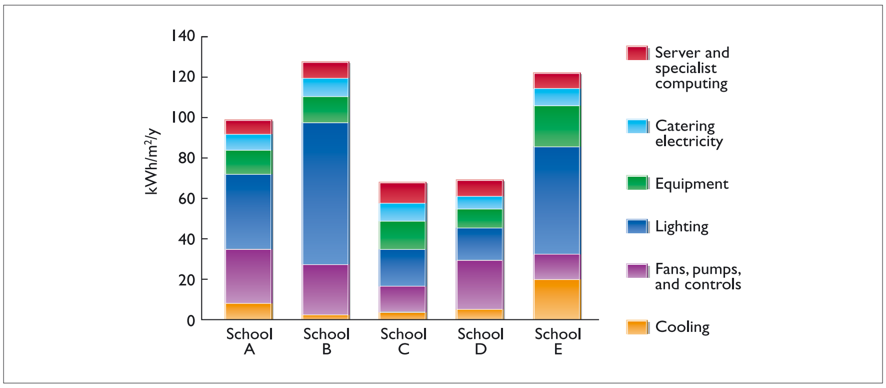


Figure 2 Breakdown of electricity consumption by end-use in the five case-study academies.

The intelligent use of the BMS to ensure appropriate time-clock control of heating and mechanical ventilation systems can also lead to significant savings in energy. Furthermore, as in the case of school C, equipment that defaults to off when spaces are not occupied produces significant energy savings.

There are some clear lessons are gained from this study:

- PIR detectors to switch lighting off is a very effective method of control.
- Manual switching of lighting is unlikely to be effective in saving energy.
- BMS controls must be set to the occupancy patterns of the building.
- Plant that defaults to off when spaces are not occupied is essential.
- Facility managers must be fully trained if all the benefits of automatic controls are to be fully realised.

While this brief study looked at five schools, it highlights how effective a POE is at tackling problem areas in a logical fashion and the same principles can be applied to the majority of buildings.

In short, a POE is an essential measure if building owners and operators are to get the most from their asset. This applies just as much to getting the best out of the people that use the building as it does to the systems that control it.

David Beck is an associate director in Specialist Consulting.

Ian Pegg is a research engineer in the Sustainability and Alternative Technologies group within Specialist Consulting.

Sound advice

Helping clients realise how sound will be heard in their unbuilt building is becoming ever more important to all manner of high quality projects. Alistair Meachin explains how to simulate sound in a meaningful way.

Sharing any technical information can be challenging and even more so when that information describes sound. Acoustics is a field that just does not translate well into words or diagrams. We can say 'Speech intelligibility is poor' or 'The STI value is 0.4', but how these statements relate to our experience of a space means little in isolation and each individual will interpret them differently.

To bridge this communication gap the acoustics group in Buro Happold is turning more and more to auralisation – the presentation of acoustic information in a form that can be heard. These presentations of simulated sound fields invariably lead to acoustic issues being better understood and we believe this understanding directly contributes to better and faster design decisions.

Auralisation is invaluable in communicating all manner of acoustic information, from intrusive noise levels to musical room acoustics.

Inside the corridors of the Solstice Arts Centre in Navan: the acoustic team ensured acceptable reverberation control and isolation from the adjacent auditorium by careful selection of room finishes and partition constructions.

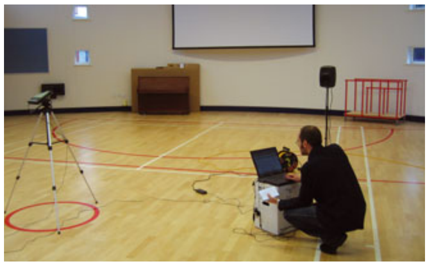
Listening in to a virtual world

To enable listeners to experience accurate impressions of a simulated space we ideally need to create every aspect of that environment using an approach already widely known as virtual reality. For the acoustics specifically, we need to simulate those aspects of the environment which significantly affect the way sounds are interpreted and this may extend beyond the sounds themselves. Research has shown that the credibility of auralisations can be improved by the use of basic visual prompts, such as still images of the simulated space. Suspension of disbelief, rather than the pure experience of listening to a recording, is the objective.

To make a simulation totally believable it should also be interactive, so that any sounds created in the reproduction room interact correctly with the virtual acoustics. So when the listener shouts in a virtual cave, an echo should be heard as well as the cry. Technology is available to make all this possible but might not always be appropriate financially. As with any simulation, a balance must be struck between the cost of the exercise and the benefits obtained.

It is also well established that differences between a simulated space and the reproduction space can lead to perception anomalies. Sounds recorded in a large space and then reproduced in a small room can seem unrealistically loud. Unless we simulate or replicate the space in every way, psycho-acoustic effects such as this may come into play. Integration into a complete virtual reality system is the obvious solution, but is not always commercially viable. Sometimes the more 'low-tech' approach of giving a demonstration in an existing space similar to the one being simulated is more practical.

Of course the audio aspect of a complete virtual reality system could be considered to be auralisation, but there is a significant difference in emphasis. Virtual reality systems, such as those used for gaming, often aim to give an approximate impression of the acoustic ambience, whereas a well-engineered auralisation concentrates on accuracy.



The Acoustic team measuring the impulse responses of a school hall.

Implicit in our complete environment approach to auralisation is that all components of the sound field must be considered. An assessment of noise nuisance would be meaningless without the inclusion of normal ambient sounds, as would an assessment of a PA system's intelligibility. Our philosophy is to create all relevant aspects of the environment, as only in context can subjective judgements be made.

Making auralisations happen

The process of generating an auralisation depends very much on the scenario being created and the starting point is always knowledge of what acoustic conditions need to be simulated. Auralisation is simply a method of expressing this information.

Creating an auralisation can generally be broken down into a process of obtaining raw sound files, manipulating them according to the acoustic conditions being simulated, and then reproducing them.

This is rarely a straightforward exercise in recording and playback as careful attention must be paid to calibration and accuracy at every stage of the signal chain.

1. Calculating acoustic conditions

The many tools used every day in acoustic calculations are also used to determine the target virtual environment for an auralisation. Effects of elements such as barriers, partitions, absorbers and reflectors can be used to deduce how our virtual space should sound.

Of course, auralisation conveys much more information about an acoustic environment than can be described by a small set of parameters. This means that much more detailed analysis may be required to give the full picture that auralisation is capable of.

An alternative approach is to use auralisation to illustrate design values. For example, if a reverberation time of 1.5 seconds or an ambient noise level of 45dB (A) is proposed for a room, what this means can be demonstrated to the design team by demonstrating to them how it will sound.

2. Obtaining raw sound files

For acoustics simulations, the starting point is often sounds totally unaffected by their environment, called anechoic recordings. These have been recorded in an anechoic chamber lined with acoustic absorbers that prevent any reflections colouring the recording. A limited number of anechoic recordings are available commercially and these include speech, musical instruments and singing.

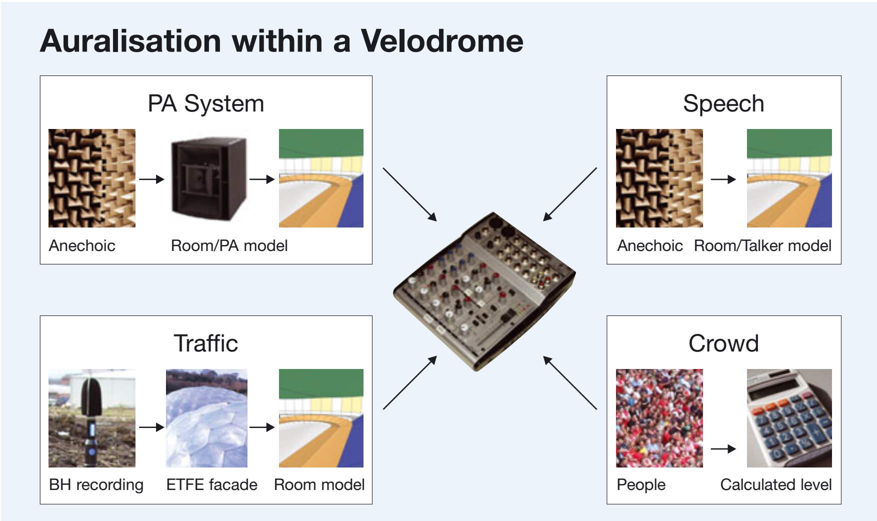


Figure 1 Each component of the velodrome sound field is individually calculated, then mixed to simulate the total acoustic environment.

