Arup in Healthcare Collaborating globally

8

ARUP

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

We are truly global. From over 90 offices in 38 countries, our 11,000 planners, designers, engineers and consultants deliver innovative projects across the world with creativity and passion.

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

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

We shape a better world



Contents

Arup in Healthcare – Collaborating globally	4-5
Planning today's estate to meet tomorrow's needs Phil Nedin Global Business Leader, Healthcare	7-12
Revitalising ageing healthcare buildings Mike Durtnall – UKMEA	13-15
Healthy sustainable cities: a roadmap to panacea Andrew Bradley – Australasia	17-20
The co-existence of clinical activities and construction Alex Ramos, Mark Aitken – Australasia	21-24
Designing a dementia sensitive environment Pam Turpin – UKMEA	26-29
Maintaining operational continuity during change Darren Briggs – UKMEA	30-33
ICU helps in building healing environment Dr Gerard Healy – Australasia	35-40
Assessing the full carbon impacts of healthcare Paul Brockway – UKMEA	42-45
Creating premises for indigenous Australians Doug Kingham and Rob Isaacs – Australasia	46-49
Do single patient rooms reduce infection risks? Katherine Roberts – UKMEA	50-52
Façade led upgrades revitalise older buildings Philip King – UKMEA	53-56
Towards merging Chinese and Western medicine Alice Chown and Elise Chan – East Asia	58-61
No walls here – a remarkable vision realised Georgina James – Australasia	62-65
Pioneering in the new Poland Andrew Kozlowski - Europe	66-70
Sustainable health design needs a different approach Tyler Krehlik, Alisdair McGregor and Afaan Naqvi – Americas	71-4

Arup would like to thank all clients, design partners and collaborators for their support in developing the papers included in this publication.

Arup in Healthcare Collaborating globally

Arup is not a healthcare provider, but Arup's expertise supports the delivery of high quality healthcare around the world. Through our broad understanding of the healthcare environment, we have the expertise to help meet the needs of patients, clinicians and administrators to benefit from well designed facilities. We have experience of the approaches necessary for the delivery of both existing and new build projects. We expect our multidisciplinary solutions to minimise infection, satisfy low energy requirements, and create spatial flexibility to ultimately provide appropriate, cost-effective and efficient facilities.

Arup has built up an enviable track record in the healthcare sector, adding value to over 3,000 healthcare projects worldwide. Just a few of those value stories are told here. These articles represent a fraction of the knowledge that is embedded in the firm. They illustrate our information sharing ethos and reflect the experience we bring as part of the delivery team, collaborating with partners and experts internationally. Yet the really impressive part of Arup is our people and their determination to stay alert to the new ideas and new technologies through multi-disciplinary collaboration that will allow us to go further and do ever more for our partners and, ultimately, for the patients. As an employee-owned firm, Arup is in a unique position to match the ambition and expertise of our people with the highest standards of independent advice and strategic delivery.

I hope you enjoy reading about our work around the world in the field of healthcare design, project management and business consulting. I hope you also gain some insight into the values, the ideas and the technologies that inspire us to 'shape a better world' for healthcare professionals and patients wherever they may be.

We shape a better world





ARUP

Is your estate working smartly for you?

The estate can be a burden or an enabler to improving financial performance and patient outcomes. Today there are many opportunities to improve existing assets to provide modern and sustainable facilities that meet new service requirements whilst optimising space, energy and costs.

Arup supports trusts to reassess their healthcare facilities and hospital estates, to understand the options available to improve clinical pathways, meet strategic aspirations and satisfy business objectives that are flexible for today's and tomorrow's demands.

Consult. Design. Deliver.

www.arup.com/healthcare

Planning today's estate to meet tomorrow's needs

Healthcare requirements are changing rapidly and these changes will have a major financial and operational impact on the existing healthcare estate. Not only are costs increasing, but there are pressures on estates to reduce costs, reduce size, become more specialised, integrate more with the community and reduce energy and carbon emissions.

In addition, the estate also has to deal with the ongoing drivers of medical and scientific change (Fig. 1). So, the challenge faced by designers and construction professionals today is how to plan the adaptation of the healthcare estate to deal with the many changes to come and communicate these complex solutions to the clinical teams.

The only part of this equation that is fixed is the quantity and quality of the existing estate. Figure 2 illustrates the age profile of the National Health Service (NHS) estate in England. There can be as many as eight generations of building types in existence, with each generation having their own spatial, environmental and construction standards, potential for flexibility and maintenance liabilities. Many other healthcare estates in the world mirror this situation. Firstly, we must consider some of the changes that the healthcare estate will be forced to accept.

Healthcare under financial pressure

The financial burden of an unhealthy population was recently estimated by the UK's Department of Health in a report which stated that the annual economic costs of working-age ill health could be over £100 bn. In short, a healthy population drives successful business and has a substantial overall benefit to the economy.

However, there is an enormous financial burden on countries that maintain a sophisticated healthcare system. Given the complex evolving nature of healthcare, neither the costs of illness nor the benefits of health remain static.

To maximise the benefits and minimise costs, innovative solutions are required across each of the drivers of change. At the same time, identifying healthcare costs and potential solutions is becoming more complicated.

Much of the 'low hanging fruit' has already been picked so we need to consider the opportunities for savings as a series of cobenefits that is underpinned by a whole-life cost based financial model. The potential for a single solution with a zero cost implication to significantly affect the bottom line of a healthcare system is a mirage. Applying multifaceted, innovative solutions are the order of the day. Yet to transfer this early adopter approach to a profession steeped in evidence-based outcomes can create discomfort, resistance and delay.

In global terms, the result is that costs can vary widely even in countries of similar economic standard. Table 1 includes the cost of some healthcare systems in different parts of the world.

Table 1 reflects the cost of healthcare per person as well as the % Gross Domestic Product (GDP) for some selected countries. GDP may be an acceptable metric for economists and politicians, but it does not easily allow the consumers of healthcare to understand the cost implications of the utilisation of the system. This is important because we are now experiencing a changing global disease burden where, for the first time, more people (60%) are dying from non-communicable disease (NCD) than communicable disease. One result of this shift is that it will be more important than ever for the public to take responsibility for their own health and manage their lifestyles to reduce their reliance on the healthcare system.

'We need to consider the opportunities for savings as a series of co-benefits that is underpinned by a whole-life cost based financial model.'

There must, therefore, be a greater understanding of the financial cost to the system of 'doing' i.e. smoking, alcohol abuse, poor diet and lack of exercise and 'treating' i.e. diagnostic scan, diabetes treatment, emergency admission and a bed day in an acute hospital etc. The changing disease burden will involve a radical shift in the approach to population screening, treatment, medication and monitoring with the inevitable changes to the healthcare estate of scale, acuity and distribution. These being underpinned by information technology systems connecting between acute centres, acute centre to community and community to home. This will undoubtedly require significant short term investment to ensure long term benefit which, at a time of global financial constraint, will be a challenge. However, the alternative is an inefficient healthcare delivery system.

Phil Nedin

Phil Nedin is a Chartered Engineer and a Director of Arup, responsible for its global healthcare business. This role has taken him to many regions in the world to investigate best practice solutions in healthcare engineering.

Phil has been with Arup for more than 23 years, currently based in the London office. Previously, he worked for the National Health Service in a regional health authority design group in London.

Phil is a past President of the Institute of Healthcare Engineering and Estate Management (IHEEM) and is currently on their international committee. In November 2011 he was awarded the IHEEM Lifetime Achievement Award. He is also a Fellow of the Institute of Mechanical Engineers and a member of the UK Department of Health design review panel.



The changing nature of disease

We have touched on the changing disease burden as a major global driver of change for the healthcare estate. At a United Nations meeting in September 2011 it was noted that the rise in NCD threatens the sustainability of healthcare systems in high-income countries, as well as the expansion of healthcare systems in low and middle income countries. NCD's such as cardiovascular disease (CVD), diabetes, chronic obstructive pulmonary disease (COPD) and common cancers can often be lifestyle diseases attributed to tobacco, poor diet, physical inactivity and the harmful use of alcohol.

This, of course, begs another question - why do we as a society do things to our bodies that creates significant long-term harm? Are we just weak in the face of temptation? Are we given sufficient information about the risks involved? Are we the victims of peer pressure? Does the DNA of some have an inherent susceptibility? Are we drawn in by slick modern marketing? Government intervention was successfully implemented with the smoking ban in many countries and perhaps now we need the same approach with the price and availability of alcohol and clearer guidance on diets, particularly relating to the balance of macro nutrients (fats, proteins and carbohyrdrates).

What we do know is that the rise of NCD is going to move the goalposts in terms of the facilities we need to deliver healthcare in the years and decades to come. A study by the Harvard School of Public Health calculated that the costs of NCD plus mental health problems will total some \$47 trillion over the next 25 years – about 75% of current global GDP!

Given the sheer scale of the challenge, there is widespread agreement that our current healthcare systems are not going to adapt easily to changing needs. We currently have systems that are by nature episodic, disjointed and acute hospital based. That means we have to think closely about the healthcare estates we will need as the manner of treatment shifts as shown in Table 2.

The ageing population

Exacerbating the rise of so-called 'lifestyle diseases' is the impact of demographics. Global life expectancy at birth rose from 47 to more than 67 between 1950 and 2012.



Figure 1: Healthcare drivers of change.

It is expected to reach 75 in 2050 as deaths become more concentrated in older age. At the same time, deaths from heart attack and stroke have been declining for more than 50 years and the screening practices for a number life threatening diseases have also improved.

The result is that in 2012 we have 800 million people over the age of 60 or around 11% of the world's population. By 2030 that number is forecast to be 1.4 billion, or 17%, and 2.0 billion by 2050 or 22%. Indeed, based on current trends, for the first time in history a higher proportion of people in the world will be aged 60 and over (21.0%) by 2047 than are aged under 15 (20.8%).

The increase in life expectancy and declining fertility has some profound implications for society. For example, the increase in older people will drive a sharp decline in the support ratio i.e. the ratio of people of working age (15-64) versus those aged 65 or over.

At the same time, those living longer are very unlikely to live free of illness. So, the incidence of chronic illness will be more prevalent in the elderly. Also people with a chronic condition usually have more than one (multi-morbidity). For example, 50% of over 65s have two or more chronic conditions and 50% of over 75s have three or more chronic conditions, such is the complexity of multi-morbidity. This means that the challenges ahead become even more complex and more expensive.

As we live longer our chances of suffering from dementia increases. Indeed, with varying

'The changing disease burden will involve a radical shift in the approach to population screening, treatment, medication and monitoring with the inevitable changes to the healthcare estate of scale, acuity and distribution.' levels of acuity it may even become inevitable for most people as they grow older. Worldwide, 35.6 million people live with dementia today and the numbers are set to double every 20 years. The projections are 65.7 million in 2030 and 115.4 million in 2050. Alzheimer's disease will also have a significant impact on the UK economy in the next 40 years. The projected increase in those suffering from Alzheimer's is forecast to rise from the current 700,000 to 1.7 million, while the care period for Alzheimer's sufferers runs from between 7 and 20 years.

In short, we must recognise that there is a great deal to be done as we map out the longterm relationship between increasing length and the associated quality of life.

Patients of the future

The good news is that we are at least making a start. Patient-centric or patient-centred healthcare are the new buzz phrases. This approach allows clinical planners and designers of new models of care to focus on what is important. This is an essential first step, but we must be aware that patients come in many forms, both physically and emotionally. For example, healthcare systems will soon be welcoming the first digital generation as a bulk patient group. They will have grown up on a diet of privacy and digital communications. They will be adept at searching the digital world for a diagnosis for their healthcare problems and engage with digital self help communities. They will possibly be as informed of the diagnostic and treatment options as the doctors they visit. After all, the patient may have had two weeks to research their particular problem whereas a doctor in a primary care setting will typically have 10 minutes or less to make a diagnosis and set a course of treatment.

That poses some interesting questions for patient/doctor relationships. However, in general, greater access to digital medical intelligence has to be welcomed. If individuals are going to be expected to take

www.arup.com



	Table	e i. The cost o	i nearcheare.		
Country	GDP/Head	Health GDP	Healthcare cost/head		
	(US\$)	%	US\$	€	£
USA	47,150	17.9	8,439.85	6,680.69	5,297.02
Norway	85,390	9.5	8,112.05	6,420.17	5,090.46
Denmark	56,240	11.4	6,411.36	5,076.68	4,023.25
Netherlands	46,900	11.9	5,581.10	4,418.77	3,502.56
France	39,450	11.9	4,694.55	3,719.21	2,946.84
Sweden	48,900	9.6	4,694.40	3,716.74	2,946.09
Germany	40,120	11.6	4,653.92	3,687.12	2,907.87
Belgium	43,080	10.7	4,609.56	3,649.88	2,893.05
Australia	50,750	8.7	4,415.25	3,495.23	2,771.29
Ireland	46,170	9.2	4,237.64	3,355.10	2,659.44
Finland	44,380	9.0	3,994.20	3,162.20	2,506.84
UK	36,340	9.6	3,488.64	2,763.84	2,189.87
New Zealand	32,370	10.1	3,269.37	2,587.71	2,052.07
Italy	34,080	9.5	3,237.60	2,473.42	1,992.88
Spain	30,550	9.5	2,902.25	2,299.34	1,821.49
Greece	26,610	10.2	2,714.22	2,149.98	1,703.77
Portugal	21,490	11.0	2,363.90	1,872.49	1,483.86
Poland	12,290	7.5	921.75	730.13	578.59
SouthAfrica	7,280	8.9	647.92	512.87	406.66
China	4,430	5.1	253.93	200.98	159.37
India	I,410	4.1	57.81	45.76	36.28

Figure 2: Age profile of the NHS estate 2007-2008.

responsibility for their own health, then it is good that they have the information to do so – as long as that information is correct.

As well as being more tech savvy, this future demographic is likely to be far more demanding about their need for privacy within the acute hospital environment. This trend is already happening, with single bed units increasingly viewed as an essential requirement in hospitals and not just for reasons of privacy. Reduced spread of infection, flexibility for more bedside treatments, family and friends support, the full use of digital systems and multi-cultural acceptability are all co-benefits of this change.

There is a cost to this single bed room provision, with a new build floor area reducing the number of beds by 30% when moving from a multi bed ward to single bed rooms. This is reduced to possibly 50% when the transition takes place in a refurbishment project. This can, however, be offset by the possible reduction of in-patient accommodation in many countries, which may balance the equation.

We can therefore conclude that these trends point to some radical changes in how and where we deliver healthcare in the future. What's more, the healthcare facilities we are designing and building today, given a typical 60-year life will be in service to experience these new patient groups and the changes they will bring to bear on the system.

Science and technology

(Data source – World in Figures 2013 Conversion \$ to € to £ Sep 2012).

So far the changes we have touched on have been financial, societal, public health and demographic. There is, of course, a relentless march of science to add into the mix.

Take the relatively new science of molecular biology, which has given us a deep level of understanding of the human body through the sequencing of the human genome. Understanding how we are constructed at base level means that we not only have the chance to gauge our vulnerability to disease but also to predict how the immune system might respond to different diseases – and more crucially, to tailored therapies. This may lead to more preventative strategies and reduced attendance as in-patients.

A further scientific area of activity is nanotechnology. In terms of medical research, there are opportunities here for advanced therapies and drug delivery, innovative diagnostic imaging and structural repair. In the near future, the process of





Table 2: How health systems need to change to be better ableto prevent and manage NCD.			
Current view	Evolving model of care		
Geared towards acute conditions	Geared towards long-term conditions		
Hospital-centred	Embedded in communities		
Doctor-dependent	Team-based		
Episodic care	Continuous care		
Disjointed care	Integrated care		
Reactive care	Preventative care		
Patient as passive recipient	Patient as partner		
Self-care infrequent	Self-care encouraged and facilitated		
Carers undervalued	Carers supported as partners		
Low-tech	High-tech		
(Source – Report on communicable diseases Imperial College London and Qatar Foundation 2012).			

radiation and chemotherapy as cancer therapies could even be replaced through more targeted nano-therapies. At the same time, we may also see a new world in diagnostic imaging, using *in vitro* nanocameras rather than large magnet-based devices.