However, caution must be exercised in the selection of anechoic files as it must be ensured they are suitable for the application. A recording of conversational speech would be entirely inappropriate for simulating speech in a cathedral; in large, reverberant spaces people naturally speak more slowly and clearly.

Another pitfall of commercial recordings is that they are generally not calibrated and recording techniques have not been well documented. This can sometimes limit their usefulness to an auralisation that aims to maximise accuracy.

For other scenarios, other types of raw sound file are needed. For example, a sound insulation assessment would be most accurate if an actual recording of the intrusive sound was used. The sound field for a proposed museum, for example, might be best simulated by a recording made in a similar, existing building.

3. Sound manipulation

An acoustic transmission path can be characterised by its impulse response, which describes how an impulse stimulus will sound at the listener position. This can be considered a fingerprint of the transmission path, containing complete information on how sound is affected in both the frequency domain (which includes such effects as high frequency attenuation) and the time domain (such as reverberation).

The impulse can represent any linear time-invariant acoustic transmission path, from reverberation in a concert hall to the sound of the TV next door. The impulse response can be combined with an arbitrary input signal (our raw sound file), by convolution to predict the sound at the listener. Room acoustics simulation software is available that can calculate impulse responses from the geometry and surface properties of a space.

Convolution processing is not always necessary and many auralisation sound components can be manipulated with enough accuracy using basic frequency-response filters and level controls.

The spatial characteristics of the sound field components also need to be manipulated so that each sound is heard by the listener as coming from the correct direction. A signal format called Ambisonics can be useful here. The sounds are stored and manipulated as four components representing the x, y and z-axes and an omni-directional component. Digital Audio Workstation technology (as used in recording studios) can then be used to give highly flexible control of spatial properties.

Walk-through simulations are also possible using these techniques. In these, we cross-fade between sound fields at calculated positions to create the effect of moving between acoustic environments.

4. Reproduction

As with the other stages in creating a virtual sound field, selection of the reproduction technique is dependant on the scenario to be simulated.

Headphones are convenient and avoid many problems with reproduction space acoustics, but are not without their own problems. Since sounds do not change when the head is moved (unless using a head-tracking device), this can cause unrealistic spatial effects. But an even bigger problem in the building industry is the difficulty in presenting to groups of people simultaneously. Design team members often welcome the opportunity to experience and discuss a virtual space together and the value of the ease, or otherwise, of conversation about their judgement of an acoustic environment should not be underestimated.

Loudspeaker reproduction systems allow easier group presentations, but of course are more demanding on the acoustics of the presentation room. Background noise and room acoustics effects must be low enough not to unduly influence the character of the space being simulated. In some cases, a standard office may be a good enough reproduction space, while in others a well controlled environment may be necessary.

There are many options for loudspeaker reproduction, including two-channel stereo, domestic type surround systems, Ambisonics, trans-aural and wave-field synthesis. No one of these is the perfect solution for all projects and again the most appropriate must be chosen. A compromise has to be found between portability, cost, sound level, bandwidth, distortion, the 'sweet spot' size and angular resolution that meets the project's particular requirements.

The limits of reality

No simulation is perfect and to make the most of it we must understand and explain the limitations. For example, reproduction room resonances make it extremely difficult to create consistent, low-frequency reproduction over an extended listening area in a small room. Listeners must therefore understand that the low-frequency response of a large hall cannot be perfectly recreated in a small presentation room.

Inaccuracies of simulations due to uncertainties in both the data they are derived from and in the auralisation process itself must also be flagged up to listeners. A grasp of the margin of error is important here, as with any method of presenting detailed engineering information.

Sound business sense

Auralisation helps ensure that appropriate acoustic designs are adopted. Although it can be very time-consuming to generate accurate simulations, this cost will often be more than offset by preventing both overkill design and expensive retro-fit acoustic solutions.

As techniques and expectations evolve, auralisation is gradually changing from a bolt-on gimmick to an essential communication tool. We expect it to become seen as a necessity for an increasing proportion of projects as the clarity it brings to acoustic issues becomes more widely appreciated.

Alistair Meachin is a senior engineer in the acoustics group within Specialist Consulting.

Applications –
How Auralisation Can Help

Music academy

How good will practice room sound insulation be?
– Simulate instrument practice in the next room

How will a concert sound in the recital room?
– Simulate performers on stage, as heard by the audience

Will services noise disturb performances?
– Simulate noise from services according to MEP design

Office development

Will traffic noise be a problem in the open plan areas?
– Simulate traffic break-in noise

How good will privacy be between cellular offices?
– Simulate conversation in an adjacent room

Will the foyer have a peaceful ambience?
– Simulate traffic break-in, conversation at reception and PA system

Wind farm

Will the wind farm disturb nearby residents?
– Simulate how the wind farm will sound in gardens and bedrooms, including normal background noise to assess masking

Arena

Will the PA system be intelligible?
– Simulate speech over the sound system, with crowd noise to give context

Will concerts be audible to nearby residents?
– Simulate break-out noise at sensitive receptor positions

Get smart

Creating truly intelligent buildings requires much more than a great deal of computer power in the basement. Robust and secure networks – which present an entirely different set of challenges – are just as important, say Neil Fletcher and Andrew Kelly.

The term 'intelligent building' is increasingly used within the construction industry, cited as a Holy Grail, often without much consideration as to how this would be achieved or even what it actually means. One might think that, given the dictionary definition of intelligence (below) it would be hard to see how any buildings, modern or otherwise, could be described as truly intelligent.

Defining Our Terms

in·tel·li·gence
–noun

1. capacity for learning, reasoning, understanding, and similar forms of mental activity; aptitude in grasping truths, relationships, facts, meanings, etc.
2. manifestation of a high mental capacity.
3. the faculty of understanding.
4. knowledge of an event, circumstance, received or imparted; news; information.
5. the gathering or distribution of information, esp. secret information.
6. *Government*.
   a. information about an enemy or a potential enemy.
   b. the evaluated conclusions drawn from such information.
   c. an organisation or agency engaged in gathering such information.

Clearly, any definition of an intelligent building depends upon personal viewpoint. For an engineer designing naturally vented buildings it may mean the use of natural forces working within a structure and facade to create a comfortable internal environment, with the minimum use of precious fossil fuels. For a structural engineer it may be the use of innovative materials, techniques and software tools to produce new shapes and structures. For the pragmatic facilities manager it may be a high quality and unfussy environment which is easy to manage and maintain while responding effectively to requirements for constant re-configuration.

Traditionally, an intelligent building has always meant one that uses the best of human ingenuity and skill in its construction. It is normally only publicly recognised and acknowledged as intelligent when it showcases radical innovation in technology employed in its construction. In the Middle Ages, a spectacular leap forward occurred with the spread of the gothic arches and flying buttresses used in the construction of the big cathedrals of Europe. Another innovation occurred with the use of iron in the structure of Victorian bridges and tall buildings. Later still, the invention of the elevator made skyscrapers viable.

Today, the key revolutionary technology in buildings is the ubiquitous microprocessor, incorporated into almost every facet of modern buildings. From networked IT systems and building management systems to sophisticated computers making the incredibly complex design of new building structures and services possible, their effect is felt everywhere.