The enabler for this technological change will be the advances in computer science which continues to shape the medical environment. Given that a typical mobile phone boasts computing power far in excess of the systems that carried Apollo 11 to the moon in 1969, we can easily predict that much more is to come.

What is clear is that the potential for change within the healthcare environment is enormous. The manner in which diseases are diagnosed and treated could be revolutionised within 10 years and would have a significant impact on the built environment that supports the delivery of healthcare services.

The challenge then is that the buildings that we create today have to be up to the task of meeting all these changes for the next 60 years. We even need to ask ourselves the ultimate flexibility question – if this were not a hospital then what could it be?

Clearly, the health planners, architects and engineers charged with designing healthcare facilities of the future need to understand the full scale of the potential developments on the horizon and plan sufficient flexibility into their designs to allow those changes to occur.

This long-term level of understanding will not simply be gained through discussions with local clinicians or patient user groups alone, but by interacting and collaborating with scientists and clinical researchers.

The impact of change on the acute healthcare estate

So, what does all this mean for the day-to-day business of shaping healthcare environments that will be fit for the future? Well, first of all, we can examine the basic model of how we approach the problem now.

Modern acute hospital accommodation can be divided in four main building types

- the hot areas (diagnostic and treatment); the hotel accommodation (wards); the administration (offices); and the industrial elements (laboratories, pharmacy, laundry, catering, etc). The need for change of each of these accommodation types was the subject of work carried out in the Bouwecollege in Utrecht, Netherlands in 2005 (Fig. 3). This model is very helpful in aligning functional building types with their need for flexibility, complexity of services and, ultimately, cost differences.

However, since this model was developed things have moved on and we must now consider what proportion of each of the functions will be carried out in the community or at home and what could be outsourced to local or remote third-party providers. This can only be ascertained by an analysis of the future clinical and ancillary services to be provided, the models of care associated with those services and the attitude towards public/private partnerships etc. Only then can the accommodation necessary to support the effective delivery of the service be fully considered.

In short, every healthcare estate will need a clinically led development control plan for the short, medium and long term. It will also be essential that this plan includes all the satellite facilities in the vicinity i.e. in-patient, outpatient, general practice and community care. This is critical to facilitate the future adoption of a less centralised, more dispersed service delivery model. This holistic approach will be the basis of a vertically integrated system incorporating prevention, intervention and care, enabled by a powerful digital intelligence platform.

Once we have fully considered the many complex changes that could occur over time on the estate, we can turn our attention to the condition of the building stock within the health estate at large. Given the complex nature of the problem, it is important that we have planning models to help frame our multidiscipline approach to the building stock. One such model is the AssetMap (Fig. 4). This model was originally developed to guide clients through the process of interrogating



Figure 4: AssetMap – an evaluation model to enable realisation of the potential of the existing estate.

'The prize will be to future-proof our healthcare systems to enable effective economic delivery for future generations of patients.'

the existing estate to maximise its potential. This makes the model ideal for recalculating floor area requirements and building adjacencies for a newly formed estate that fits with the new clinical requirements and reflects the inevitable shrinking of the healthcare estate.

The opportunities are significant. As the estate shrinks, so the maintenance and energy costs reduce. At the same time, land becomes available that can be used for other healthcare building developments or used to provide green spaces, healing gardens, or sold off to free up capital for investment.

The model also tells us a lot about the potential for maximising legacy and new healthcare estates. If we take the NHS in the UK, for example, we know that the healthcare estate has developed over many years into a number of distinctive types.

Figure 5 illustrates typical building arrangements and relationships that have been used over the years to develop campus sites. These forms are expressed in more detail in Changing Hospital Architecture, (a Royal Institute of British Architects publication). The structural frame, floor slab details, wall construction, façade composition and building services requirements are different for each form. Some of these forms and specific building types lend themselves to a reasonable level of flexibility for the adoption of new clinical functions while others do not. A further component of the 'construction form' is the effectiveness of the floor plate to accommodate a radical change of use.

Specific building types need to be analysed to ensure that cost-effective upgrading can be carried out. The extent of the refurbishment can be as simple as a redecoration or as complex as multiple floor extensions utilising new structural frame, façade and building services systems: integrating multi-bed wards into single bed accommodation or creating outpatient clinics from existing in-patient facilities. Whatever the project, it is essential that any upgrading review is considered with the potential to introduce therapeutic or healing environments.

Any revamped facility or healthcare environment should be developed to enhance the patient experience and allow



Figure 5: Different configurations of the acute healthcare estate.

'It is important that we have planning models to help frame our multi-discipline approach to the building stock.'

for future flexibility – but just as importantly, it has to increase the performance efficiency and effectiveness of the clinical staff. A well executed new design or refurbishment has the added benefit of enhancing the recruitment and retention of the best staff by creating improved external and internal environments. This is an important subject given that there is already a shortage of qualified clinical staff with aggressive competition for this rare commodity.

Conclusion

There is no doubt that the planning and delivery of the future healthcare estate is an extremely complex subject. Necessarily, it has to deal with the strategic blue sky approach to future clinical and estate reconfiguration, as well as with the multi-faceted changes that are being imposed by everything from new technology to novel gene therapies. Across all of this, we need to overlay the more practical requirements of site master planning, building by building analysis and project delivery.

The jump from strategic thinking to practical planning and delivery is never easy. However, with the changing healthcare environment we must think holistically to provide the necessary cost-effective clinical facilities that future generations can rely on.

It is a multi-disciplinary approach where technological and clinical scientists, engineers, medical practitioners, healthcare planners, architects, cost consultants and constructors will be the agents of radical change.

It is a significant challenge, but the prize will be to future-proof our healthcare systems to enable effective economic delivery for future generations of patients. To do otherwise is unacceptable!

Acknowledgements

- Innovation Health and Wealth UK Department of Health Improvement and Efficiency Directorate, December 2011.
- Countering Non-Communicable Disease Through Innovation – Global Health Policy Summit 2012.
- The United Nations High-level Meeting on the Prevention and Control of NCD's (New York, 19-20) September 2011.
- Primary Care The Central Functions and Main Focus – Global Health Policy Summit 2012.
- Changing Hospital Architecture Royal Institute of British Architecture (RIBA Publishing 2008).

We shape a better world

ARUP

Revitalising ageing healthcare buildings

How many of us have heard people complain that their local hospital is crumbling, dirty or unsafe. The reality is usually that the quality of care provided is excellent. However, people's perceptions are often influenced by the condition and appearance of the buildings from which care is delivered.

Occupiers are faced by many challenges in today's healthcare market, not least the problem of what to do about their ageing building stock. Although some of the oldest buildings with the most urgent needs have been replaced, large numbers of buildings still in the use in the UK date back to the 1960s or earlier. Many of these replaced earlier, Victorian hospital buildings themselves and at the time were welcomed as modern, bright and spacious. After 35 years or more of service they are suffering however, both from deterioration of the building fabric and from the poor impression they give to patients, visitors and staff.

The economic downturn means that capital for investment in new buildings to replace those seen as old and tired is in short supply, with financial markets taking a much more risk-averse approach when deciding whether to invest and with public capital also less accessible. In addition, lack of space to decant into, the need to maintain 'business as usual' and avoiding disruption often constrains the ability of healthcare providers to undertake a major new build. These providers are therefore increasingly looking

'The economic downturn means that capital for investment in new buildings to replace those seen as old and tired is in short supply.'



An aerial view of Guy's Tower.

for innovative ways to inject new life into existing buildings.

A good example of an organisation that faced these challenges is Guy's and St Thomas' NHS Foundation Trust (hereafter referred to as 'the Trust'), a large teaching hospital serving south east London and beyond and a founding partner of Kings Health Partners, one of the UK's first Academic Health Science Centres.

Today the Guy's campus is home to both the NHS Trust and one of London's leading research universities, King's College London (KCL).

At 143 m high and reputed to be the tallest healthcare building in the world, Guy's Tower was designed by architects Watkins Gray and opened in 1974. The building actually comprises two towers, the User Tower, containing most of the occupied space and the Communications Tower, housing the lift shafts, risers etc. They are joined at each floor by a modest link bridge. The tower is occupied by a mixture of hospital departments, a dental institute and teaching space and research laboratories run by KCL.

By 2008 the building facade was exhibiting significant signs of deterioration and the Trust realised that it needed to make a once-in-a-generation level of investment to secure its future. At the same time, the Trust wanted to take advantage of the opportunities that this level of investment offered. It selected Arup, as a one-stop, full multidisciplinary team appointment, together with sub-consultants Penoyre & Prasad architects, to help deliver its vision.

Mike Durtall

Mike Durtnall, BSc, MAPM, joined the health consulting team at Arup after spending nearly 10 years in senior posts at NHS Trusts in the UK. In addition to leading capital planning, development and property, he was Project Manager on a PFI development.

Mike is an experienced Senior Programme and Project Manager and has worked on a number of healthcare assignments both in the UK and overseas. He was Project Manager for Guy's Tower from feasibility stage through to planning



'No project of this nature could be attempted without the assistance and cooperation of the building users and the client's asset management and operations staff.'

The business case

The value drivers that incentivise organisations like the Trust to consider this type of project fall broadly into two categories, what we might call 'pushes' – those factors compelling the organisation to act because failure to do so would result in unacceptable levels of risk to their business – and 'pulls' – the opportunities that exist to improve performance.

In the case of Guy's Tower, the main push was the condition of the concrete facade and windows, but different approaches were adopted for the User and Communications tower facades. The User tower has a horizontal profile with balconies wrapped around all but the lowest levels faced with pre-cast concrete panels. These were in relatively good condition for their age, but had become badly stained through the deposit of carbon and other particles in water trickling down the external surfaces. The Communications tower is encased in an insitu concrete profiled cladding forming a dramatic vertical effect. However, the concrete here was suffering badly from spalling. The Trust had taken appropriate measures to manage this by undertaking regular, roped access inspections to check the spalls, break off loose material safely and seal. However, it was clear that this would only be a short-term solution and that something more radical was needed. The chemical changes in the concrete that cause spalling cannot be detected, so that it is

impossible to predict where they will occur next. The deterioration is progressive, however, and if left unaddressed the risks to safety and to operational and business continuity would have become unacceptable.

In addition the windows, although double-glazed units, were at the end of their working life, with the frames in particular being badly corroded. Even though the original thermal performance of the facade would have fallen short of today's standards, the condition of the windows and frames only served to exacerbate the poor energy efficiency of the building, particularly under winter heating loads.

On the pull side, in dealing with the deterioration of the concrete and failing windows, the Trust recognised that there was a big opportunity to reduce cold bridging in the User tower balconies and to make significant improvements in the performance of the facade.

Improving energy efficiency, reducing consumption and reducing carbon are on the agenda for all organisations and for the Trust in particular, which has a strong commitment to sustainability and was already seen as a leader in the field of carbon management in the NHS. The Trust therefore wanted to use the Guy's Tower project to make further advances in this area.

Although the Trust was committed to investing a significant sum of money in the project, this was conditional on achieving value for money. If sufficient paybacks on



This image shows the concrete balcony panels being cleaned. The impact this will have can be clearly seen.

energy and carbon could not be demonstrated in a business case, the Trust Board of Directors would not allow the project to continue. The Arup team were able to achieve this through a process of thermal modelling and analysis.

Energy consumption

The project was confined solely to the external facade and did not encompass the tower's building services and on this basis, the Arup building services team estimated that the project could only influence 18.5% of total energy consumption. 3D thermal models of the tower were built to assess the likely impact of the façade design options. Individual room models were also built for each facade to show the effects of the facade refurbishment from a cooling plant perspective. Two separate models were built, a base model to provide a common comparison point, and a refurbishment façade option, proposed by Penovre & Prasad, which would meet the latest thermal standards. The thermal analysis indicated that re-cladding the tower to provide this compliance would result in a 7.6% reduction in annual energy consumption, compared with current levels.

'Guy's Tower is a good example of what can be achieved with the refurbishment of an old building that would once have been considered beyond salvaging, or at the least not worthy of the investment..'



An exploded view of Guy's Tower showing the different sections of the buildings.

Carbon reduction

The environmental impacts of the facade refurbishment were assessed by Arup's facades and materials specialists based on a life cycle assessment (LCA) process to show positive impacts from day one and how these impacts would be reduced in the future. Impacts against six environmental categories were assessed for six facade types and then multiplied by the planned area of each type. A carbon 'payback' analysis was then undertaken, calculating the initial carbon 'spend' and the annual carbon savings, plotted on a graph. The results were compelling - over 18,000 tonnes of CO₂ would be avoided compared to a new build, over 8,000 tonnes saved over 30 years and a carbon payback point of around 12 years.

The challenges

There were a number of significant challenges for the Arup team to overcome. Although all of the inpatient beds had already been moved out, there was no space into which to decant occupiers and the building had to remain operational throughout design and construction. Managing disruption would therefore be a key priority.

There were also considerable logistical problems to be overcome. Over time since 1974, podium buildings and atria had been added and today the tower only touches the ground externally on the western face of the User Tower, so getting access to work on the facades required significant temporary works. Planning contractor's compounds would also be difficult in a congested, live hospital site.

Approach

Although the benefits had been established, a practical approach to design and delivery still needed to be developed. In the User tower in particular, the need to minimise disruption, avoid intrusion into clean environments such as the pharmacy manufacturing unit pointed



New façades for the Communications and User tower window bays.

in the direction of a flexible design solution being required. The design team also wanted to provide a solution that would allow further improvements to be made in the future, such as the introduction of natural ventilation through mixed mode cooling.

For the Communications tower, the only realistic solution was to repair the damaged concrete and seal the facade in a new skin that would prevent further deterioration and contain any subsequent loose material. A distinctive and bespoke profiled, anodized aluminium rain screen cladding design was selected. At the same time, Arup's access specialists designed a new monorail cleaning system to replace the inoperative existing one.

For the User tower, having first stabilised the concrete surface, a new thermal layer was designed by Penoyre and Prasad. This high performance layer will be placed in a line just in front of the existing columns to provide a new thermal line, up the building, to minimise thermal bridging.

Solar selective glass will be used to control the balance between solar gain in summertime (which adds to cooling loads) and natural light admittance, and will respond to the orientation of each facade.

This innovative solution was designed to



The environmental impact of the facade refurbishment was assessed, based on a life-cycle assessment process.



be fitted in front of the existing windows which allows them to be removed where possible, or left in place until a future

refurbishment, where removal is not practical. The successful development of the design resulted from a partnership approach between the Trust projects and estates teams, the Arup team, the building users and specialist supply chain members.

Successful delivery

No project of this nature could be attempted without the assistance and cooperation of the building users and the client's asset management and operations staff. The Arup team began an extensive process of stakeholder engagement at an early stage, keeping them informed on progress at regular intervals, and this paid dividends in the longer term. In order to plan the works at a floor and department level, questionnaires were designed to gather as much information on working arrangements, risks and hazards as possible.

The project is currently on site with the appointed contractor. Due to the fact that the building users will remain in occupation throughout, for delivery of the construction works the overriding principle was to work from the outside wherever possible. The User tower balconies facilitate this in part, but there remain parts of the facade that require working safely at considerable height and above glass atria. Access is also difficult, but with early design by Arup's construction planners and final design of the substantial temporary works by the contactor, a system of gantries, crash decks, roof-mounted hoists and wall climbers that will support delivery of the project has been developed.

Conclusion

Guy's Tower is a good example of what can be achieved with the refurbishment of an old building that would once have been considered beyond salvaging, or at the least not worthy of the investment. By taking a different approach, not only will the Trust have delivered an exemplar major refurbishment on an occupied building, it will also have continued its remarkable record in terms of reducing energy consumption and improving carbon performance.





Moorfields Eye Hospital, London, UK

Healthy, sustainable cities: a roadmap to panacea

Andrew Bradley offers a vision of some of the options that could be adopted on a city-wide basis if wellness was to be truly integrated into the fabric of our cities in the future to help reverse many of the current global healthcare challenges such as obesity and diabetes.

Globally, we are facing challenges on a scale not seen before. For example, the global population is expected to grow by 50% by 2050; we are experiencing a transition from rural to urban communities; we are depleting our natural resources; there is an increased demand for resources from developing nations; additional stresses are being placed on health services due to increasing chronic illnesses/lifestyle illnesses; there is additional economic stress due to our ageing societies and an increase in mental health issues across the age spectrum.

Our cities have developed and are continuing to develop in a reactionary manner to accommodate these challenges. The same can also be said for the way healthcare is developing. Healthcare provision has to react to the changing needs of the community it serves. For example, Australia, which is famed for the sporty outdoor lifestyle, now has the fastest obesity growth rate in the world, following fast on the heels of the United States in its obesity rates.

Australia is by no means alone with this

'The Organization for Economic Co-operative Development (OECD) countries currently spend a median of 9% of their Gross Domestic Product (GDP) on the provision of healthcare.'



Figure 1: Schematic showing the city of the future with an integrated wellness model adopted.

issue and most of the developed nations of the world are facing a similar obesity challenge. This indicator of modern lifestyle is changing the face of healthcare, resulting in rapid increases in chronic illnesses such as diabetes and cardiac problems.

There is a clear link between obesity and chronic illnesses. In addition there is a direct correlation with obesity, diet and exercise.

Unfortunately, the focus to date has been on treatment rather than prevention. At present, we are seeing unprecedented growth in healthcare spending in the developed nations. Most of this expenditure is dedicated

Andrew Bradley

Andrew Bradley is a Chartered Professional Engineer with nearly 20 years in the construction industry. Throughout his career, he has been responsible for the delivery a number of high profile projects, both within Australia and internationally.

Currently he leads Arup's Building Energy Services team in Queensland, which integrates all of the key engineers and specialists required to design, manage and optimise buildings which are both energy efficient and resilient.

In addition he also leads Arup's Buildings Healthcare team in Australasia and has experience of best practice in healthcare design to pharmaceuticals and maintaining or upgrading existing healthcare facilities.

The Organization for Economic Cooperative Development (OECD) countries currently spend a median of 9% of their Gross Domestic Product (GDP) on the provision of healthcare. While this is a huge sum of money for countries to continue to fund, we should consider this against the current spending of the USA which currently sits at 16% of GDP.

If we look at an example in real dollars, Australia spends \$103 bn (\$4,120 per person) annually on healthcare. The USA



spend of \$2,500 bn (\$7,140 per person). It is clear to see which direction spend is driven by Western societal consumption.

If the increase in ageing population is combined with the increase in GDP, it is estimated that Australia's spend on healthcare will exceed 20% of its GDP or \$500 bn by 2050.

This level of spending for treating illnesses is unsustainable and will impose a huge financial strain on the economy of a country. The potential scale of the problem is so large that it is necessary to think outside of the box if we are to find a solution. For example, what if 1% of that spend annually was pushed towards wellness rather than illness?

Healthier cities: by design

A group consisting of Australia's leading healthcare practitioners, providers and designers were gathered together within a design charrette to discuss what could be possible if 1% of the annual national healthcare spend was transferred to the provision of wellness rather than the treatment of illness. The focus was to develop a sustainable solution, working towards the year 2050.

The current estimated total spend on healthcare between now and 2050 is \$12.3 trillion. 1% of this would be \$123 bn. Any solutions proposed had to be flexible enough to cater for a range of scenarios from an existing city with historic hospital infrastructure to a new build acute hospital on a green-field site, to a remote town in far north Queensland where there is a high proportion of indigenous communities.

For each scenario, the group worked through what could be achieved, within the available 'budget' of 1% of annual health spend. Four key challenges were addressed:

- Culture
 Masterplannir
- Masterplanning
- Healthcare facility design
 Low carbon solutions
- Low carbon solutions

Cultural change

Lifestyle and cultural changes in Western society is adding to the problem. Again, we can turn to Australia as our indicator. Australians pride themselves on their sporting prowess. This is well deserved as they have consistently punched above their weight in most sports. Historically, the image of a typical Aussie is a healthy sun-kissed being. In fact, in 2007, Australia had the third highest life expectancy in the world. However, the average Australian is now overweight and it is estimated that 5% of the population will be diabetic by 2020.

New arrivals to Australian shores are often astonished by the high cost of fresh foods compared to other areas such as Europe and America. These high costs prohibit some lower income families from providing their children with a healthy balanced diet and this is an issue that needs to be addressed.

The average Australian child (between 2-16 years) eats a paltry 15% of their



Figure 2: We are experiencing a transition from rural to urban communities.

recommended daily fruit and vegetable intake. It is imperative that this is reversed and that children and young adults are educated in the benefits to their future health by eating fruit and vegetables. Recent research suggests that there can be up to 45% reduction in risk from some cancers due to eating a good daily quota of 'five-a-day'. Further research indicates that encouraging young children to get involved with growing their own vegetables can have a large influence on them actually eating them.

Developing a culture where each person has ownership of their wellness is also critical. People need to be informed on the implications of poor behaviour patterns. We need to move towards a future where people are aware of their wellness and illnesses and have easy access to the data for their own use and quick transfer to healthcare professionals. The technology is now available – all that's missing is the willpower!

Healthcare facilities are generally thought of as places you go to when you are ill, not places to help you stay healthy and this is a perception that needs to change. Hospital estates could be rebranded as 'Wellness Centers' which include public gyms, swimming pools, healthy food stores, community gardening schemes and wellbeing awareness centers. If these facilities are to be a success they also have to be freely available to all.

'It is envisaged that hospitals of the future will be co-located with universities and research institutes.' Investment in the provision of such facilities would pay dividends with the longterm health of the nation and as such will reduce the cost of healthcare overall.

How the community is engaged with the Wellness facility is a key issue. The public need to see the hospital as a good place to visit and spend time. This would mean a radical rethink in how these buildings are designed and what other facilities are included within them. There would have to be a dramatic improvement in the design of the buildings to make them more welcoming places to spend time. This may include bringing in retail and recreational outlets.

Faith, which is often overlooked in the healthcare industry, also has a role to play. Research carried out by Blue Zones (www.bluezones.com) suggests that faithbased communities tend to have a longer life expectancy.

This is thought to be due to having a sense of purpose and of belonging. Again, this would be another aspect which we could bring to our Wellness Centers. It sounds like a cliché, however the centers could be beneficial for the body as well as the soul.

Masterplanning

Historically, cities have evolved with healthcare facilities in and around the centre. In addition, the cities have evolved somewhat separately to suit the needs of business, largely ignoring the impact of the city's design on the wellbeing of its occupants.

In most cities, people movement occurs via car or public transport. The roads are generally so congested that people would not feel safe cycling. In addition, most places of work do not have end of trip cycling facilities. Surveys indicate that the vast majority of people would prefer to live and work in a city which has an exclusion zone for vehicles, only permiting people on foot or by bicycle. If we could get people to build in natural movement and exercise into their daily routine – such as cycling or walking the last 2 or 3 km to their offices – this would have a major impact on the wellness of the populous.

Major hospitals are typically located in the hearts of towns and cities. As healthcare practice changes and fewer beds are required within hospitals, there will be spare land capacity on each site. These existing healthcare facilities could become the heart of the new Wellness campuses. The hospital would, effectively, become a high-tech diagnostic, specialist treatment and research facility with a medi-hotel co-located on site.

This Wellness campus would contain endof-trip cycling facilities, free gymnasiums and swimming pools. There would be an exclusion zone around the central hub, which would typically be 5 km radius. At the 5 km boundary, there would be multistorey parking where people would commute partly to work by car and finish the rest of the journey by bicycle.

Figure1 demonstrates the model where at the heart of the community, there is a specialist acute/diagnostic/treatment/ research facility. This facility would have minimal patient beds as in-patient care would generally be provided in the distributed community facilities.

The red zone indicates the outer perimeter of the city where general commuter transport is permitted. At this outer zone there will be park & ride facilities where vehicles can be parked and exchanged for a bicycle or it is possible to walk into the centre of town. There would also be limited electric vehicular transport for people with disabilities.

Also, at this outer perimeter, there would be newly built sports centers incorporating a range of free facilities such as swimming pools, tennis courts and gymnasiums.

The green zone indicates the 'no car zone' in which there are only roads for emergency and service vehicles. These areas are generally clear and safe for commuters to enjoy their stroll and cycle to their offices.

This would mean that people would drive/commute to the outer perimeter each morning, park their cars in the 'park and ride', potentially take part in some form of sport or exercise and then complete their journey to work by bicycle or by foot. It is acknowledged that very few work places have end of trip facilities, therefore a number of shower pods would be strategically located around the city to provide adequate coverage for those



+ DISTRIBUTED COMMUNITY CARE

Hospital estates could be rebranded as 'Wellness Centres' and integrate with more community-based facilities and activities.

workers that would wish to take a shower after their short cycle/walk.

Healthcare facility design

As already discussed, there are major changes in the way we live our lives which will impact on the way that healthcare will need to be delivered. The increase in chronic, cardiac and mental health illnesses over the next 30-40 years will mean that a lot of the health facilities we currently have, or are building, will not be suitable.

As diagnostics, treatments and recovery rates improve there will be less requirement for in-patient accommodation. It is more likely that, where traditional inpatient accommodation is required, it will be provided in distributed health centers and community hospitals based out in the communities.

This then leads us to rethink the central hospital model. It is likely that the city centre hospital will retain A&E, diagnostics and specialist clinical services. In addition, there will be stronger links with universities and increased research.

Furthermore, with the semi-privatisation resulting from the move towards PPP delivery, there will be more collaboration with the private sector – particularly pharmaceutical companies.

It is envisaged that hospitals of the future will be co-located with universities and research institutes. Given that hospitals tend to have large parcels of city centre land, there is every likelihood that the Universities and private sector companies will relocate to what was originally the hospital estate. We estimate that the on-site inpatient accommodation will be less than 10% of what is normal today. However, there will be a much higher demand for hotel and short stay facilities for visiting families, research work and clinical staff. Co-sharing of hotel rooms with minor surgery recovery suites will become commonplace, ensuring capacity can fluctuate without impacting on the patient experience.

The key to all of this will be complete flexibility in what we are designing today for tomorrow.

Other key issues, such as single patient rooms will also be addressed. The huge benefits in terms of patient dignity, security and infection control outweigh the perceived social benefits of multi-bed bays, which are preferred by the minority. This is a debate we should put behind us, find the capital expenditure to resolve it and move on to the next challenge.

Recent studies carried out by Fiona Stanley Hospital (Perth, Australia) found that the extra capital expenditure required to provide an increase of 53% (23% to 80%) single beds was recouped in 3.6 years due to the other savings gained in the overall treatment process.

Further consideration has also been given to infection control and the impact that hospital design has on this. A recent study into a number of hospitals in Queensland, Australia, established that over 90% of hospital facilities are served via HVAC systems which recirculate large proportions of air within the building in an effort to save energy. Further analysis of one of these facilities discovered that the actual amount of fresh air being delivered was well below that which was required or that the system had been designed for.

In some cases, air was being recovered from areas that are considered 'dirty' and recirculated to areas that are required to be 'clinically clean'.

At present, typical healthcare design briefs do not specify targets for Indoor Environmental Quality (IEQ). This is something that needs to change. HVAC systems have the potential to greatly hinder or improve the cross infection rates within a hospital. It is essential that designers have the adequate experience and knowledge to provide solutions that ensure the continuous flow of fresh air from clean to dirty zones.

Energy consumption is often cited as the

'A hospital is one of the largest single energy consumers in a city. It has a unique load profile with high daytime demands for cooling and evening demands for hot water. When this is combined with the load profiles of offices, schools, restaurants, cinemas, etc, there are very real opportunities to provide district energy schemes where the base heating/hot water load can be generated as a by-product of the electricity generation.'

main reason for adopting recirculating HVAC systems, particularly in tropical and subtropical climates. However, new technologies, such as solar cooling and high efficiency heat recovery systems, negate this issue.

In a critical environment such as a hospital, patient and staff safety are of paramount importance. Therefore, we should be moving towards systems with 100% outdoor fresh air.

Low carbon solutions

Healthy communities are inter-linked with low carbon communities. The proposed masterplan would remove a significant amount of air pollution from the city thus improving the air quality and reducing the carbon footprint at the same time.

However, there are additional benefits to be gained if we could combine the energy

load profiles of a hospital with those of other city centre buildings.

A hospital is one of the largest single energy consumers in a city. It has a unique load profile with high daytime demands for cooling and evening demands for hot water. When this is combined with the load profiles of offices, schools, restaurants, cinemas, etc, there are very real opportunities to provide district energy schemes where the base heating/hot water load can be generated as a by-product of the electricity generation (Co-Gen). There are also opportunities to utilise district wide cooling schemes with chilled water storage.

If we go back to our proposed masterplan, the distributed Wellness Centers on the boundary of the 'no car' zone could be nodes on a district wide energy solution. Depending on the unique location of each Wellness Center, there would be varying opportunities for renewable technologies to be applicable – for example wind power, solar cooling, large solar arrays and heat pump technologies. If we had distributed generation then we would also achieve distributed resilience, which is essential for healthcare and modern cities.

Consideration could be given to peak load management with the incorporation of electric vehicles, plugging into the solar powered car park during the day when the owners are at work. The vehicles would collectively act as a large capacitor to take up some of the over production and over demand periods.

In conclusion, all of the above is technically possible today. All we need is some out of the box thinking in terms of funding streams, a lot of vision and some willpower.

We shape a better world

ARUP

The co-existence of clinical activities and construction

According to Australian Health Facility guidelines "Building, renovation and maintenance activities within a healthcare facility imposes risks upon the incumbent population unlike any other building site."¹ Increasing health service needs continue to place pressure on existing healthcare facilities. This is often exacerbated by constrained city centre locations and an ageing infrastructure. As a result, a high proportion of healthcare capital works projects are refurbishments and/or expansions.

In such projects, the traditional construction industry expectation of a project being mainly to design, build and hand over to a customer/user can be challenged at many levels.

The Cairns Base Emergency Department redevelopment project demonstrates best practice in both user engagement and clinical services integration throughout all phases of the project lifecycle. It demonstrates how positive clinical staff involvement during planning, design, procurement and construction phases can result in decreased stress and increased safety for patients and staff as well as improved efficiency in clinical service delivery.

The initiatives undertaken by the project team helped overcome the challenges inherent in this type of complex work and demonstrate how the implementation of a new model of care can be translated into a functional facility design.

The redevelopment project was initiated in February 2008 with construction commencing on site early in 2009 and finishing early in 2011. It involved a refurbishment of the existing Emergency Department (ED) with an expansion of the original facility from 30 treatment spaces to 52 spaces, including an integrated three space mental health 'pod' area. The client requested that the ED be increased in bed capacity to 36 beds by February 2009 and that these 36 beds were to be maintained as a minimum baseline operational



Cairns Base Hospital, Emergency Department.

requirement throughout the construction phase. The following performance objectives were set by the client:

- Increase capacity of the ED and design the new floor layout to meet the Clinical Services Plan which identified a need to meet increased demand, particularly with outpatient discharge stream (category 4 and 5 presentations) and emergency mental health care services.
- Implement improved model of care by bringing forward increased clinical decision making to the triage desk and introducing a discharge and admissions dual-stream triage system. The successful implementation of this new model was to be enabled and supported through the effective design of the floor plan to allow

Alex Ramos MEng CEng MICE MAIPM

Alex Ramos is a Senior Project Manager based in Cairns, Queensland. He joined Arup in 2001 and has worked on the design and construction phases of a wide variety of projects in Spain, Belgium and Australia.