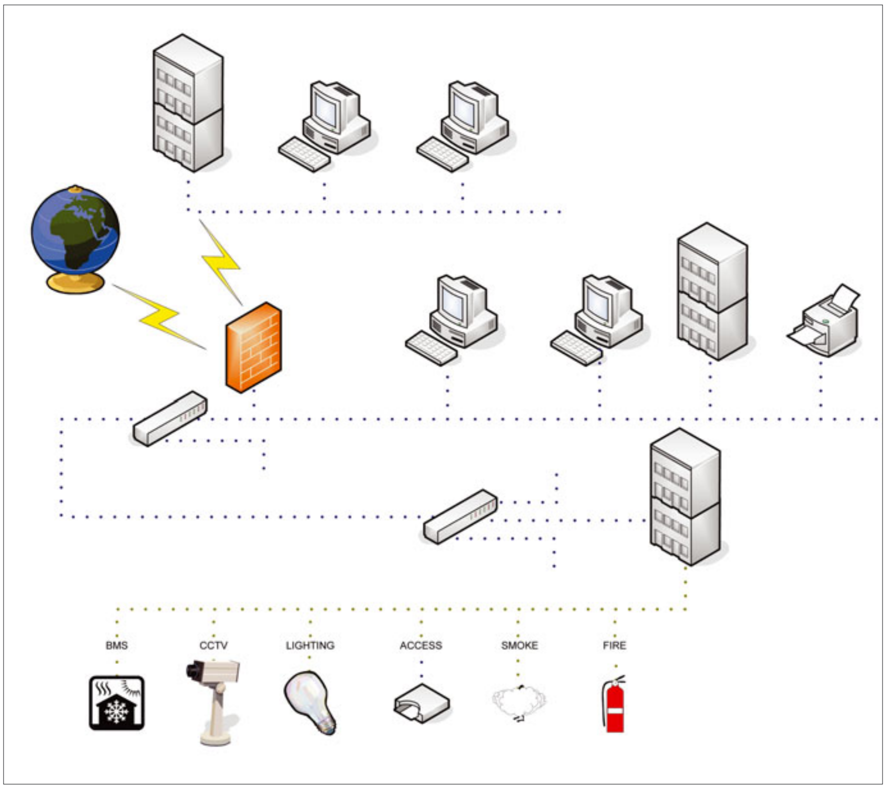


Figure 1 An example topology of a converged building communications network.

For the purposes of this paper the meaning of intelligent buildings is restricted to a narrow definition of those that have integrated microprocessor-based building systems, working together to provide comfortable, secure and safe environments. However, even when this definition is clarified, great care must be taken in dealing with the many other, related issues that all play a role in a truly intelligent building.

The conceptual framework of the building design and construction, as well as the business processes of its future occupants, is fundamental to the building systems analysis and design. All too often, when these issues are ignored or not understood, the outcome is an over-complex technology-focused product, which fails to meet the needs of the end-user.

Whatever the definition, the demands of intelligence, coupled with the increasing provision of management and control systems within the built environment, requires underpinning by an appropriate support infrastructure. In order to provide a more flexible approach to building management while reducing infrastructure costs and enabling automation of systems that are conventionally manually controlled, consideration should be given to the integration of traditionally separate systems.

Structures particularly suitable for the application of systems integration and convergence include mixed-use high-rise buildings, shopping centres, sports stadia, university campuses, high quality residential properties and large sites requiring remote system monitoring.

Systems commonly found within buildings and that need to be accessible through a single network, include:

- Environmental controls (including heating, ventilation and air conditioning)
- Lighting controls
- Lift management
- Fire detection and suppression
- Automated access control
- Security surveillance
- Intruder detection
- Leak detection
- Audio/visual systems
- Telephony
- ICT (Information Communications Technology) data

Experience has shown that these installations operate as separate systems with little consideration given to the facility management team tasked with the operational procedures of managing a building. Providing the building facilities management team with integrated buildings systems will give the client numerous potential benefits including a single operator interface for these systems, easy implementation of back-up or fall-back facilities and assistance with the management of the installed systems. One example of this could be efficient management of a building's energy use, thus providing the client with a potential whole life cost saving.

To integrate systems within buildings successfully, one possible solution is to provide the client with a resilient communications backbone enabling all installed building systems to communicate information via a single, logical network. In practice, this may not be a single physical network for resilience reasons but is likely to result in considerably less network infrastructure than the numerous disparate closed systems present in the vast majority of current buildings.

This resilient, converged backbone acts as a building's central nervous system. When coupled with suitable software it can constantly watch and monitor local conditions and control relevant systems such as CCTV cameras, ventilation and heating. It is ready to respond automatically to an external threat, such as an intruder, and is able to use gathered experience or building data to optimise performance 'consciously'. A specific example of this could be intelligent evacuation where the sensor systems direct evacuees away from further hazards in an emergency situation, and possibly even monitor the flow to avoid bottlenecks during evacuation.

Getting physical

In the human body, information flows easily from nerves to brain and the body's vital functions are controlled without distracting the conscious mind with breathing or regulating temperature. However, in buildings the information flow is often blocked by incompatible networks and competing protocols. Careful design is also needed to ensure the appropriate systems are not outdated by the time a building's lengthy construction process is complete.

Caution is urged at the design and specification stages for any integrated building communications network. Never before has the designer and specifier of these networks had to be so vigilant of so many different sub-systems, all of which are wholly reliant on their infrastructure. Careful consideration should be given to the security implications of such installations, particularly when bridging a local building area network with a large, wide area network such as the internet.

Traditionally, the security industry is deemed a closed industry; over-sensitive to applications that permit unauthorised access. But these are legitimate concerns and even greater care should be taken in the make-up of these converged backbones when life safety systems, such as fire detection or suppression systems, are connected to them.

The benefits of intelligent buildings with a converged and integrated architecture are readily apparent, but the caveats to ensure effectiveness are as follows:

- Achieve the correct level of co-ordination at the correct stage in the design process.

The international connectivity possible through the internet can present security issues for the specifier of a building's communications network.

Image: National Oceanic and Atmospheric Administration/Department of Commerce

- Allow sufficient bandwidth headroom for expected expansion and multiple system operation.
- Ensure Quality of Service systems are in place to prevent network monopolisation.
- Provide adequate resilience for business critical and life-safety applications, focusing on 'graceful degradation' with warnings as a baseline level rather than a sudden systems failure, as more often occurs with current systems.
- Incorporate inherent security provisions specified during the system design stage. This includes implementing systems and procedures to prevent hacking and Denial of Service attempts, made more attractive by utilising a single logical network potentially connected to the internet.

Implementation of intelligent buildings requires a suitable transmission medium (for example twisted pair cable or fibre optic cable), suitable transmission equipment and an appropriate protocol. One such backbone protocol is Ethernet/IP. This provides both control and information capabilities and gives businesses the ability to consolidate their communications architecture.

The benefits of a single-network design results in savings both in capital expenditure and installation time and requires installation and maintenance personnel to be conversant in only one solution. Ethernet/IP is a well established communications protocol that offers capabilities not generally achievable with a conventional communication fieldbus, for example: voice and video transmission, variable topologies, IT integration and remote management. These are all attractive features for building automation users.

Analogies can be drawn between the built environment and the manufacturing sector, where a single communications network can support both the office network and the building management communication network. The advantage of this would be making critical building performance information available to office-based facilities management staff, and for multi-use accommodation this information would be readily available to building tenants.

Recent press reports have identified that Rockwell Automation and Cisco Systems have agreed to work together to integrate ethernet-based manufacturing and IT networks to allow seamless connections throughout businesses. This is likely to further strengthen the momentum behind converged network solutions. It is understood that this has been approached by developing detailed design guidelines for the use of common networking technologies across production, automation and enterprise networks. This initiative was triggered by a meeting between the two companies and representatives from some of their major manufacturing customers, who highlighted some of their frustrations with existing technologies.

It is interesting to note that one of the frustrations mentioned with the use of networking technologies was the need for improved flow of information between manufacturing areas and offices, and also between manufacturers and their customers.

Once all these systems can operate securely and safely over a single, logical network the next challenge is far more interesting, in terms of being people-focused, namely: to produce user-friendly and robust, intelligent applications that automatically maximise the safety, security, comfort and efficiency of a building, leaving its occupants free to work, rest or play in their chosen environment. Perhaps tackling this challenge, though, could be more difficult than the issue of convergence upon which it will rely.

Neil Fletcher is a consultant in the security engineering team within Specialist Consulting.