Mark Aitken BEngTech CPPM

Mark Aitken is a Senior Project Manager based in Brisbane, Queensland. He joined Arup in 2006 and commenced work on the Cairns Base Hospital Emergency Department before relocating to Brisbane in 2010. His work has included delivery of remote indigenous health clinics and health facilities throughout Queensland over the past five years.

during delivery'.3



efficient operation of the two clinical

Control and minimise disruption by

staging the works. The project team was

tasked with extending and refurbishing

24-hour operations with zero reduction in

treatment space numbers. The Cairns Base

opportunity to decant the ED to another

area of the campus or to utilise temporary

works. The target for the project team was

patients with all efforts directed towards

the existing ED while maintaining full

Hospital site constraints negated any

off-site facilities during construction

zero impact on health service care to

achieving 'no harm to staff or patients

streams, but also to allow adaptable and

flexible use of the facility in the long term.



These plans provide an overview of the four main stages of work: blue indicates temporary accommodation; red indicates construction areas; and, yellow indicates clinical flows.

Stage 4 H Hall





Integrated project team

The project team recognised the need for clinical staff involvement in deciding how the project was to be built, to minimise the impact on clinical services during construction. To achieve this, an integrated project team was developed with shared objectives and a common goal.

Conventional delivery of capital works projects involves a design team developing the facility design with some level of consultation with user groups comprising the operational clinical staff. This can create a level of tension between the two teams as the design is progressed with each team having competing and differing priorities. Arup's Cairns ED project management team recognised that the two groups should be integrated into a high performing project team. The vehicle to achieve this was the requirement for the works to be staged with no impact on healthcare service delivery. In order to galvanise this shared goal in the team, a series of staging workshops were undertaken to increase involvement of both the clinical user groups and the design team in designing the construction staging.

Designing the staging

During the design, staging sequences were developed to meet the project objectives. Each stage was tested against the minimum treatment space compliance, clinical workflows, operational requirements and logistics, in addition to contractor access for labour, material delivery, and construction workflows and activities.

The vehicle for this was a series of specific staging workshops. These were held separately, and in addition to the traditional design team and user group coordination meetings. The primary aim of these workshops was the shared objective of designing the staging to allow full operation of clinical services. The benefits of this approach included:

- The design team gained an understanding of the clinical needs of the user groups and were able to adapt the design to accommodate the staging plans.
- The clinical user group also gained an understanding of the complexities of the design and construction activities and

'The project liaison officer fills a knowledge management role that is critical to the success of any health project. They are a repository of invaluable unstated information.' constraints which helped their acceptance of construction impacts during later stages of delivery.

These workshops developed a shared understanding of the project and developed a high-performing integrated project team, with a positive team culture. This allowed the team to work collaboratively and openly during the difficult stages of construction as well as providing a robust staging plan to the contractor for delivery.

Specific provisions made in the design to enable the implementation of the staged construction process were:

- A temporary demountable was added to the scope during construction to provide a buffer of additional treatment spaces, thereby enabling the requirement of 36 treatment spaces to be met.
- An additional pneumatic tube station was introduced to limit long walking distances during the staging works which additionally provided future flexibility.
- Several treatment spaces were internally clad with panels and converted into provisional consumables stores.
- Additional joinery and essential power were provided to non-acute areas for use during construction as temporary resuscitation bays.

The integrated project team looked at the opportunity of implementing the new dualstream model of care during the construction works to facilitate uptake of change by staff. This needed to be balanced against the risk of increased waiting times leading to a compromise of patient care and adverse community perceptions.

To alleviate this risk, the implementation of the dual-stream model was brought forward to the commencement of the works in February 2009. This was done by fitting out a store room with three fast-track beds and a procedure room, staffed by a small team consisting of one registrar, two registered nurses and a nurse practitioner to make the new fast-track team operational on a small scale. The outcome was positive.

In 2007, the Cairns Base Hospital Emergency Department was one of the worst performing departments in Queensland with regards to patient waiting times.³ With commencement of construction, it would have been expected that the waiting times for category 4 and 5 patients would escalate. However, with the early introduction of the dual-stream fast-track team, reductions in patient wait times were evidenced when compared to 2007-2008 patient wait time figures.

Procurement and risk

The procurement model for works deserves special mention. In many complex projects, the client and project team will seek to pass risk to the contractor through either a design and construct, or a managing contractor type contract model. While this strategy reduces 'At completion of the ED works there were zero incidents involving construction work impacting on patients or health staff, and at no time was there a reduction of bed capacity or essential services.'



Cairns Base Hospital.

delays and complexity for the project team in the early design phases, it does not mitigate the need for staging of the works to be addressed later. In doing this, there is a risk that construction needs of the contractor drive the staging process rather than the clinical operating needs of the ED. In terms of clinical safety, the service provider will always retain ultimate risk and responsibility; therefore, it was recognised that in order to retain control over this process, the procurement would be a fully documented traditional lump-sum model, supported with robust staging plans embedded in the contract documentation.

Project liaison officer – the unsung hero

The project liaison officer fills a knowledge management role that is critical to the success of any health project. They are a repository of invaluable unstated information which is pivotal to the successful management of stakeholder risk and project scope creep. The project liaison officer is also the gatekeeper of daily clinical risk, having final say and responsibility to approve or reject all 'permit to work' requests issued by the contractor.

Change management

Change management during the design was implemented through progressive sign-off of documentation at specified milestones, where scope and cost were locked in at increasing levels of detail. Within these stages, design took place as a normal iterative process.

During the construction phase, changes to the project scope can come from sources such as latent site conditions, constructability issues and errors in documentation. To distinguish the sources and provide necessary controls for each variation, during the construction phase variations were classified in two types:

Type 1 variations: These were necessary to deliver the original scope of works as required by the client. These types of changes did not generally require client approval and were issued by the principal consultant for the purposes of statutory compliance. The project manager was informed of the variation and of the drawdown in contingency funds.

Type 2 variations: These were a change to the original scope of works required by the client. As such they were generally instigated by the client, the user group stakeholders or as a request by the contractor for an alternative material, finish, or product. All Type 2 variations required project manager and client approval prior to proceeding.

Decanting

This is usually a time of discovery and stress for the user of any new health facility. Clinical staff members have their normal jobs to do but have an added expectation of improved performance as a result of the new facilities, all the while adjusting to a new environment and workflow.

There is a consequent risk of disconnect

between construction and user group teams immediately after occupancy, as one group will be focussing on the construction of the next stage and the other on working effectively in the new space. If not managed properly, this can lead to high levels of staff stress and low morale in both teams.

One of the measures introduced in the Cairns Base Hospital ED after each phase of decanting was a walkthrough by key staff members directly after practical completion of the stage was reached, but before the start of clinical operations. This served to familiarised staff with the new area ahead of the pressures of operating clinically within the new space. It helped clinical staff to locate storage areas, nurse call communicators, lighting controls and duress alarms.

During the decanting period, a suggestion book was also introduced to the staff canteen to enable staff to translate stress into constructive feedback. Importantly, the logs in the suggestion book were periodically reviewed and some converted into defect notifications or variations to the contractor, thereby closing the feedback loop into something practical and effective.

Clinical safety

Although a physical barrier by way of hoarding was in place, other aspects of construction were impossible to physically demarcate from clinical services. For example:

- Requirement to isolate electrically different areas, including shutdowns to distribution boards and switches between essential and non-essential power.
- Requirements to tie into existing medical gas networks, involving partial or total shutdowns.
- Access requirements in shared entrances and exits.
- Isolation and de-isolation of fire detection and alarm systems.
- Logistics of construction deliveries conflicting with ambulance access.

These issues were managed through the use of a disruptive works notice system. The contractor would raise a disruptive works notice justifying the need to undertake disruptive works and describing their nature, duration and proposed timing. It would also state if there was a requirement for hospital fire and security staff to be on standby. Following receipt of the notice, the project liaison officer would contact the relevant internal hospital stakeholders and discuss the implications before approving the works.

Defects

The constant rotation of construction areas in the project with individual practical completion of each stage called for a methodical approach to the proactive management of defects to prevent the clinical-construction relationship from deteriorating.

To most clinical professionals, the implied term 'defect' is different from its contractual



Cairns Base Hospital.

meaning. The tendency by end-users is to apply it to anything they do not like, whether it be a genuine builder's defect, an omission in the original design or a difference of user expectation as to what the scope constituted.

In a staged approach to construction, once a typical stage is handed over, it is reasonable to expect that the majority of defects identified by the users in the first few weeks will be builder's defects. However, an emergency department, by its very nature, suffers a significant amount of heavy use, and wear and tear, so damage to the facilities is not uncommon.

In order to manage this effectively, in the stage immediately preceding that under construction at the time, defects identified by the users were processed by the project team, whatever their implied source. The project liaison officer and the project manager would bring the defect to the superintendant's attention who would then



advise the contractor and request action.

For the stages completed prior to that, however, the defects were issued directly to the client's Buildings Engineering and Maintenance (BEMS) under the assumption that by then, the most likely cause of the 'defect' was wear and tear and not workmanship. If, however, the BEMS team believed the defect did result from quality of workmanship or material then the issue was passed on to the project manager and processed normally.

This process allowed the contractor to focus on the construction of the current stage instead of investigating defects in the prior stages, which could have been completed up to a year previously.

Conclusions

At completion of the ED works there were zero incidents involving construction work impacting on patients or health staff, and at no time was there a reduction of bed capacity or essential services.

The process of refurbishing existing healthcare facilities is challenging but need not be a stressful endeavour. Some lateral thinking can often unlock opportunities at the planning phase which pay dividends for the project later on. Staging exercises before and during the design phase should, ideally, be led by a competent project manager. However, to do this effectively and get the most out of the combined knowledge of the project team, high-quality user engagement is important and having a project liaison officer with the right attitude and time to devote to the project can help to achieve this.

References

- 1 Part D Infection Prevention and Control. Australasian Health Facility Guidelines V4; 2010
- Fawcett W. and Palmer J. Good Practice Guide to Refurbishing Occupied Buildings; CIRIA, South Wales; 2004
- 3 Queensland Health, Queensland Government. Quarterly Public Hospitals Performance Report; September 2007.

Ysbyty Aneurin Bevan, South Wales, is the first NHS general hospital built in the UK incorporating 100% single bed-room accommodation. Improving the privacy and dignity of patients and reducing the risk of spreading infection.



Charlotte Wood Photography



Designing a dementia sensitive environment

We are all affected by our surroundings. The quality of the environment is a fundamental factor in determining the wellbeing and health outcomes of older people and can be adapted to reduce the day-to-day difficulties faced by older individuals, such as sensory and cognitive impairments and increasing frailty.

Dementia has been recognised as a key health and social care priority in the UK where currently 750,000 people are living with the condition. This number is predicted to double in the next 30 years.

Although dementia can affect younger people, it is primarily a condition of older age, when the symptoms can interact with other chronic conditions such as heart disease, arthritis, hearing and sight loss.

As the condition deteriorates, a person with dementia can find their environment confusing and difficult to comprehend, leading to feelings of inadequacy and high levels of stress. It is, therefore, important to consider what environmental features and assistive technologies (AT) could be introduced that would help ameliorate such difficulties and improve quality of life.

Wherever people with dementia reside, it is important that they can have a good quality of life, are treated with dignity and respect, encouraged to be as independent as possible and live within a safe environment.

Florence Nightingale championed the importance of the environment in improving wellbeing as long ago as 1860. During the 1970s and 80s, conceptual frameworks centred on understanding the role of the environment on the course and outcome of the aging process. 'Environmental press',

double in the next 30 years.'

'Dementia has been recognised as a key health and social

are living with the condition. This number is predicted to

care priority in the UK where currently 750,000 people



espoused by Lawton,1 focused on the interaction between a person's ability to undertake activities and the demands of their environment. Such considerations are particularly pertinent to those with dementia, whose ability to undertake daily living tasks diminishes with the progression of the disease.

Approaches to dementia care

Until the 1970s, the needs of older people, particularly those with mental health conditions, were generally disregarded. Care was

underpinned by the 'medical model' of the condition, which focused on the steady decline of a person's mental and physical capacities and subjective experiences of dementia were disregarded. Often care practices were abusive with a lack of dignity and respect for individuals.

A paradigm shift in the delivery of care for people with dementia came with

Pam Turpin

Pam Turpin has an MA in Gerontology looking at improving the quality of life of people with dementia and sight loss. Before moving to consultancy work, Pam worked for seven years with the RNIB where she led a number of multi-agency projects. As a health care consultant with Arup, Pam now leads on older people service development; particularly dementia, dementia design and end of life care.



FACILITY DESIGN



the development of person centred approaches that conferred equal importance to biological, psychological and sociological experiences of dementia.

This approach has been criticised for overlooking the impact of the physical environment, particularly on people with dementia and additional sensory impairments.2 Research has shown that staff in dementia services can lack the time and expertise to respond adequately to sensory problems.3 The importance of early interventions to adapt surroundings to support people with hearing and vision loss has been stressed because of the increased risk of a person developing challenging behaviours due to diminished interpretation of their physical environment.4.5 Many design professionals are not familiar with the special needs of people with dementia and additional sensory impairments; resulting in little real understanding of the impact such challenges have on quality of life.

To assist with improving awareness, incorporating medical, disability and citizenship models of dementia when considering design issues could be helpful (see Table 1). This combined approach would enable the consideration of holistic environmental support needs and empower the active participation of people with dementia rather than allowing them only to be passive care recipients.



Building a therapeutic care environment

People with dementia live in different care settings, the majority living in their own homes. A third reside in care homes, mostly in facilities without specialist provision for people with dementia.⁶ It has been argued that the expected increase in the incidence of dementia will result in increased need for specialised units.

A number of reviews of dementia design have been undertaken. The majority focused on specialist facilities rather than individual home environments,⁷⁻⁹ although domestic care settings have recently been considered. Whatever the setting, therapeutic design principles can enhance a person's quality of life. Such principles can:

- Compensate for disability.
- Maximise independence.
- Enhance self-esteem and confidence.
- Demonstrate care for staff and visitors.
- Aid orientation and understanding.
- Maintain and sustain personal identity.
- Provide links with the local community.

Sensory impairments

When considering the design of physical environments, it is important to note that people with dementia may have decreased functionality due to sensory impairments. For example, as people get older they experience age-related differences in a

	Table 1: Dementia models.
Model	Design and technology considerations
Medical	Focuses on keeping people safe and comfortable
Disability	Focuses on accessibility for maximising functioning.
Citizenship	Focuses on the views of people with dementia, regarding environmental design, being taken into account.

number of visual functions. Eye conditions include untreated refractive errors, cataracts, glaucoma, macular degeneration, diabetic retinopathy and stroke. These result in changes in vision ranging from gradual blurring, partial loss of visual field, visual hallucinations through to total blindness.

Older people with dementia are doubly disadvantaged because they often experience additional changes in visual abilities due to neurological damage. Research has shown that up to 60% of people with Alzheimer's disease have difficulties with contrast sensitivity, visual attention, object and facial recognition, colour and depth perception, glare, motion perception and visual misinterpretation.¹⁰ Vision difficulties could result in a variety of 'visual mistakes' including misperceptions, misidentifications, illusions and hallucinations.

Because people with dementia may not be able to make sense of what they see, or be able to explain what they have seen, this could impact on personal behaviours.

Light and lighting

An important feature of the visual environment in supporting people with dementia is the source and quality of light, which should be twice normal levels. Domestic housing often has lighting levels that are too low for older people but by increasing the number and wattage of lights and ensuring even illumination levels, a clearer view of the environment will be achieved.

Older people find it difficult to adapt to changes in light levels. It is important to ensure that hallways, stairs and entrance foyers have balanced lighting to enable a person's eyes to adapt more easily as they move from one area to another.

In care homes, lighting can be used to reinforce a sense of home, by using domestic style fittings that reduce institutional atmospheres. Glare can also be problematic, so the use of clear glass light fittings should be avoided. While overhead lighting and flickering from fluorescent lamps are also important considerations.

The best way to assess the lighting in a particular setting is to lie or sit in the same position as the residents to get an idea of their day-to-day experiences.

Colour, contrast and visual perception

There has been debate about how colour is affected by dementia. While some research indicates that colour discrimination abilities remain well preserved,¹¹ other studies have reported a deficit in the blue-green range.¹² Designing a colour scheme that minimises the use of these shades has been recommended.¹⁵ Using particular colours for specific rooms or fittings may help with recognition. For example, toilet doors having the same strong distinctive colour, which contrasts with the surrounding wall, with the addition of clear signage using words and pictures, may aid recognition and reduce



incontinence. While signs should be placed at average height, or just below, so residents are attracted to them. Conversely, painting a door leading to a hazardous area the same colour as the wall can deter access.

It has been suggested that the use of contrast would be more beneficial to people with dementia and visual impairment than colour. The importance of contrast has been emphasised in a number of design publications.¹⁴⁻¹⁶ For instance contrasting coloured flooring could help distinguish the furniture from the floor. It is possible to purchase tools that scientifically identify contrast levels. However, a simpler and cheaper option would be to take a black and white photograph of a room and see how easily the furniture stands out against its surroundings.

A person with dementia can interpret a highly polished floor as water. Such areas are often seen in hospitals and can prove hazardous to individuals who are already disoriented by being in unfamiliar surroundings. They may refuse to walk across the area and become agitated or distressed.

Patterned wallpaper and carpets can also

be problematic. A person with dementia may perceive patterns such as leaves or food as real and patterns in carpeting as being at different heights. Using consistent plain coloured matte surfaces will help individuals to move around more safely.

Auditory challenges

In addition to visual challenges, many older people experience hearing difficulties. Seventy one per cent of people over the age of 70 years are deaf or have significant hearing loss.

Untreated age related hearing loss, or presbycusis, is caused by loss of hair cells in the inner ear. It is also associated with degeneration of the central auditory pathways and auditory cortex. A link between Alzheimer's disease and central auditory processing (CAP) has been demonstrated. This is a general term applied to people whose hearing in quiet settings is normal, but have substantial hearing difficulty in the presence of auditory stressors such as competing noise.

Acerbating the situation is the fact that people with dementia may lack the ability to

'When considering the design of physical environments, it is important to note that people with dementia may have decreased functionality due to sensory impairments.' interpret what they hear accurately, predisposing them to have auditory hallucinations.

Often people in residential settings, particularly if they have increasing frailty and immobility, are constantly bombarded with loud sounds throughout their day. Examples include alarms, electric hoists, sounds produced by pressure relieving mattresses and televisions blaring. In addition, hard surfaces can be particularly noisy as they do not absorb sound but rather bounce it back into the room.

Noise is a known stressor and excess noise can result in individuals becoming more confused, exhibiting agitated behaviour and having reduced ability to communicate. It is essential that the reduction of noise in dementia design is a vital consideration.

Other considerations

The use of pleasant aromas has been found in studies to reduce agitation and promote sleep.^{17, 18} It can also aid orientation in a person with visual difficulties. For example, a gentleman who had sight loss and dementia used the smell of beeswax polish to help locate his living room.

Family and professional carers need to be aware of the effects the indoor climate may have on people with dementia.¹⁹ In general, older people prefer warmer atmospheres and are more sensitive to drafts.

A person with dementia may perceive the thermal environment differently due to ageing and atrophy of parts of the brain involving sensory perceptions. For instance, individuals may wander outside in the winter wearing light clothing and be unaware they are becoming dangerously cold or people with severe dementia who are unable to independently put on or take off clothing, or communicate if they are feeling uncomfortable, may show signs of agitation and distress.

Garden and outdoor areas

Therapeutic use of outdoor spaces can encourage positive behaviours and care facilities should be designed to enable easy access to outside areas, allowing residents opportunities for fresh air, sunlight, exercise and social activities. While gardens can provide respite for visiting families or staff in need of an emotional break from caring, unfortunately, in many care homes, allowing residents to go outside can prove extremely challenging due to poor security, dementia units not being located on ground floor level and lack of staff to accompany residents.

For individuals living at home, wandering can be viewed as dangerous if they are prone to getting lost. One solution is to put the person's name and address in pockets to enable them to be returned home if such a situation arises. However, this could lead to dangerous situations by alerting inappropriate strangers to the location of a vulnerable person's home. 'Therapeutic use of outdoor spaces can encourage positive behaviours and care facilities should be designed to enable easy access to outside areas.'

Assistive technologies

Such a dilemma leads discussion onto the use of AT and its benefits and challenges. Electronic tracking devices are available and can increase a person's safety and independence. Adapted bracelets, brooches and watches can be used, having the benefit of being removable allowing for personal autonomy. Implanting sensors into individuals has been also suggested. However, my personal view of such permanently intrusive devices, where the recipient has no control over its use, is that it has serious ethical implications and is counter to ethical principles used by health and social care providers.

AT can help people remember to do tasks such as taking medication; provide a safer environment by automatically switching off a cooker; monitor the movements of a person within their home or help with modifications such as turning on lights if a person gets up in the night. Such devices can reduce the risk of accidents and/or ensure a prompt response by emergency services if an accident does occur.

Active participation of people with dementia is in keeping with current UK Government policy. The National Dementia Strategy²⁰ advocates that people with dementia and their carers should be included in the development of AT and telecare; while the Dementia Declaration for England supports people with dementia to continue living in their own homes.

Early diagnosis of dementia can allow for advanced care planning regarding a person's future support needs to take place. Such conversations should include the possible future use of AT, enabling the views of the individual with dementia regarding such technology to be understood and taken into account when personalising their future care plan.

People with late stage dementia

It has been argued that people in the final stages of dementia are not aware of their environment; do not respond to visual or acoustic stimuli and require only basic physical care rather than social or environmental support. However, this



hypothesis has not been tested and unlike research into the needs of people with dementia in the early or moderate stages of the disease, there is little corresponding literature regarding what constitutes an appropriate social and physical environment for people in the later stages of dementia, which is characterised by immobility and end of life issues.

If such individuals have only a limited awareness of their surroundings, a first step in developing environmental design ideas must be to consider how they perceive their surroundings and to explore particular influences that could negatively or positively affect their wellbeing.

With the anticipated rise in the number of people with dementia, designs that consider the environmental needs of people with dementia at end of life would seem timely.

References

- 1 Lawton MP (1982). Competence, environmental press and the adaptation of older people. In M P Lawton, P G Windley, and T O Byerts (Eds), Aging and the environment. Theoretical approaches. New York: Springer.
- 2 Bartlett R and McKeefry D (2009). *People with dementia and sight loss: a scoping study of models of care.* London: Thomas Pocklington Trust.
- 3 Lawrence V, Murray J, FFytches D, and Benerjee S (2008). The experiences and needs of people with dementia and serious visual impairment: a qualitative study. Thomas Pocklington Trust Research Findings No 19. London: Thomas Pocklington.
- 4 Stokes B (2000), Challenging behaviour in Dementia: A Person-centred Approach. Chichester: John Wiley and Sons.
- 5 Brawley EC (2001). Environmental design for Alzheimer's disease: a quality of life issue. Aging and Mental Health, 5 (Supplement 1), S79-S83.
- 6 National Audit Office (2010). Improving Dementia Services in England – an Interim Report. London: The Stationery Office.
- 7 Marshall M (1998). Therapeutic buildings for people with dementia. In S Judd, M Marshall, and P Phippen (Eds), *Design for Dementia*. London: Journal of Dementia Care.
- 8 Day K, Darreon D and Stump C. The therapeutic design of environments for people with dementia: A review of the empirical research. *The Gerontologist* 2000; 40 (4): 397-416.

- 9 Fleming R, Crookes P, and Sum S (2007). A review of the empirical literature on the design of physical environments for people with dementia: Translating dementia research into practice. Stirling: The Dementia Services Development Centre.
- 10 Jones G, van der Eerden-Rebel W and Harding J. Visuoperceptual-cognitive deficits in alzheimer's disease: adapting a dementia unit. In B M Miesen & G M Jones (Eds), *Care Giving in dementia: research and applications* 2006; (4): 2-57. London: Routledge.
- 11 Wijk H, Berg S, Bergman B, Hanson AB, Sivik L and Steen B. Colour perception among the very elderly related to visual and cognitive function. *Scandinavian Journal of Caring Sciences* 2002; (16): 91-102.
- Calkin M. How colour throws light on design in dementia care. *Journal of Dementia Care* 2002; 10 (4): 20-23.
- 13 Dunne T (2004). Improving performance on activities of daily living in Alzheimer's Disease: Practical applications of Vision Research. In Vision in Alzheimer Disease (Vol. 34, pp 305-324). Basel: Karger.
- 14 Habinteg (for Thomas Pocklington Trust (2010)). A comparative review of design guidance for people with dementia and design guidance for people with sight loss. London: Thomas Pocklington Trust.
- 15 Utton D (2007). Designing Homes for People with Dementia. London: The Journal of Dementia Care.
- 16 McNair D, Cunningham C, Pollock R and McGuire B (2010). *Light and lighting design for people with dementia*. Stirling: The Dementia Services Development Centre.
- Nguyen Q and Paton C. The use of aromatherapy to treat behavioural problems. *International Journal of Geriatric Psychiatry* 2008; 23: 337-346.
- 18 Van der Ploeg ES, Eppinstall B and O'Connor DW. The study protocol of a blinded randomised-controlled cross-over trail of lavender oil as a treatment of behavioural symptoms in dementia. *BMC Geriatrics* 2010; (10): 49.
- 19 Van Hoff J, Kort HS, Henson JL, Duijnstee MS and Rutton PG. Thermal comfort and the integrated design of homes for older people with dementia. *Building and Environment* 2010; (45): 358-370.
- 20 Department of Health (2009). Living with Dementia: A National Dementia Strategy. London: Crown Copyright.

Maintaining operational continuity during change

As is the case with many private finance initiative (PFI) developments, the new building at King's Mill Hospital, part of the Sherwood Forest Hospitals NHS Foundation Trust, in the UK, was not an entirely standalone structure and, as such, had significant links to the existing estate, presenting the challenge of maintaining operations during a major construction project.

Being able to ensure the hospital could continue to deliver patient services during the construction programme was a major challenge for the PFI delivery team led by Skanska Innesfree.

The Mansfield Hospitals development covers three hospitals in Mansfield, UK, including the new 840-bed King's Mill Acute Hospital. The redevelopment of existing facilities at King's Mill created a single unified hospital, made up of 28 new wards, new diagnostic and treatment and women & children's centres, a new emergency care and assessment centre with an out of hours GP service, plus an extensive education and training centre. The project also included Mansfield Community Hospital, which was designed to be a landmark for the community it serves with greatly improved access for patients and visitors, and Newark General Hospital, for which maintenance and facilities management is being provided.

The delivery team needed to focus not just on the operational efficiency of the hospital.

'Being able to ensure the hospital could continue to deliver patient services during the construction programme was a major challenge for the PFI delivery team.'



Vertical and horizontal routes at Kings Mill.

It also needed to ensure that no compromises were made to infection control protocol and hence patient safety. Arup was appointed to undertake the operational review of the existing facilities and coordinate the operational requirements with the construction programme to minimise disruption to operational running of the hospital and, ultimately, the patient experience. The new building ties into retained facilities and therefore links into existing corridors and buildings, which were mostly kept operational during the construction programme.

These developments introduce considerable change in the way the hospital will function and how staff undertake their day to day activities. Such change can have a considerable impact on how a hospital delivers its services, on staff morale and ultimately how comfortable a patient feels in the hospital environment and therefore how they may respond to treatment.

Although Arup's appointment focused on the operational components of the Trust's activities, we also recognised and emphasised the role that the Trust would have to play in preparing its staff for the change that was about to take place and this paper sets out some of the methods used.

Business as usual

The first activity undertaken by Arup was to assess and map how the current hospital operated, with specific regard to key flows within and around the King's Mill Hospital site. Flows were divided into categories consisting of outpatients, visitors, inpatients,

Darren Briggs

Darren Briggs has worked for Arup for 10 years and is currently an Associate Director in the Arup Operations team specialising in advising organisations on operational improvements, usually associated with the development of a new building and therefore advising clients from the feasibility study, through the design process, construction, operational readiness and occupation. His work has covered international projects across a range of sectors, including healthcare, retail, hotels and construction.



staff, FM supplies, waste and catering. These were mapped from the access point onto the site, to the parking location, entry into the building and internal distribution routes, including the vertical distribution routes used. This consisted of a number of physical surveys of the hospital and interviews with the operational and facilities management teams. Other items recorded included:

- Access times.
- Interdependencies between operations.
- Critical adjacencies.
- Unit of transport.
- Equipment used.

Using this data, Arup prepared a number of operational maps for each type of flow that reflected the day to day movements on site.

This was then reviewed with the Trust and Skanska to ensure there was agreement on the business as usual site operational requirements.

Construction phasing

Skanska and Arup developed the construction phasing drawings based on site restrictions, construction programme and possible phasing. These were then superimposed on the business as usual flow drawings and all the routes that were going to be blocked were highlighted. This information also highlighted the facilities that needed to be replaced to ensure the Trust could continue to provide all services. Following this, remedial actions and proposed alternative access routes were

included on the drawings along with replacement facilities, some of which had to be moved a number of times. This information was then presented to, and discussed with, the Trust for approval. The process of mapping and identifying the core flows within the hospital, which were required to enable 'business as usual' operations, meant that Skanska and Arup were able to develop a construction phasing programme that minimised the impact of the estates work on the operation of the hospital. Due to the size and scale of the development it was not possible to avoid the construction works having an impact on certain flows but in instances where flows were affected proposed alternative routes and construction mitigation plans were developed and staff





Bandwidth diagram for FM deliveries showing access routes.

made fully aware of the changes prior to the commencement of works.

This was an iterative process and involved several reviews of the construction phasing proposals and meetings with the Trust to discuss the extent of the operational changes that could take place. Some of the changes required different vehicles to be used, different equipment, the scheduling of deliveries and changes to staff requirements. The key strength of this approach was ensuring that the key operating processes, including various flows and infection control elements within the hospital were not negatively impacted by the construction works. The construction phasing was finally signed off by the Trust in the knowledge that the operational activities of the hospital had been considered and integrated in the proposed solution.

A new hospital

The development of a new hospital at King's Mill provided an opportunity for Skanska and the Trust to review how various flows interacted and needed to be considered within the new and remaining estate. This resulted in a segregation strategy which indicated the flows that needed to be kept separate, covering the following areas:

- Inpatient movements between wards and theatres.
- The management of clean and dirty movements.
- The creation of 'front of house' and 'back of house' circulation areas.

Additionally, the masterplan created a very visible front address for the public, with easy access from the bus stop and public car park. Multiple back access routes were provided for staff with access from more fragmented car parks, ensuring parking local to the place of work. This ensured easy way finding for the people who needed it most.