Andrew Kelly is a senior consultant in the security engineering team within Specialist Consulting.

Creating a virtual world

Having been the buzzword of the 1990s and, largely, science fiction, virtual reality now offers a level of communication never before possible. This is already having a major impact on the design and construction industry, according to David Stribling, Ian van Duivenbode and Shrikant Sharma

Communication is a major hurdle that all multi-disciplinary design teams must overcome on every project they tackle. As engineers communicating design ideas, we must take account of the different background and expertise that each team member possesses. Also to be considered are the sensitivities of individuals and the most desirable format in which they would like to see information presented.

Clearly, to have design ideas heard and duly considered by others they need to be communicated in a format which is easily understood. This is made particularly difficult in construction where, as it may be several years before a project is built, the design team is essentially working in a virtual world. In this scenario, an acoustics engineer may be presenting what a space will feel like acoustically, or a services engineer may want to discuss service routes and co-ordination with the structure in a complex three-dimensional geometry.

Ideally, we would like to put our clients into their building years before it is built. They will be able to see the problems of co-ordinating pipework and ductwork on a highly serviced building or hear what the building would sound like with a certain floor covering. In a fire simulation we could place the architect into their building, watching the smoke layer grow and seeing how people evacuate, accompanied by the associated sounds and smells of a real fire.

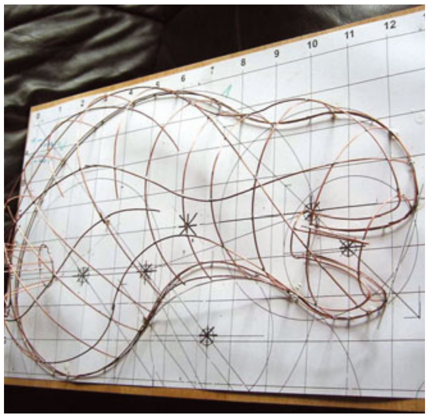
Is this a realistic goal for building designers or a pipe dream? After the major hype of the 1990s, virtual reality

VR was used as a visualisation tool for the redevelopment of the stadium at Ascot Racecourse.

(VR) and virtual environments are making a comeback, particularly in the built environment and in relaying the expectations of new buildings. This technology is expected to affect how building professionals do business in a big way.

The multi-dimensional world of Virtual Environments

Imagine a three-dimensional virtual world full of life-like objects, buildings, people and surroundings. Imagine yourself to be fully immersed within it and walking through it, as the objects around you are also moving. Now imagine you are able to interact with and manipulate this world around you by pushing a switch to turn the lights on and off or by picking up objects and placing them elsewhere. Imagine further that you are able to not only see but also touch, hear and smell the objects around you. Finally, imagine that you are not alone in this world but are sharing it with other people and the world itself is evolving as a result of the interaction between its inhabitants and the environment.



VR used as a tool for prototyping structural options for the Hydro Pavilion in Oslo.

This is the emerging world of Virtual Environments, a sub-set of the technology of VR. The applications of VR range into areas as diverse as architecture, archaeology, marketing, healthcare, tourism, media, aviation and gaming. Today, VR is being used by travel agents, industrial design engineers, architects, interior designers, doctors, games and movie makers alike. In using VR technology it is possible to place someone visually in a virtual building and to add other dimensions such as sound, smell and temperature.

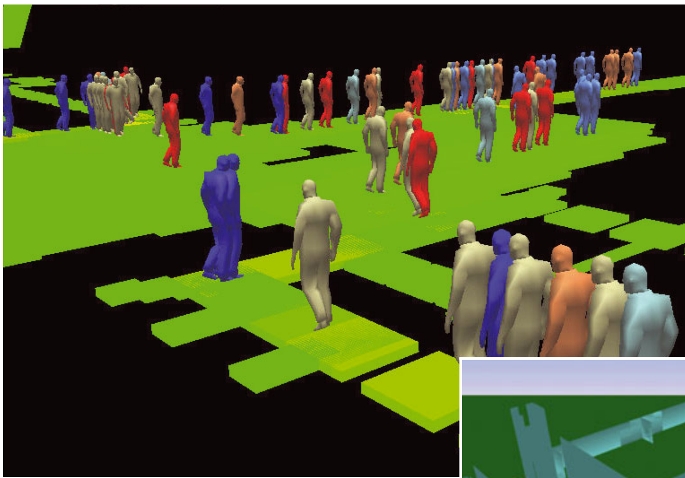
So what exactly is Virtual Reality?

The term virtual reality has been used in so many different contexts that there exists no single, universally accepted definition. Broadly speaking, VR is a technology that uses computer hardware and software to create an artificial but realistic environment for the purpose of simulation, design, entertainment and other pursuits. In contrast to conventional visualisation systems, the user may also become an active part of the scene.

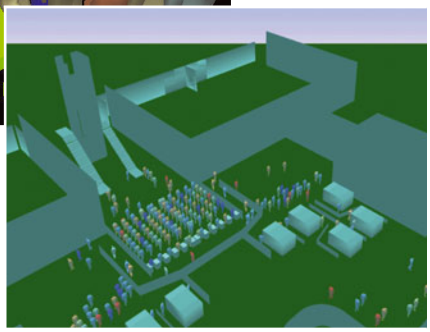
Basic VR hardware can include a standard PC with a monitor and mouse for interaction. More advanced systems can include 3D stereoscopic displays (with or without the use of glasses), or head-mounted displays. This may use head or hand motion tracking for user interaction and feedback to enable the immersion that adds realism to the user experience.

Depending on its use, a VR system may also include additional sensory information, such as sound through speakers or headphones. And some advanced haptic systems now include tactile information, generally known as force feedback, to allow realistic touching sensations in VR. These are useful in medical and gaming applications.

Other key elements of VR are the 3D-based data and the software to interpret and render this data.



Crowd flow modelling in public spaces is made possible through use of VR.



Working in the built environment

The latest computer simulation techniques are revolutionising the construction industry through powerful mathematical modelling. Previously, scale models were limited as a design aid but now planners, architects, engineers and builders can assess a full-scale version of a finished building, incorporating external physical processes and simulations of its intended use, before the foundations are laid. This is possible thanks to VR technology.

All the key stakeholders in the built environment can benefit from VR, as it is used as a planning, architectural, structural/building engineering simulation and construction tool.

Planners use VR to visualise and analyse impacts of construction on urban infrastructure and interaction with the myriad of physical and social data needed to plan and manage cities. Features such as interaction, immersion and animation provide planners with powerful tools to explore and analyse, in meaningful and intuitive ways, environmental data as a function of time as well as construction parameters.

Architects use VR to communicate better about proposed projects, for the interior as well as exterior spaces. It is also used to test various design options. For an architect, communicating his or her vision of a building is sometimes extremely difficult. In recent years 3D modelling and visualisation tools have helped in this task with the architect now able to “walk” a client through a virtual rendered building model to understand the complexities of planning a functional and pleasing space. VR is taking that process one step further.

Building engineering analysts use VR in many different ways. The role of the building simulation engineer is being recognised more and more as a core function in the delivery of a successful and energy-efficient building. A building simulation engineer uses VR to advise an architect on the consequences of building orientation or facade type, for example, while the services engineer can demonstrate the feasibility of natural ventilation, a mechanical ventilation scheme or other system.

Structural engineering analysts use VR to prototype and test various structural solutions for the building.

Construction schedulers use VR to develop, visualise and test various construction and scheduling options in 3D.

Similarly, **fire engineers** and **security analysts**, as well as planners and architects, use VR-based crowd flow simulations to aid spatial planning, safety and security assessments.