Segregation within the hospital was then considered using horizontal and vertical distribution routes (corridors and lifts). As can be seen on the diagram below, visitors are split for each major department at ground level and use a central bank of lifts to access corridors at each ward level. Staff and FM, on the other hand, have corridors at ground level, which link into dedicated lifts that access each ward and department directly.

The corridors used at ground level and above by visitors and patients are all part of the new estate, whereas the corridors for staff and FM at ground level are within the existing estate and link into new corridors providing access to the new 'back of house' lifts. This mixture of horizontal and vertical segregation, and the use of existing and new building access routes and vertical transportation ensured corridors and lifts were kept to a minimum while delivering the segregation required by the Trust.

The distribution strategy also considered the use of automated guided vehicles (AGVs) to undertake the movement of linen, waste, catering, pharmacy and other ward supplies. Although automation was not part of the final solution the vertical and horizontal distribution strategy does allow for the use of AGVs. Also, the 'back of house' lifts going to each ward access a lobbied clean and dirty drop off and collection point that ensures any AGVs would not have to access the wards for drop offs and collections.

In parallel with the design work, process flows were also developed. These were first used to reflect the decision making process facing visitors, staff and FM when accessing the site, parking, accessing the hospital and going to individual departments. These showed how the design ensured as few options as possible were required to access the hospital, assisting way finding. Process flows were then developed for particular functions such as the operations within the pharmacy, taking into consideration the movements around the site and other sites that received pharmaceutical deliveries from King's Mill. These were used to ensure that

'For the Trust to realise all the benefits that can be realised, it is vital that staff are engaged in the process.'



King's Mill Hospital, part of the Sherwood Forest Hospitals NHS Foundation Trust, UK.

the design integrated all operational requirements and there was a clear understanding of the interactions of King's Mill with other hospitals, GPs, etc.

A redevelopment such as that undertaken by King's Mill is a key opportunity for a hospital to assess how it delivers care and to evaluate how patient pathways can be changed to improve this care. The retention of the existing estate will create compromises, but the King's Mill masterplan improved access and way-finding to and within the site and adjacencies within the hospital reducing travel distances for patients and staff. The scheme, therefore, introduced new facilities, new equipment and new ways of delivering care.

The PFI process, however, is very much focused on the delivery and maintenance of an asset, so any changes to the delivery of services reside with the Trust. For the Trust to realise all the benefits that can be realised, it is, therefore, vital that staff are engaged in the process and become involved in developing operations and procedures for the new hospital. This requires a comprehensive stakeholder engagement activity that needs to deliver the buy-in of hospital staff, while at the same time not impacting on the PFI process.

A stakeholder strategy can be used to formulate the extent of the required engagement, the programme available to deliver this in line with the PFI programme, the objectives of the engagement and measures of success. Once agreed, the strategy can then be used to formulate the delivery methodology through the use of workshops, simulations and information dissemination (such as newsletters and web sites). It is also key that, for such a programme to be successful, senior management support the stakeholder engagement exercise.

Conclusion

The successful PFI redevelopment at King's Mill Hospital was completed in 2011 with operational continuity maintained throughout the duration of the construction. In any redevelopment of a hospital, it is crucial to ensure that operational processes are not impacted to prevent risks to patient 'In any redevelopment of a hospital, it is crucial to ensure that operational processes are not impacted.'

safety and experience that can lead to significant reputational damage. The two key processes which mitigated the disruption to services, and ultimately patient experience, were the development of operational maps identifying core business as usual processes, which informed the construction phasing plans, and a clear process of informing all affected stakeholders in instances where there were changes to processes during the construction. This approach allowed the Skanska and Arup teams to integrate the core operational processes of the hospital into the construction phasing plan.



ARUP



Alfred Hospital ICU, Melbourne, Australia

ICU helps in building healing environment

In an article that first appeared in the *The Australian Hospital Engineer*, the monthly magazine of the Institute of Hospital Engineering Australia, Arup's Dr Gerard Healey examines the design and construction of a new intensive care unit (ICU) at Melbourne's Alfred Hospital in Victoria, Australia. Two of the project's key goals, and indeed major design drivers, were to reduce to the absolute minimum the risk of hospital-acquired infection, and to provide an environment that 'intentionally fosters staff and patient well-being, rather than just housing staff and patients'.

This is a case study of Melbourne's Alfred Hospital Intensive Care Unit (ICU). It has a building design driven by the risk of hospitalacquired infection, while providing an environment that intentionally fosters staff and patient well-being, rather than just housing staff and patients. Design drivers such as these are having a significant impact on hospital design around the world, and the case of the Alfred ICU can provide insight into potential challenges and solutions.

A brief review of literature indicates just how significant the issue of hospitalacquired infection (HAI) is. A World Health Organisation (WHO) survey indicated that an average of almost 9% of patients in Europe, the Eastern Mediterranean, South-East Asia, and Western Pacific, had hospital-acquired infections (WHO 2002). In Australia, it is estimated that, each year, there are in the order of 200,000 hospital-acquired infections, resulting in around two million bed-days lost.¹ While the exact economic impact of HAI is difficult to calculate, it is clearly significant, not to mention the emotional and psychological cost to the patients and their families. Patients in ICUs are particularly susceptible to adverse affects from HAI;1 they are even at risk of infections

This article first appeared in the September 2011 issue of *The Australian Hospital Engineer*, the monthly magazine of the Institute of Hospital Engineering Australia. Health Estate Journal acknowledges the help of *The Australian Hospital Engineer* and the International Federation of Hospital Engineering (IFHE) in publishing it.



Figure 1: The pre-cast concrete wall.

from organisms such as *Aspergillus*, which is a common fungus that poses low risk to healthy people, but can prove fatal for immuno-compromised patients.²

Impact of building design

While HAI is a serious issue, it is not the only issue in hospital design. It is widely recognised that building design can influence patient and staff well-being.^{3,4,5} The Alfred ICU has a focus on providing good daylight and high indoor air quality, both of which can have a positive influence on

Gerard Healey

Dr Gerard Healey is a mechanical engineer and Green Star-accredited professional with a PhD on how to better foster sustainable technologies. Since joining Arup in 2006, he has been the lead mechanical engineer and building services design coordinator for a university medical imaging project in Victoria, and contributed to the design of another medical imaging facility, a regional Victorian hospital, and the Alfred ICU. His other projects have included offices, education buildings, a brewery, student accommodation, and a rail tunnel. More recently, he has researched the skills required to deliver intelligent buildings, after being awarded the 2009 International Building and Construction Fellowship by Australia's Construction and Property Services Industry Skills Council and the ISS Institute.

patient and staff health.

The Alfred ICU is designed to have 45 beds, with approximately 2,000 patients per year passing through the unit. It is regarded as one of Australia's leading intensive care units, with a unique and complex case mix, being Victoria's main burns treatment centre, and providing for heart and lung transplantation, artificial heart technology, adult cystic fibrosis, pulmonary hypertension, adult trauma, and HIV treatment, and bone marrow transplantation. In its first six months of operation it treated



patients from Victoria's 2009 'Black Saturday' bushfires, which were among Australia's most lethal and damaging fires, and victims of H1N1 (swine) flu.

The new ICU was designed by architects Billard Leece Partnership (BLP), with services engineering by Arup, and construction management by John Holland.

An overview of the Alfred ICU

This case study is a valuable contribution to knowledge on infection control and healthcare design because it illustrates realworld challenges and solutions, including valuable feedback from construction and operation.

The paper begins with an overview of the ICU and feedback from staff. It then summarises the design drivers, and how they influenced the features of the design process and building. Next, it takes a more detailed look at the key features of the design process and building, before concluding with the key lessons learnt.

The Alfred Hospital is located approximately 5 km south-east of Melbourne's CBD, directly south of open parkland. The ICU is located at the western end of the hospital complex, above the emergency department, and next to the helipad. The new ICU refurbished and extended the previous ICU.

Internally, the ICU is custom designed for its unique case mix, and planned around three pods – general, trauma, and cardiac. The unit includes four 'Class N' negative pressure isolation rooms, four 'Class P' positive pressure isolation rooms, a number of notionally-negative pressure enclosed rooms, and open bays. The staff workflows were extensively studied to inform the design and final layout.

Feedback obtained from the director of the ICU, Dr Carlos Scheinkestel, in February

on key parameters after six months in operation Category Rating Temperature Unsatisfactory 1 2 3 4 5 6 7 Satisfactory Air quality Unsatisfactory 1 2 3 5 6 7 Satisfactory 4 Lighting Unsatisfactory 1 2 3 4 5 6 7 Satisfactory Noise, comfort, Unsatisfactory 1 2 3 4 5 7 Satisfactory 6 and design Response to staff/ Unsatisfactory 1 2 3 4 5 6 7 Satisfactory patient needs 2 3 7 Health (perceived), Less healthy/ 1 5 More healthy/ 4 6 image to visitors excellent poor Productivity Decreased 1 2 3 4 5 6 7 Increased (-20%) (+20%)

2011, after six months, and again after three years of operation, was very positive, from both staff and visitors. An overview of feedback at six months is shown in Table 1. At three years, rates of hospital-acquired infection, staff sick leave, and feedback from patients' relatives, had all shown a significant improvement. Feedback on specific design features has been included throughout this paper, and lessons learned are noted at the end.

Design drivers

In 2005, following a detailed investigation of difficulties experienced in the delivery of services, it was announced that the Alfred Hospital was going to upgrade its ICU.⁶ As part of the design process, the design team conducted tours of recently completed intensive care units around Australia. Arup also developed benchmarks based on international best practice, including the US Centre for Disease Control (CDC), and our experience on the west coast of the US, and in the UK.

In consultation with the hospital and staff, a number of design drivers were identified, including:

- The introduction of natural light for each bed and circulation areas.
- Providing good indoor air quality (odours from burns treatments were noted as an issue in the previous ICU).
- The ongoing management of the risk of *Aspergillus* spores.
- The ongoing management of hospitalacquired infection.
- To plan in 45 beds arranged into pods.Pods to provide good observation of
- patient cubicles.
- Finishes to provide a less clinical feel.
- High resilience and reliability.
- Improved maintenance access.

The upgrade of the ICU also provided the hospital with an opportunity to make allowances for an increasing number of immuno-compromised patients, an increasing number of patients with contagious infections, increased storage, and for new (and space-demanding) technologies that provide artificial heart and lung support.

The right connections

Further to these, the new ICU was to be a full refurbishment of the existing ICU patient areas, partial refurbishment of support areas, and expansion to the west. It was above an operating accident and emergency department, and required to connect to existing hospital services with minimal disruption. The following sections will discuss the key features in more detail.

Managing Aspergillus spores

As noted earlier, managing *Aspergillus* spores was one of the drivers in the design of the new ICU. This was approached through a variety of measures, including:

- Providing a well-sealed envelope.
- Pressure testing the building following construction.
- Pressurising the ICU relative to outside.
 Minimising access/egress and using air-
- locks at entries.



Figure 2: The rubberised roof alongside the plant room.
A well-sealed building envelope

Providing a well-sealed envelope was a primary concern for the architects Billard Leece Partnership (BLP), and particularly the external walls and roof, which were a source of leaks in the previous ICU.

For the external walls, BLP incorporated pre-cast concrete panels with fixed glazing, which provide a robust and airtight construction, provide an acoustic barrier between the ICU and the nearby helipad, and could be prefabricated offsite and erected quickly (Fig. 1). For the roof, BLP selected a rubberised membrane system bonded to ply over a steel frame. Because it provides a guaranteed weather tight barrier, it can provide a seal across the whole ICU roof and plant room walls, and is trafficable for maintenance. From a building services perspective, the number of roof penetrations was minimised.

Pressure testing

The builder for the ICU was required to achieve a specified level of sealing of the ICU envelope. To confirm that the envelope was well-sealed, Arup required the mechanical contractor to perform building air leakage in accordance with CIBSE Technical Memoranda TM23 – *Testing buildings for air leakage*. This required that the building be tested to maintain a standard pressure differential at 50 Pa, with smoke visualisation used to identify leakage paths.

Pressurisation

Pressure gradients within the ICU were also used to control the ingress of *Aspergillus* spores, and the spread of contagions within the unit. A differential pressure is maintained between the unit and outside, between the circulation areas of the unit and the positive (Class P) and negative (Class N) isolation rooms, and between circulation areas and notionally negative enclosed bed bays. To maintain this differential, the following strategies were used:

 Central plant air intakes and discharges were located and designed to minimise effects from wind.



Figure 3: Pressure-independent venturi valves installed. Inset: a valve in section.

- Variable speed fans to correct for changes in filter resistance as they load.
- Pressure-independent venturi valves were used to maintain constant flow rates to and from each space.
- Central HEPA filtration of supply air.
- A well-sealed envelope, as discussed previously.

The central air handling units for the ICU are located in a roof-top plant room (Fig. 2). Following extensive wind investigations and analysis, there was concern that wind pressure at the air intakes and discharges could adversely affect the air flow within the ICU, and consequently the pressurisation. To manage this risk, the outside air intakes were designed with roof cowls, and exhausts are vertical stacks, rather than louvres in vertical walls.

As a further measure to ensure constant air flow within the ICU, pressureindependent venturi valves were used on all supply and exhaust outlets rather than conventional balancing dampers (Fig. 3). These valves maintain flow using a springmounted cone that moves in and out of a venturi orifice, providing more reliable airflows compared with conventional dampers. Venturi valves are common in laboratory and healthcare projects overseas.

Cross-connected air handling units

Pressurisation is an important part of infection control within the ICU, so the central air handling plant consists of two cross-connected AHUs, to provide a level of redundancy. Room pressurisation is monitored, and alarms activated, if the reference differential pressure is lost.

Central HEPA filtration

HEPA filters were used in the central air handling plant to reduce the potential ingress of *Aspergillus* spores and other particulates via the supply air.

Managing other hospital-acquired infection

Managing cross-infection is a challenge shared by all hospitals – and met by a variety of design features and management procedures. Two design features of the Alfred ICU are particularly worth noting: 100% outside air supply, and switchable glazing.

100% air supply with energy recovery

In traditional air supply, a portion of the air from the space is mixed with outside air and recirculated. This helps to reduce the energy required to heat or cool the outside air, because the return air is already at about room temperature. The drawback of this approach in the ICU is that the return air from the space may not be free of contagions. This could be managed through the use of



Figure 4: Central air handling units with runaround coil supplying 100% outside air during design (above), and as constructed.





Figure 5: Switchable glazing in opaque/transparent modes above a nurses' station.



central HEPA filters, although this shifts the risk of cross-infection to the effectiveness of the maintenance programme. Arup's approach was to design this risk out by using 100% outside air, i.e. exhausting all the return air from the ICU, and supplying air from outside.

The potential drawback of such an approach is that larger heating and cooling coils are required, leading to increased energy consumption. This was mitigated by using a run-around coil (Fig. 4) to provide energy recovery between the exhaust and supply streams. A run-around coil was chosen over a plate heat exchanger or thermal wheel because it had the lowest risk of exhaust air entering the supply air stream. A coil bypass is used to save fan energy when thermal energy recovery is not required. The variable speed drives automatically correct for filter loading and the coil bypass.

Switchable glazing

Traditionally, fabric-based curtains and blinds provide privacy for patients, and control sunlight and glare. However, they are also a potential infection hazard. To overcome this tension, the design team for the Alfred ICU used switchable glazing (Fig. 5) in the roof lanterns and patients rooms. Switchable glazing uses liquid crystal technology to become transparent when an electric current is applied, and opaque when the current is removed. This enables staff and patients to manage privacy and sunlight, without surfaces or materials that are difficult to clean or disinfect.

Feedback from acting nurse managers is that the switchable glazing has been well received. The only negative comments have related to the automatic timer in the glazing. While it is currently set to automatically frost over at night, some staff were not aware that this setting is adjustable, or that there is a manual override. This has been corrected by increasing staff awareness about how the system operates.