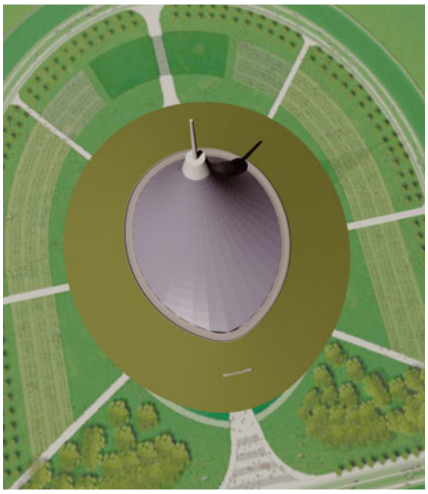
VR can therefore now provide a virtual prototyping capability, something that has been not possible before. The nature, cost and size of buildings mean that building a physical mock-up is simply not feasible. But being able to model a building on a computer and test its performance under a number of operating scenarios can be a powerful design optimisation tool and is increasingly becoming an inherent part of environmental design.

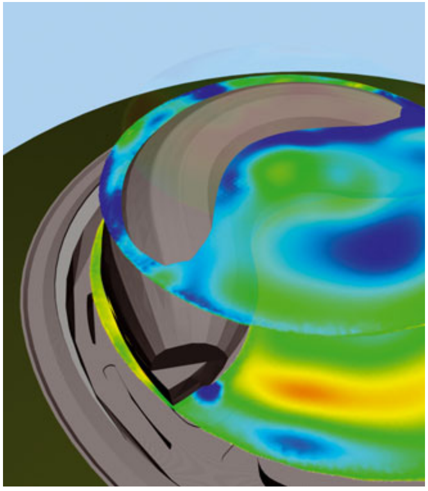
It's all about Data… and Integration

The quality of the virtual world depends on the quality and integration of three main components: the data, the software and the hardware.

While the advances in VR hardware and software have been great in recent years, the lack of portability of 3D data between various applications remains a concern. This effect is further magnified in the multi-discipline field of design in the built environment, well known for the complex challenge of communication between the very different stakeholders: planners, architects, engineers and developers – each with their own peculiar language, operational styles, software and culture.

However, it is VR that provides a visual, language-independent framework to integrate the various data and models and make it clearer to a non-technical audience. Through advances in computer hardware and software it has become possible to combine many of these solutions in an interactive, virtual world, to communicate precisely and interrogate individually – to more effectively sell the architectural and engineering ideas within it.





This animation combines sections on daylight and shadow casting, thermal modelling and airflow modelling in one sequence.

Collation of data from different disciplines is inherently difficult as each discipline will use different software to generate their final product. Architects typically use Computer Aided Design (CAD) packages, structural engineers use Finite Element Analysis packages, building simulation engineers typically use Dynamic Thermal Modelling and Computational Fluid Dynamics packages, fire engineers typically use smoke modelling and crowd flow modelling packages – the list goes on.

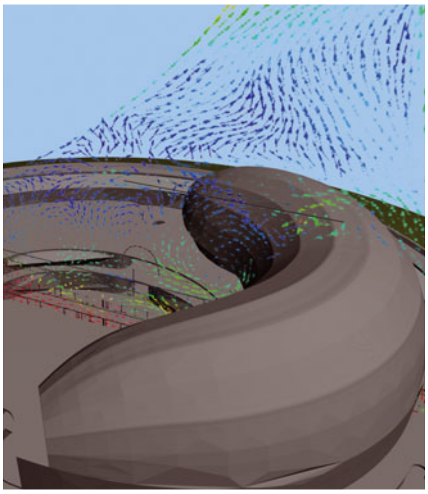
Unfortunately, due to the specialised nature and complexity of computational design tools, there is no single software package that can effectively produce the results to the same standard as the individual discipline packages. This leads to multiple models created in multiple packages and multiple results presented at meetings that can become, as previously mentioned, overwhelming, particularly for a non-technical audience.

It is, however, possible with the correct software, to export the data sets (or representations of them) from the different packages into one common model. The figure above shows some images taken from an animation that combines architecture visualisation, daylight and shadow casting, thermal modelling and airflow modelling in one sequence.

As the results are all combined on a single model and the different layers of detail can be individually or collectively interrogated, this will not only help to communicate the design clearly to the client but also show the integration of the different disciplines working on the project. The added value given by the ability to view and interact in real-time with designs in three dimensions brings a whole new level of understanding to everyone involved in the design process and can not only be used for presentations, but as a design tool.

Total Immersion

Currently a simulation engineer represents temperature or air speeds by colours or numbers laid on top of images. As a non-technical viewer is unlikely to be able to mentally convert



these numbers or colours into the physical experience, it would be much more helpful if we were able to create a virtual environment that can stimulate more than just the visual sense.

Imagine walking into a demonstration chamber where you could not only see the imagined designs but you could feel, hear and smell them too. 'Walking' round a three dimensional model where virtual people also walk around; where you walk round the corner of a building and physically feel a 5m/s wind blow at you; where you can walk into a building and feel air velocities reducing and temperatures rising, where you can turn on a ventilation system and hear the background noise this produces. Total immersion may not be as far away as you think…

David Stribling is an associate director in the specialist simulation group CoSA Solutions within Specialist Consulting.

Ian van Duivenbode is an engineer in CoSA Solutions specialising in development of virtual environments for communication of engineering analysis.

Shrikant Sharma is an associate and team leader in the Software Modelling Analysis Research and Technologies (Smart) group.

VR Myths

VR is CAD
Wrong, VR is CAD++. It includes the geometry and the environment that may include tactile feedback, sight, sound and smell.

VR is a modelling language for 3D geometry
Although there are some standards for defining 3D data in VR (e.g. VRML) VR is not just that.

VR means wearing heavy, head-mounted displays
While this was the original image in the early and mid-90s, with better stereoscopic displays coming onto the market, better immersion can be achieved without head-mounted displays.

VR must be viewed in an expensive, immersive room
VR can be expensive, but the basic kit requires only a PC with a powerful processor and graphics adapter. Depending on the applications, further add-on elements become necessary.

VR is for pretty visualisations alone
The applications of VR are many and include scientific visualisations, simulations and data management.

VR is a single-user experience
On the contrary, one of the big advantages of VR is that it allows interaction with other users and it is used as a collaboration tool.

VR and CAD

VR is CAD, plus many additional features.

- The focus in CAD is on the geometry. In a virtual world, the focus is on the environment including other senses in addition to the visual, usually represented as a scene-graph – geometry is only a part of it. A virtual environment may contain a wide range of objects. In, for example, generating a virtual environment of a small town, a great number of different objects must be created for the representation to be both interesting and believable.
- Another important difference in VR modelling is that objects in the environment will have their own, possibly complex, behaviours. These behaviours may also change in response to real-time events such as collisions. In CAD, objects are generally stationary or will only have simple motions such as rotations.
- A further addition is that objects in the environment must also be able to interact with the viewer. This can occur when the user collides with the model, by walking into a wall for example.
- Similarly, one of the great strengths of VR is the interaction between objects and the user. The user should be able to manipulate various objects within the scene by 'picking' them and moving them at will.

Speculate to accumulate

The use of the latest technology in a building's systems not only make its operation more efficient, it can help save the developer a great deal of money. Jack Treble looks at how investing in IT can result in a sizeable payback

The benefits of integrating the entire suite of modern building services equipment in a building, all of which are networked and communicating efficiently with each other, are well understood in terms of occupant comfort, ease of use and reduced running costs. What has received less attention – but is certainly just as important, to developers and the design and construction team alike – is the effect on a project cash flow due to use of the different building services technologies.

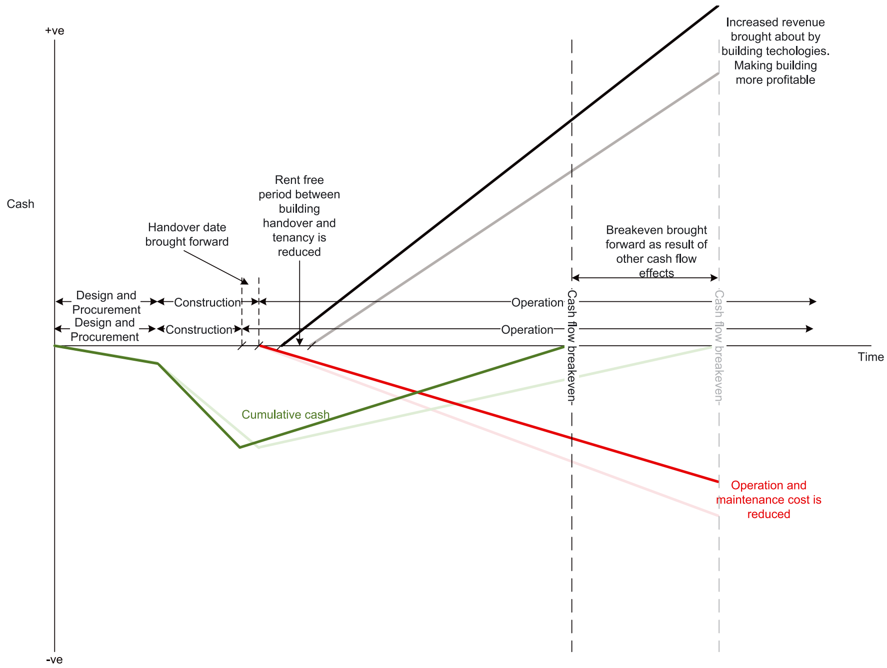


Figure 1 Cash flow effects of a 3i building (bold lines) compared to a conventional building.

By analysing the project cash flow throughout the construction process of a conventional building compared to that of an innovative, integrated, intelligent building (3i building), it is possible to see the scale of the savings on offer.

It is worth noting that there is, of course, a multitude of possible solutions between the two extremes defined here and the effects on cash flow (detailed on page 34) are purely for illustrative purposes.

What is 3i?

The 3i building is a hypothetical intelligent building solution, which fully implements advanced, integrated technologies into the built environment.

A 3i building entails the following:

- Innovation – through the use of building technologies to change, control and operate in our surroundings. Also, ensuring that the final design is future ready, by employing forward thinking.
- Integration – of the management platforms and communications infrastructures (converged networks) of the building technologies. This integration is enabled by innovation.
- Intelligence – enabled through integration, allowing the inputs and outputs of one system to intelligently (i.e. through processing) affect the inputs and outputs of another. This leads to increased functionality that benefits the building and its occupants.

The key predicted effects (as illustrated in figure 1, above) are as follows:

1. Through network integration, 3i buildings bring forward completion dates and reduce rent-free fit-out periods, so bringing forward the point of cash flow break-even. It should be noted that reducing the rent-free period is more a function of installing any infrastructure prior to handover, but that a 3i building approach makes it more feasible to do this.
2. Through building intelligence, 3i buildings heighten the revenue potential of the building and decrease the running costs once operational. This increases the rate of return and, in turn, brings further forward the point of cash flow break-even and increased building profitability.
3. Property value is increased as a follow-on effect of the above.

In addition, it is predicted that the effect on capital cost would be negligible compared to the overall cash flow life cycle.

For ease of analysis, the abstract project cash flow period (PCFP) has been split into a number of time stages that incorporate typical construction project phases, applicable to the systems discussed here. These periods are:

1. Design and procurement process – equivalent to RIBA stages A to J. The outcome of this period is usually performance specifications for tender and, subsequently, appointed contractors.
2. Construction, testing and commissioning – equivalent to RIBA stages K and L. This phase includes the required materials and labour costs plus contractor design and management.
3. Handover – An instant in the PCFP marking the point of project completion and the handover of building operation and ownership to the client. There is no PFCP cost associated with handover.

4. Operational – The indicative cost of this period includes the day-to-day operation of the systems, system repairs and renewals and also the revenues generated by the systems. Realistically this period ends at the end of the building's life. However, this analysis only considers the period up until the cumulative cash flow returns to zero, ie: when the cash flow breaks even.

Making technologies work

Although a term that can encompass any application of science to a building, when referring to building technologies in this case, it is to the technologies that enable wired and wireless networked systems to control and communicate information around the built environment (whether this is for control information or otherwise). These networked systems currently include: telephony, data networks, audio visual distribution (including TV, public address, etc), fire alarm, intruder alarm, CCTV, access control, HVAC (heating, ventilation and air conditioning), lighting control, lift control and the active and passive communications infrastructures that enable all of the above.

Figure 2 (below) illustrates the 3i building concept while figure 6 (on page 35) details the systems it will contain.

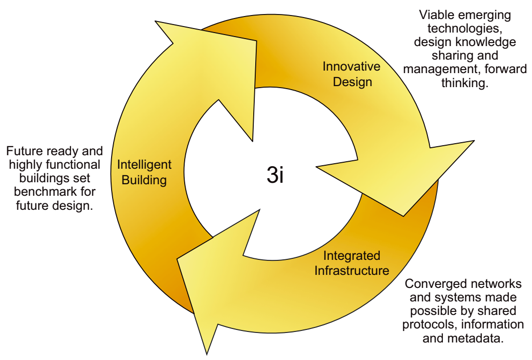


Figure 2 The 3i building concept.

All of this can be compared to the base case of a conventional building, which refers to one that, by and large, has a number of independent management systems and communications infrastructures for the systems above. It will have a structured cabling system and management console per system.

Improving cash flow

The economic effects of the 3i building can be defined as direct (more easily measured) and indirect (less easily measured). For example, a direct effect of a 3i building is reduced cabling material and labour as it has one common infrastructure. An indirect effect could be the increased revenue from providing increased functionality such as video conferencing via PCs, in the case of an office. The table below provides descriptions of the direct and indirect effects of a 3i building and which period is affected:

PCFP	Effect description
Design and Procurement – time	May slightly increase design cost as it requires more specialised consultants and more design time. However, the effect on cash flow would be negligible.
Construction – capital increase (materials)	More sophisticated networking hardware would be required to provide higher bandwidth and more intelligent communications equipment / processes. This would result in a higher materials cost.
Construction – capital decrease (materials and labour)	Converging the systems and their networks will result in a single, larger (at the edge) structured cabling system as opposed to a number of structured cabling systems. This would result in reduced costs for cabling materials and smaller labour costs due to there being less to install and only one contractor required to install it.
Construction – indirect capital decrease	An indirect effect of converging the networks into an integrated infrastructure is that the time spent on site is shortened, bringing the completion date forward which can help create further cost savings and revenues (for example, government tax breaks for completing a hotel in time for a national event).
Handover	Should the client wish, it is easy to offer serviced commercial space, effectively negating the rent-free fit-out period. If un-serviced, the rent-free fit-out period is significantly reduced by implementing a 3i building as the tenants need only to connect to the infrastructure. This means developers / landlords can start bringing in revenue earlier.
Operation – running cost decrease	Human resource requirements are lessened for two reasons. Firstly, it is possible to automate more of the building controls, as the building systems are intelligent. Secondly, because the management systems are both integrated and remotely accessible, fewer staff are required to effectively monitor them.
Operation – running cost decrease	Some of the maintenance contracts and SLAs could be consolidated, while those remaining can be simplified, so negating the profit margins introduced by third parties.
Operation – indirect revenue	As a 3i building provides better functionality to all users, marketability (and hence rental / sale value) of the building increases for the developer which can claim the quality of occupier comfort, safety and the general experience leads to increased productivity or revenue.
Operation – indirect revenue	Consumers using a 3i building (particularly for retail or a hotel) may increase revenue by using applications or services enabled only through 3i buildings systems. For example, web surfing on a hotel bedroom TV or remotely accessible security systems for guests.
Operation – cost decrease	A 3i building allows increased building performance through more efficient energy management, for instance, via lighting management systems that turn lights off when not in use

To summarise, the effects on each project phase (design, construction, handover and operation) are:

1. A negligible capital design cost increase is estimated, as design consultants may have to spend more time co-ordinating designs.
2. The capital construction costs are predicted to remain largely unchanged as savings created by structured cabling systems are offset by the cost of more sophisticated hardware and software.
3. A crucial effect is that both the completion date is brought forward and the rent-free fit-out period reduced (in un-serviced builds). This means the cash flow break even point is also brought forward.
4. A further effect is that operational costs are reduced and revenues increased, meaning rate of return is higher. Again, this means the cash flow break even point is brought forward even further.