High indoor air quality

Providing high indoor air quality was another design driver. It had been noted by staff that the previous ICU had undesirable odours from some of the burns treatments, and that surgery-like procedures were sometimes performed in the ICU because it was not possible to transport the patients to a surgical theatre. Consequently, it was important for staff and patient well-being that the ICU had high indoor air quality. Strategies used to achieve this were:

- 100% outside air supply, as discussed previously.
- Provision for central carbon filters if required.
- Central HEPA filtration.
- Provision of space for humidifiers centrally, and for burns rooms.

Feedback from the acting nurse managers has been that the air quality has improved in the burns treatments rooms.

In addition to assisting with infection control, the 100% outside air system was also

expected to improve the indoor air quality. Anecdotally, the nursing managers report that there have been fewer complaints from staff working on burns patients than in the previous ICU. Not all odours have been removed, however, with the nurses noting that it still smells if a patient soils themselves. This is not unexpected given that the ventilation is via an overhead mixed air system.

Carbon filters

The new ICU was always intended to be closer to the ambulance helipad than the previous ICU. There was uncertainty as to whether exhaust fumes from the ambulance helicopter might be drawn into the supply air plant. Given that the issue was uncertain, and the tight construction budget, it was decided to provide space and fan power in the air handling units for carbon filters, but not the filters themselves. Carbon filters are designed to adsorb gaseous pollutants such as SO₂ and NOx, rather than particulates. This low-cost approach maintained the flexibility for later retrofit of the filters if required.

Feedback from the acting nurse managers is that there was not an issue during the first few months of operation over the summer. However, in the last few months in winter, the smell of helicopter exhaust fumes became more noticeable. The reason for this change is not well understood. At the time of writing,

'To minimise disruption to the ICU operations and risks to patients, all maintenance access is from outside patient rooms, or via the roof plant rooms.'



Figure 6: A section showing the relationship between the roof lanterns, nurses' stations, and patients.







Figure 7: Roof lanterns over nurses' stations during design (left), and construction (centre).

Dr Carlos Scheinkestel, ICU director, advised that the carbon filters were going to be installed.

There was concern from Arup that 100% outside air could lead to low relative humidity in the ICU during the colder winter months, and space was provided for the installation of humidifiers. The Alfred Hospital conducted an investigation into the use of high humidity burns rooms nationally, and found that present treatments do not rely on high humidity as they had in the past. Consequently, the burns rooms were not provided with humidifiers, but there is space so that they can be retrofitted in the future, should treatment practices change. The burns rooms are also able to achieve internal temperatures of 29°C, as required by treatment practice.

Daylight

Providing good access to daylight was a key requirement of the new ICU, and the space planning strongly reflects this, along with easier observation of patients. BLP took advantage of the relatively large extent of new building façade to introduce natural light directly into patient bays and, where possible, located cubicles on the external walls of the new building. This also allowed staff and utility areas to be located relatively centrally, with good access and views to patient areas.

Natural light was provided to staff stations and circulation areas via large roof 'lanterns' (Figs. 6 and 7). These also enhanced the quality of space provided to cubicles adjacent to the stations – particularly those without an external window. The team chose roof lanterns over skylights because they provided better views to outside, better control over solar gains, and an opportunity to reticulate services. The lanterns were finished with a light timber veneer, which provides a less clinical feel, a point of visual interest, and acoustic absorption. Switchable glazing was used in the roof lanterns to provide glare control.

Feedback from the acting nurse managers is that staff, patients, and visitors, love the daylight provided by the roof lanterns. The only issue has been with a cubicle opposite a north-facing lantern. At some times of the day, the daylight through the frosted lantern is still quite bright, and creates glare on the patient monitors. This has not been a major issue, because it happens infrequently. It probably could have been mitigated during design if a detailed daylight and glare analysis had been undertaken.

Minimising disruption using 3D modelling

A key goal for the construction of the ICU was to minimise disruption to adjoining hospital spaces. This was a challenge for two particular reasons – firstly, because the ICU site was located above the accident and emergency (A&E) department, with some of the existing ICU services reticulated in the ceiling space, and, secondly, because the intensive care unit had to connect to existing building services for power and water that also supplied the rest of the hospital.

To minimise disruption and clashes during construction, Arup used 3D modelling (Figs. 8 and 9) to spatially co-ordinate services with structure and architecture. This proved to be a valuable and effective tool for



communicating with the rest of the design team, the building contractor, and Alfred Hospital engineering staff, and led to improved maintenance access, and a far lower number of physical services clashes during the construction phase. For contract purposes, 2D design documentation was extracted from the 3D model.

Improved operation and maintenance

The construction of the new ICU provided an opportunity to improve the operation and maintenance of the ICU. This was achieved through the following features:

- Increased flexibility of bed bays.
- Safer maintenance access.
- Increased resilience.

Flexibility of bed bays

The design of the Alfred ICU is enhanced compared with standard Victorian DHS practice, in that the segregated rooms were made notionally negative in accordance with Centre for Disease Control Guidelines.⁷ This has had benefits for the ICU during its first six months of operation. When responding to the large number of burns victims from Victoria's 2009 Black Saturday fires, it enabled the hospital to turn the segregated rooms into temporary burns-style rooms.



Figure 8: 3D modelling of building services for the ICU.

Similarly, when treating victims of H1N1 (swine) flu, which exceeded the number of Class N negative rooms, it enabled the hospital to put swine flu patients on ventilators in the notionally negative rooms, and provide a measure of infection control (the Class N rooms were prioritised for patients breathing independently).

Other features of the cubicles include:

- They are larger than normal, to allow for the large amount of equipment around patients.
- All power comes from three overhead pendants (2 head, 1 foot), rather than wall outlets, to remove the tripping hazard of cables running across the room.
- Cubicles for burns, ECMO (artificial heart and lung technology), and spinal trauma, are equipped with mobile hoists to assist with moving patients safely.

Feedback after three years of operation was that room sizes and storage spaces have been sufficient to date. Mobile hoists have now been retrofitted to the majority of rooms. It would have been good to have included these in the original brief, as clashes with services and pendants have meant that it has not been possible to retrofit hoists in all rooms.

Safe and convenient maintenance access

The ongoing operation of the ICU relies on regular maintenance of components. In general, to minimise disruption to the ICU operations and risks to patients, all maintenance access is from outside patient rooms, or via the roof plant rooms.

For high-risk items, such as HEPA filters that could contain contagions, it was imperative that maintenance staff be protected. To achieve this, all HEPA filters on Class N exhaust air were of 'bag-in-bag-out' style. This means that the maintenance worker is not exposed to the HEPA filter itself. Feedback after three years of operation is that there has been no noticeable disruption due to maintenance.

Resilience and uptime

The ICU was made more resilient by providing UPS back-up power supply, duty/standby air handling fans, and duty/standby HEPA units on the Class N negative rooms.

Lessons learned

As noted in the paper, the feedback from the acting nurse managers has been generally positive, and issues have either been minor (e.g. staff training for switchable glazing), or can be managed within the design (e.g. carbon filters for helicopter exhaust).

The nurses have noted two areas where they have proposed additional works to hospital engineering:

Isolation room intercoms - the nurses noted that it is very difficult for staff within an isolation room to communicate to someone outside the room. To date

their techniques have included tapping on the glass, holding up written messages, or pressing their ears against the glass. They have proposed an intercom system to overcome this issue.

Anteroom size - the nurses noted that it is difficult to get medical equipment (e.g. X-ray machines) through the anterooms into an isolation room because both doors open into the anteroom. The nurses suggested that the patient-side door should open into the patient's room, rather than the ante room; however Arup notes that the current arrangement was designed to encourage the room seal, i.e. the negative room pressure sucks the doors against the frame sealing, rather than pulling it away from the frame.

These issues were ongoing at the time of writing.

A further issue noted by Dr Carlos Scheinkestel is that the air conditioning system struggled to cope with the extreme temperature experienced at the start of 2009, which included three consecutive days above 43°C (BOM 2009).8 The chiller was sized for 45°C ambient, and it was subsequently found that it was tripping out due to high pressures, rather than ramping down as intended. These settings have since been changed, and it is expected to perform better in the coming summer.

Conclusions

The Alfred ICU project was a technically challenging project that combined issues of infection control and designing for occupant well-being. The design incorporates many interesting design features that have responded to these issues and opportunities, as described throughout this paper. The design team has delivered a building that has performed successfully during its first six months of operation, and provided a valuable service to the Victorian public. In the words of Phil Nedin, global leader of Arup's healthcare business, the Alfred ICU was "... a good solution and possibly [world's] best practice".

Acknowledgements

The authors would like to acknowledge the staff at the ICU who shared their experiences with us and took the time to review draft versions

References

- 1 Cruickshank M, Ferguson J. Reducing harm to patients from healthcare-associated infection: the role of surveillance. Australian Commission on Safety and Quality in Health Care, 2008 (http://tinyurl.com/bl9ndbg).
- 2 Centers for Disease Control and Prevention. Aspergillosis. Atlanta: CDC, 2008 (http://tinyurl.com/bp8o82q).
- 3 Glanville R, Nedin P. Sustainable design for health. In: Rechel B, Wright S, Edwards N, Dowdeswell B, McKee M eds. Investing in hospitals of the future. Geneva: WHO, 2009





Figure 9: 3D modelling design, and as-built images for the exhaust from the Class N (negative) room.

(http://tinyurl.com/c6uaeyy).

- Georgia Tech and Center for Health Design. A 4 review of the research literature on evidencebased healthcare design. Health Environments Reasearch & Design 2008; 1 (3) (http://tinyurl.com/d272d6t).
- Rubin H, Owens J, Golden G. An investigation 5 to determine whether the built environment affects patients' medical outcomes. The Centre for Health Design, 1998 (http://tinyurl.com/bva9sye).
- 6 Nader C. Alfred intensive care unit upgrade to fight fungus. The Age April 20, 2006 (http://tinyurl.com/dykwbxr).
- 7 Sehulster L, Chinn RYW. Guidelines for environmental infection control in health-care facilities. In: Morbidity & Mortality Week Report (MMWR). Atlanta: CDC, 2003: 52 (RR10), 1-42 (http://tinyurl.com/ctzwldb).
- 8 Australian Bureau of Meteorology. Melbourne heatwave approaches Black Friday record. 2009 (http://tinyurl.com/by8yzt).
- 9 Edwards L, Torcellini P. A literature review of the effects of natural light on building occupants. Colorado: National Renewable Energy Laboratory, 2002 (http://tinyurl.com/cc6agxg).
- 10 Joseph A. The impact of light on outcomes in healthcare settings. Concord CA: The Center for Health Design, 2006 (http://tinyurl.com/cnqflu9).
- 11 World Health Organization. Prevention of hospitalacquired infections 2nd edn. Geneva: WHO, 2002 (http://tinyurl.com/cby58ob).



UCH, Macmillan Cancer Centre, London, UK

ARUP

Assessing the full carbon impacts of healthcare

A "carbon constrained" world is becoming a reality. Current scientific evidence indicates an emergency pathway of greenhouse gas (GHG¹) emission reductions is required to stabilise temperature increases at below a 2°C threshold in an effort to avoid catastrophic climate change.

How we work, live, eat and travel will be subject to significant changes.

The UK's Climate Change Bill 2008 set a legislative target of an 80% reduction in the GHG emissions from 1990 levels to 2050. The UK Climate Change Committee recently set interim carbon budgets to provide the roadmap of how to meet the 2050 target. Public sector organisations are expected to take a lead role.

The NHS in England faces a particular challenge. The demand for its services continues to increase: healthcare expenditure in the UK has risen from 4% of GDP in 1960 to a projected 10% of GDP by 2010. Against this trend, the NHS in England will need to deliver significant reductions in emissions, of the scale and speed illustrated in Figure 1.

The NHS Sustainable Development Unit (SDU) was established in 2008 to help develop a coordinated approach within the NHS in England not only for carbon reduction, but also to achieve sustainable development in general. Faced with the emissions reduction challenge described above, the SDU set out to develop a carbon reduction strategy which was subsequently

'The key project aim was to estimate the full "consumption-based" footprint of services and activities of the NHS in England.' published in 2009.² To inform the strategy, the SDU commissioned a carbon footprint study to calculate the carbon footprint of the NHS in England. This report summarises the carbon footprinting research that was undertaken.

The NHS SDU funded the research project, which was undertaken by the Stockholm Environment Institute (SEI) and Arup. The Department of Health (DH) and the Sustainable Development Commission (SDC) were also key stakeholders, providing an important peer review process for the results and the development of the overall carbon reduction strategy.

Objectives

The key project aim was to estimate the full "consumption-based" footprint of services and activities of the NHS in England. This means estimating the emissions from direct energy use and travel, but importantly also the embedded emissions within goods purchased and used by the organisation. This is discussed in more detail in the sections below.

In addition to the overall project aim, the following project objectives were identified:

- Development of a credible, transparent and robust methodology for the carbon footprint calculation.
- Calculation of historical emissions back to 1990, to serve as a baseline for future emissions monitoring and forecasting.
- Identification of carbon "hotspots".
- Projection of future emissions to 2020, using current known estimates

of consumption by NHS England.

 Identification of a pilot set of carbon policy "wedges" that would help to reduce emissions. These follow the Socolow Stabilisation Wedges approach,³ as shown in Figure 2.

The three project outputs were a 1990-2004 carbon footprint report,⁴ a 1990-2020 carbon modelling report,⁵ and the production of a strategic carbon modelling tool for the SDU's future use.

GHG Protocol

The globally recognised approach for documenting the carbon footprint of an organisation or organisations is the Greenhouse Gas Protocol (GHG Protocol),⁶ which categorises carbon emissions as Scope 1, 2 or 3 emissions, as shown in Figure 3 and as defined below:

- Scope 1 Emissions are direct emissions occurring from sources that are owned or controlled by the organisation (for example, emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc); and emissions from chemical production in owned or controlled process equipment.
- Scope 2 Emissions are emissions resulting from the generation of purchased electricity consumed by an organisation.
- Scope 3 Emissions cover all other emissions which occur from sources not owned or controlled by the organisation, but which are emitted as a consequence

Paul Brockway MEng (Hons) MSc (Distinction) in Climate Change and Sustainability

Paul Brockway currently works in Arup's Sustainability Group in Newcastle. Previous to this he worked in Arup's Building Engineering (Newcastle) and Industrial Projects (London).

In 2004 he returned from a two-year Voluntary Service Overseas (VSO) placement as a civil engineering lecturer and Vice Head of Department at Jimma University, Ethiopia.

Originally a structural engineer by training, Paul Brockway has developed a particular focus on climate change and sustainability. In 2008 he completed a six-month secondment in the energy, buildings and transport team of the Sustainable Development Commission (SDC), London.

Paul Brockway was the project manager responsible for the carbon footprinting research projects of the NHS in England. He developed project specifications, assisted data collection, reviewed results from the analyses and was lead author of the research reports. Following the NHS England projects, Paul Brockway has since been the project manager responsible for a similar carbon footprint project for NHSScotland and a regional study for NHS London.









Figure 2: Socolow Stabilisation Wedges.

'This ground breaking carbon footprinting research forms an important foundation block for the development of the carbon reduction strategy of the NHS in England.' 'Carbon reduction actions may focus on "quick wins" such as reducing wastage of pharmaceuticals, or creating longer-term initiatives, such as creating alternative, less carbon intensive models of patient care.'

of the activities of the organisation. Examples of these indirect emissions include the extraction and production of purchased materials, transportation of purchased fuels, and use of sold products and services.