Although there has been research into the effects detailed above in isolation, there has been no reported analysis that explicitly and holistically measures these cash flow effects. And while these cash flow effects are hypothesised, and detailed analysis of the construction of a real 3i building would truly justify these claims, they are based on previous experience and knowledge of integrated infrastructures and intelligent buildings.

Figure 3 and figure 4 right gives a more detailed illustration of the above effects by providing a hypothetical financial case for a conventional building versus a 3i building.

This table is based around a hypothetical office building and its estimated cash flow and build period for conventional or 3i systems. This is a building with six floors totalling 30,000m², of which 20,000m² can be leased out. The results are also summarised in the graphic opposite.

		Design and Procurement (Consultancy costs)	**Construction (Materials and labour inc. testing and commissioning)**	**Operation (Average running costs inc. HR, repair and renewal, utilities)**	**Revenue (Direct i.e. rent inc. service charges and indirect e.g. alternative revenue streams – managed services etc.)**	**Rate of return post completion (Operation – Revenue)**
Conventional Building	**Cost**	£10m	£45m	£3m/yr	£500 per m² x 20,000m² = £10m/yr	£7m/yr
	Time	2yrs	2yrs	NA	Break even point: 12yrs 7 months from start of RIBA stage A (7yrs 10 months from Handover)	
3i Building	**Cost**	£10m	£45m	£2.9m per year	£510 per m² x 20,000m² = £10.2m/yr	£7.3m/yr
	Time	2yrs	1¾ yrs	NA	Break even point: 11yrs 8 months from start of RIBA stage A (7yrs 5 months from Handover)	
Net Difference (conventional – 3i)	**Cost**	**£0m**	**£0m**	**£100k per year**	**£10 per m² x 20,000m² = £200k/yr**	**£300k/yr**
	Time	**0yrs**	**3 months**	**NA**	**Break even point: 11 months from start of RIBA stage A (5 months from Handover)**	

Figure 3 Estimated financial performance for a hypothetical office building employing either conventional or 3i technologies.

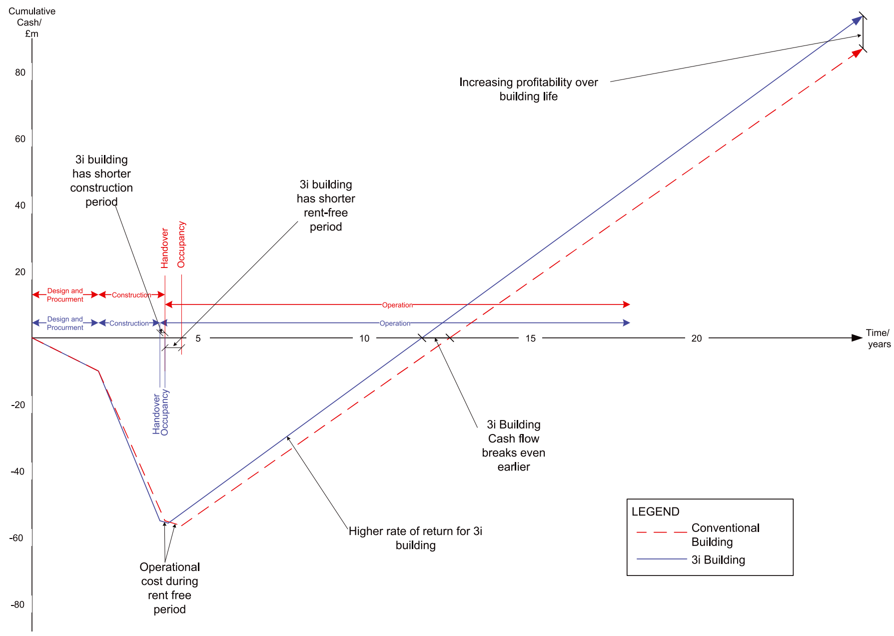


Figure 4 Effect on cash flow during the life of a hypothetical office building employing either conventional or 3i technologies.

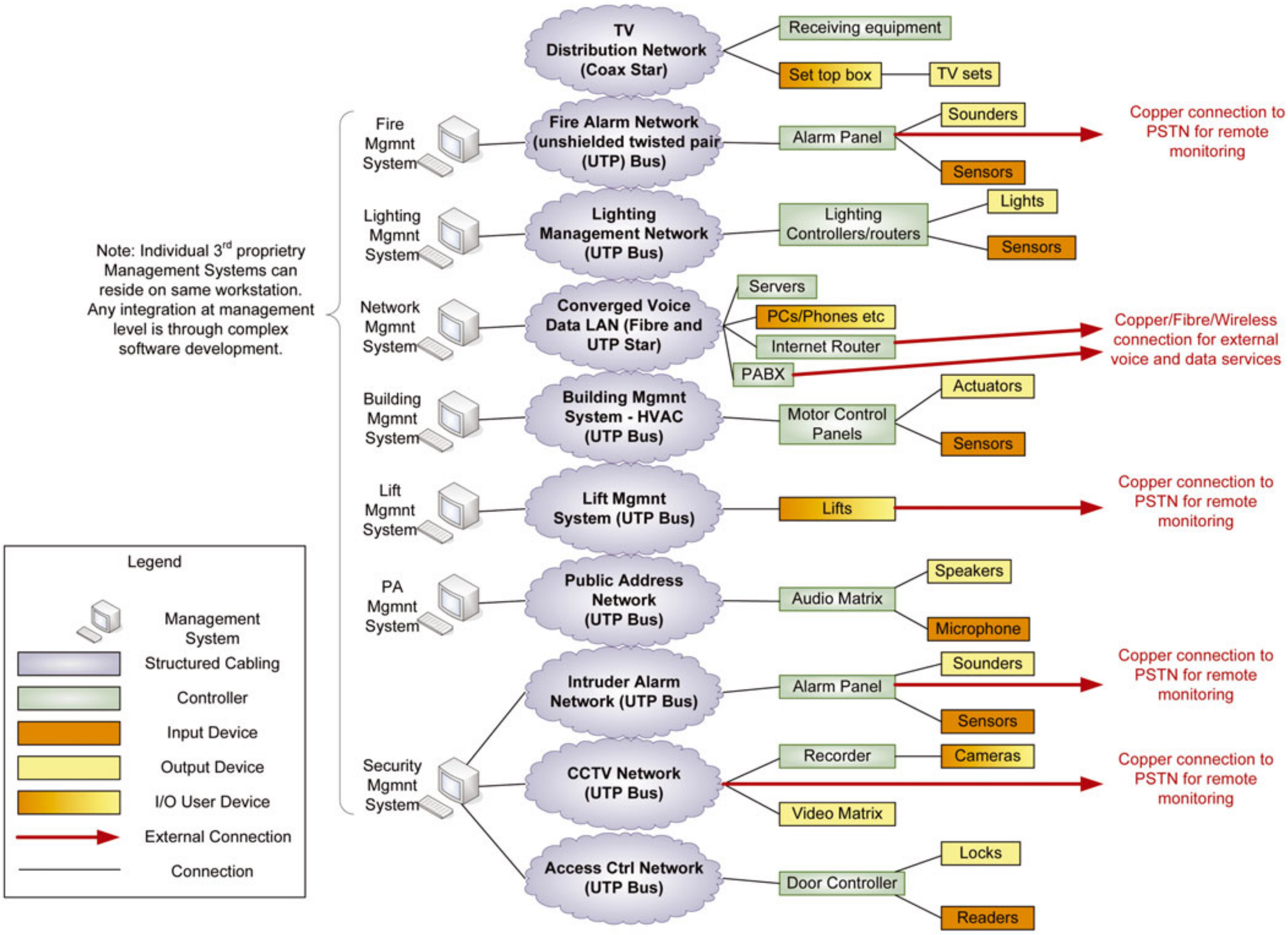


Figure 5 Conventional building systems.

Appropriate technology

It is worth discussing specific technologies, as there might not always be a simple case for or against their use. The first is wireless infrastructures. These offer many benefits over wired infrastructures with the most obvious being mobility. But there are disadvantages too, in particular, reduced information security as data can more easily be "snatched" out of the air.

It follows that certain types of non-sensitive data should be transmitted wirelessly, taking advantage of the benefits, while other, more sensitive data should be kept secure on a material medium. An infrastructure that integrates the transmission mediums as well as the communicative systems would be the ideal solution. Therefore, the questions a developer and its design team should consider first are: "Wired and wireless: how?" along with "Wired or wireless: for which technology?"

Critical systems are also worthy of careful consideration. All information requires a certain level of security and high levels can be provided through certain techniques, such as the creation of virtual local area networks for a particular type of information flow.

However, some building systems are considered too critical (to the operation of the building and – more importantly – to the safety of its occupants) to be converged with other systems and have

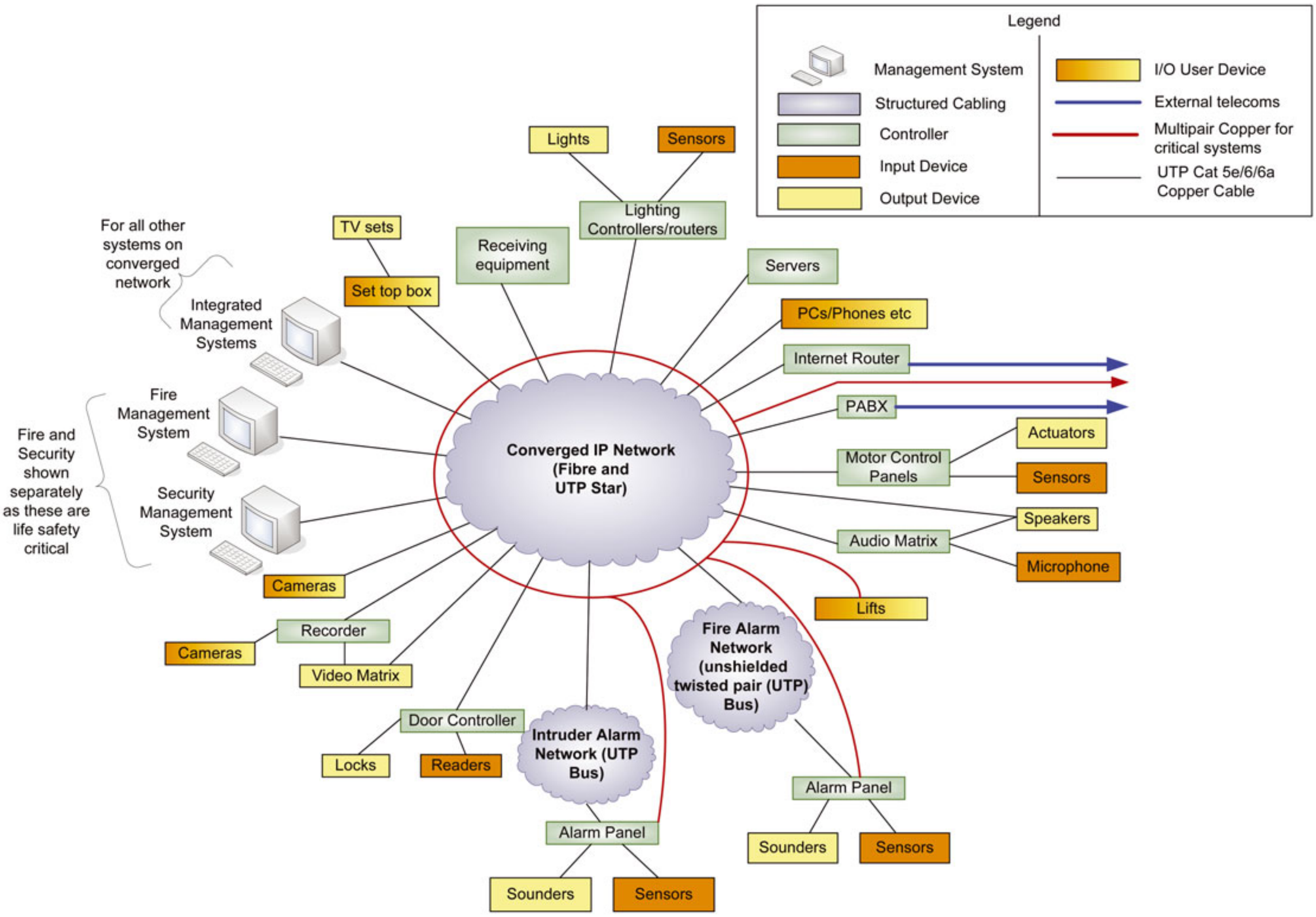


Figure 6 3i building systems.

them share the same medium. These often include fire protection and intruder alarm systems.

Even though these systems require separate cabling, their outputs can be used to effect a change in another system via the management applications. A good example is a fire alarm that could cause all doors to unlock and CCTV to display the alarm location.

The integrated management platform that sits on the network infrastructure provides the final level of integration in a 3i building. As with any management platform, the inputs and outputs (effectively the causes and effects) must be very carefully considered in parallel to the design of the building. Beyond that, how the management platform fits into the overall facilities management strategy is the ultimate enabler of the building intelligence (this is easier with an integrated management platform.) Without intelligent use, the benefits of a state of the art, integrated infrastructure and management platforms become redundant. In fact, they would become an obsolete operational expense.

Jack Treble is an information and communications technology consultant in the Specialist Consulting group.

Our authors

David Beck
BSc (Hons) CEng MCIBSE

David Beck is an associate director in Specialist Consulting.

Henrietta Cooke
BA (Hons) ACA

Henrietta Cooke is a consultant in the Sustainability and Alternative Technologies group within Specialist Consulting.

Rob Cooke
EngD MSc BEng (Hons) MInstE

Rob Cooke is a senior consultant in the Sustainability and Alternative Technologies group within Specialist Consulting.

Salmaan Craig
Bsc (Hons)

Salmaan Craig is a research engineer in the Sustainability and Alternative Technologies group within Specialist Consulting.

David Dropkin
BA NRAC

David Dropkin is a senior access consultant in the Inclusive Design group within Specialist Consulting.

Neil Fletcher
BEng PhD MIEE ASyI

Neil Fletcher is a consultant in the security engineering team within Specialist Consulting.

Mick Green
BEng CEng MICE MIStructE

Mick Green and Peter Moseley are co-leaders of the Specialist Consulting group.

Andrew Kelly
MEng MIET ASyI

Andrew Kelly is a senior consultant in the security engineering team within Specialist Consulting.

Francesca Madeo
PhD – Arch

Francesca Madeo is a senior facade engineer in the facade engineering group within Specialist Consulting.

Alistair Meachin
BSc(Hons) MSc CEng MIOA MAES

Alistair Meachin is a senior engineer in the acoustics group within Specialist Consulting.

Peter Moseley
BSc CEng FCIBSE MInstE MIFireE FFB

Peter Moseley and Mick Green are co-leaders of the Specialist Consulting group.

Andy Nicholson
BTEC BEng MIFireE MSFPE

Andy Nicholson is an associate in the Fire Engineering group within Specialist Consulting.

Ian Pegg
BEng (Hons)

Ian Pegg is a research engineer in the Sustainability and Alternative Technologies group within Specialist Consulting.

Shrikant Sharma
BEng MTech PhD CEng MIMechE

Shrikant Sharma is an associate and team leader in the Software Modelling Analysis Research and Technologies (Smart) group.

David Stribling
BEng PhD

David Stribling is an associate director in the specialist simulation group CoSA Solutions within Specialist Consulting.

Jack Treble
BSc (Hons)

Jack Treble is an information and communications technology consultant in the Specialist Consulting group.

Ian van Duivenbode
MEng

Ian van Duivenbode is an engineer in CoSA Solutions specialising in development of virtual environments for communication of engineering analysis.

Mark Whitaker
ato psc† GCGI MBA MIExpE MSyI

Mark Whitaker is head of Happold Safe and Secure within Specialist Consulting.

Buro Happold

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Buro Happold
Camden Mill
Lower Bristol Road
Bath BA2 3DQ
Tel +44 (0)1225 320600
www.burohappold.com