Carbon footprinting methodology

Traditional organisational carbon footprinting methodologies typically capture only Scope 1 and 2 emissions, as they generally calculate emissions from the consumption of energy by the organisation - including electricity, on-site gas use and transport fuel. The Carbon Trust's Carbon Management Programme⁷ is a common example of this approach. However, in many cases (including this NHS in England analysis) the majority of an organisation's emissions are attributable to Scope 3 emissions, and it follows that these traditional techniques can significantly underestimate the total consumption-based carbon footprint of an organisation.

Therefore, in order to capture the full consumption-based footprint, a methodology was developed which included Scope 3 emissions, in addition to Scope 1 and 2 emissions. The consumption-based methodology incorporates both direct (i.e. on-site) and indirect (i.e. off-site) carbon emissions, and considers the full supply chain impacts of activities of the NHS in England and has been sub-divided into its principal contributory components, as defined below. The methodology for the three primary emissions sectors is summarised. For a more detailed description refer to the 2008 carbon footprint report.⁴

- Procurement (emissions embedded in goods and services): this uses nationally available economic and environmental accounts to combine an expenditure breakdown of the NHS in England with carbon intensities to determine overall procurement emissions of the organisation.
- Travel (emissions associated with

Figure 3: GHG Protocol classification of emissions.





Figure 4: 2004 NHS in England carbon footprint primary sector breakdown.

movement of staff, patients and visitors): mainly uses National Travel Survey (NTS) data in conjunction with known/estimated numbers of staff, patients and visitors.

Building energy (e.g. emissions resulting



Figure 5: 2004 NHS in England carbon footprint Scope 1-3 emissions breakdown.

from consumption of heating and electricity): emissions were calculated based on energy consumption data from the Estates Return Information Collection (ERIC) annual returns by Trusts, provided by DH.⁸

Projected emissions to 2020 are based on future estimates of consumption and carbon intensities in these sectors.

Two notes of clarification are worthwhile at this point. Firstly, emissions of the NHS in England are calculated and reported in terms of CO_2 . This is a valid assumption as CO_2 emissions account for over 85% of the UK's GHG emissions.⁹ Secondly, the term "carbon" footprint is a slight misnomer, as CO_2 emissions are reported.¹⁰

Size of footprint

The 2004 carbon footprint of the NHS in England is broken down in the three primary sectors as shown in Figure 4. At an estimated 18.6 MtCO₂, the carbon footprint of the NHS in England represents over a quarter of England's public sector emissions, and around 3% of the UK's total consumptionbased CO₂ emissions.

The emissions produced in the production and distribution of goods and services are seen to account for 60% of the carbon footprint of the NHS in England. This is typical of a service sector industry, where consumption of building energy is much lower than would be the case in a manufacturing organisation, which uses heavily energy intensive processes. This observation is further evidenced by the breakdown of Scope 1-3 emissions (Fig. 5). Scope 3 emissions include all procurement emissions, and in addition include travel emissions from staff commuting, patient and visitor journeys. This supports the rationale to determine and baseline emissions of the NHS in England using Scope 1, 2 and 3 emissions.

Within the procurement sector, the emissions occurring in the manufacture and distribution of pharmaceuticals consumed by the NHS in England are responsible for a fifth of the overall carbon footprint, as shown in Figure 6. This is equivalent in magnitude to either the building energy or travel sectors, and reflects the fact that around a quarter of the NHS England procurement budget is used on pharmaceuticals.

Results over time

The analysis estimated the NHS in England emissions for the period 1992-2004. The results are illustrated in Figure 7. At 12%, the growth in total NHS consumption CO_2 emissions over 1992-2004 is slightly lower than the 17% rise in the same period for overall UK consumption CO_2 emissions.⁹ Despite a 13% fall in building energy emissions, this rise in emissions resulted from increases in travel emissions (+11%) and procurement emissions (+26%).

Modelling to 2020

Having established the historical NHS in England emissions, the second phase of the carbon research project examined projected emissions to 2020 (Fig. 8). The analysis was split into two parts. Firstly, emissions were projected to 2020 using a baseline scenario, which combines a continuing trend analysis with known estimates of future consumption - for example Wanless spend projections¹¹ are used to estimate the procurement expenditure to 2020. It is therefore similar but not the same as a business-as-usual scenario. Under the baseline scenario, emissions are projected to rise to 23 MtCO₂ by 2020, 55% higher than in 1990.

Secondly, the model that had been developed to project emissions to 2020 was then used to test "pilot" carbon "wedge" savings, based on a given policy interventions. The results are illustrated in Figure 8. Examples of the pilot wedges include:

- **Procurement:** lowering consumption of pharmaceuticals to 10% below the 2020 baseline projection.
- Travel: smart travel plans adopted across all NHS estate.
- Building energy: increase use of combined heat and power (CHP).

Conclusions

Firstly, this ground breaking carbon footprinting research forms an important foundation block for the development of the carbon reduction strategy of the NHS in England, by allowing a far more comprehensive plan to be developed across a range of policy areas.

Secondly, it has also highlighted the importance of considering the full consumption footprint of the NHS in England, since only a quarter of the organisation's emissions are Scope 1 and 2 emissions, which are captured by "traditional" carbon footprinting techniques. Thirdly, the analysis results confirm the scale of the challenge to the NHS in England: emissions are projected to rise by over 50% between 1990-2020, at a time when significant reductions are required.

In addition, the results have important strategic impacts for the NHS. As well as providing a baseline for monitoring of future emissions against targets, by developing a carbon scenario modelling tool, future carbon "wedges" can be tested to determine the most effective mitigation actions. Carbon reduction actions may focus on "quick wins" such as reducing wastage of pharmaceuticals, or developing longer-term initiatives, such as creating alternative, less carbon intensive models of patient care. Finally, it is important to note the wider benefits of carbon reductions to the NHS in England, which include:

 Contributing to the wider sustainable development agenda, including direct health benefits, reducing consumption, and investment in the local economy.



- Ability to reinvest financial savings back into patient care.
- Achieving greater business resilience and continuity.
- Acting as an exemplar to other public sectors.

References

- 1 Greenhouse gases (GHG) include carbon dioxide, nitrous oxide, methane, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. They trap heat in the earth's atmosphere, and increases in GHG levels lead to higher temperatures – the so-called greenhouse effect. *The Need for Sound Carbon Accounting in Scotland.* Available at www.sei.se/scotland
- 2 Saving Carbon, Improving Health NHS Carbon Reduction Strategy for England. NHS England (2009) www.sdu.nhs.uk
- 3 Socolow R. et al. (2004) Solving the Climate Problem: Technologies Available to Curb CO2 Emissions. Environment, Vol.46, No.10, pp.8-19.
- 4 NHS England carbon emissions: carbon footprinting report – September 2008. Available at



- 5 NHS England Carbon Emissions; Carbon modelling to 2020. 2009. Available at www.sdu.nhs.uk
- 6 Refer to www.ghgprotocol.org
- 7 Refer to www.carbontrust.co.uk/carbon/ publicsector/nhs
- 8 Refer to www.hefs.ic.nhs.uk
- 9 Wiedmann T., Wood R., Lenzen M., Minx J., Guan D., Barrett J. Development of an Embedded Carbon Emissions Indicator – Producing a Time Series of Input-Output Tables and Embedded Carbon Dioxide Emissions for the UK by Using a MRIO Data Optimisation System, Report to the UK Department for Environment, Food and Rural Affairs by Stockholm Environment Institute at the University of York and Centre for Integrated Sustainability Analysis at the University of Sydney, June 2008. Defra, London, UK.
- 10 As one mole of CO_2 (which weighs 44g) contains 12g of carbon, the masses of carbon and CO_2 are directly related by the fraction 12/44.
- 11 Our Future Health Secured? Available at www.kingsfund.org.uk/research/publications/ our_future.html





Figure 8: 1990-2020 NHS in England carbon footprint/carbon wedges.

Creating premises for indigenous Australians

Since the beginning of the 20th Century, life expectancy has increased markedly for Australians overall, reflecting improvements in areas such as public health and medical interventions. However, as we approach the second decade of the 21st Century, indigenous Australians have, on average, the same life expectancies as the total Australian population 100 years ago.

The significantly lower life expectancy of indigenous Australians, compared with the average Australian population, reflects their higher death rates at all ages. This is largely the result of relatively high death rates in adulthood, especially between the ages of 45 and 65 years. In the period 1998-2000, deaths of people aged 25 years and over accounted for 18 years of the 21 year gap in male life expectancy and 17 years of the 20 year difference in female life expectancy between the indigenous population and the total Australian population.¹

Good news is that a recent study has claimed that dire death rates for indigenous Australians suffering chronic diseases have shown their first tentative signs of slowing down. However, mortality rates for the total Australian population have improved much faster. This has served to widen the gap between the groups.²

Focus on community controlled health

The first Aboriginal medical service was established in Redfern in Sydney in 1971 shortly after the establishment of a local Aboriginal legal service. Redfern, and other early medical services around the country, reflected the aspirations of indigenous Australians for self-determination as well as a frustration with, and alienation from, mainstream services that had a less than desirable tolerance and recognition of the specific needs of indigenous Australians.

These early Aboriginal medical services provided sites for community development, political advocacy and the intellectual development of a cultural identity and social "movement". Their innovative approaches and focus on holistic, culturally appropriate and self-determined health services foreshadowed the international Declaration on Primary Health Care, which was agreed to at Alma-Ata (now known as Almaty in present day Kazakhstan) in 1978, with its assertion of the importance and effectiveness of comprehensive primary health care.

Currently, the delivery of health and health-related services to indigenous Australians is primarily the responsibility of Australian state and territory governments. Sponsorship of Aboriginal Community Controlled Health Services (ACCHSs) is provided across all three levels of government (Commonwealth, state/territory and local) to provide culturally valid and bespoke processspecific health services that form an important part of the overall health system.

In the same way that general practice is the backbone of the mainstream primary care system, when it comes to addressing ill health in the indigenous community, ACCHSs, and their associated health services, are the central part of the primary health care sector.

The specific community approach is intended to provide innovative clinical and health development services where cultural imperatives, social realities and technical necessities are taken into balanced account.³

ACCHSs have adopted an approach to health service delivery that utilises current recognised medical diagnostic and treatment

'In the design of indigenous health infrastructure, there is a need to consider important local variations and characteristics that are particular to individual health services and client populations.' processes, in an environment that is in keeping with the philosophy of Aboriginal community control. The approach is responsive to the community's social and cultural determinants of perceptions of health and illness, of health status and of the perceptions of appropriate responses to poor health that this entails.

It has been stated that the solution to address the ill health of Aboriginal people can only be achieved by local Aboriginal people controlling the process of healthcare delivery. Aboriginal community control allows Aboriginal communities to determine their own affairs, protocols and procedures.³

In practice, "community control" means that each ACCHS is legally incorporated, independent of government and other ACCHSs, and has a board of directors and/or governing committee comprising community people selected by and representing the organisation's community membership.

The ACCHS model essentially requires that ownership and management of the health agency are taken on by the local Aboriginal and Torres Strait Islander (ATSI) community, generally through a local ATSI board of management. This arrangement allows the local community to decide on priorities, policies, management structure, staff and service profile, within government funding guidelines.⁴

Rob Issacs

Rob Isaacs is a senior associate with Arup and is the leader of the programme and project management practice in NSW. He joined Arup in 1987 as a structural engineer and since 1992 has worked almost exclusively in the field of programme and project management. Rob Isaacs has been closely involved in Arup's work with indigenous Australians since 1994, in all states and territories.

Doug Kingham

Doug Kingham is a senior project manager with Arup's programme and project management practice in NSW. He joined Arup in 2006 after working as a project engineer in the US and the UK. Doug Kingham has spent most of his three years with Arup working as a programme and project manager providing health infrastructure for indigenous and non-indigenous Australians.

Arup is a global firm of designers, engineers, planners and business consultants providing a diverse range of professional services to clients. 'Health facilities with sufficient natural light have also proved to be more inviting and pleasant for patients, which is important as many indigenous Australians can be reluctant to visit health clinics on a regular basis.'

All Australian governments have a formal commitment to the ongoing funding of ACCHSs and to the principle of "community control". In July 1995, the Australian Government transferred responsibility for indigenous Australian health from the Aboriginal and Torres Strait Islander Commission to the Commonwealth Department of Health and Ageing's portfolio, along with funding responsibility for over 200 community controlled health and health related organisations, located in urban, rural and remote areas.

Engaged as programme manager

Since 2000, Arup has been engaged as the programme manager for the Commonwealth's capital works projects that focus on indigenous health infrastructure. The purpose of this support is to provide best value for money health facilities that enable funded ACCHSs to deliver high quality healthcare services which meet the needs of their stakeholder communities.

As the capital works programme manager, Arup facilitates the engagement of third party project management consultants and architects to deliver health clinics, substance misuse centres and staff housing around the country. The consultants who are engaged are in businesses ranging from small, one or two person firms to large, global consultancies. They have varying skills and experience when it comes to health infrastructure delivery throughout Australia. As such, one of Arup's primary responsibilities is to work with and guide the consultants to maintain consistency around the country in terms of the end product.

Design considerations

In the design of indigenous health infrastructure, there is a need to consider important local variations and characteristics that are particular to individual health services and client populations. In order to ensure fit to local needs, it is necessary for the consultant that is managing the individual capital works projects to gain a familiarity with the local context, which can be accomplished through detailed discussions with experienced local individuals and organisations.

The following sections contain some of the more important considerations which designers employ.

Cultural factors

Cultural factors vary substantially between communities across Australia. Relevant



Striking, appropriate design.

factors that are considered and consulted on broadly with the community include the following:

- The concept of death.
- Perceptions of personal/gender privacy.
- Spiritual issues.
- Family and community social structure and relationships.
- Gender and age relationships and "avoidance" practices.

For example, in some indigenous communities a son-in-law must not be in the same room with his mother-in-law. In order to accommodate these relationships and other cultural factors, key design considerations include:

- Discreet entry/exit points for men's/women's health services.
- Separate men's and women's consultation/treatment areas large enough for group consultations.
- Separate men's and women's toilet/bathroom amenities with planning to provide discreet, private entry/exit from amenities.
- Overall design to provide a comfortable and inviting environment.
- Protected external waiting areas and general community meeting space.
- Generous internal waiting areas for extended family visitation.
- High level of privacy provision for consultation and treatment areas.

• Location and provision of body holding facility.

Consultation with the community during the early design phase of a project not only helps the consultant ascertain the needs of the community, but it also helps to create a sense of ownership among the indigenous community.

Disaster management

As with any health facility, disaster management will factor in the design process. Buildings must be designed to continue to function in the event of a disaster/emergency.

Generic design considerations include designing the facilities to be flexible in regards to consultation, examination and treatment areas so that emergency situations, such as flu epidemics, can be accommodated. In addition, patient and staff security must be taken into account.

And while having an emergency power supply is an important element for any health facility, the remoteness of many indigenous communities makes this even more critical. Even with an emergency power supply, blackouts can still occur, so design consultants are encouraged to design treatment areas in the facilities with sufficient natural light to maintain use.

Acoustics

Remote community health facilities often attract large gatherings of people, including children. Control of noise and protection of client privacy and confidentiality are essential for the effective management of a facility.

- In the design process, consideration is often given to the following:
- Provision of generous and pleasant outdoor waiting areas to reduce demand on internal spaces.
- Planning of facility to separate areas requiring privacy or quiet from other noisier areas.
- Selection of sound absorbing materials and finishes to reduce overall background noise levels.
- Where specialist activities require high levels of sound insulation, alternative construction systems including separated wall framing to achieve necessary levels of isolation may need consideration.

Natural light and ventilation

In addition to playing a role in disaster management, access of natural light and ventilation to all functional areas of a facility can assist in improving the overall amenity of the facility as well as reduce energy/running costs.

In design, consideration of the following is important:

- Large clear panel windows for staff and general public areas provide a pleasant outlook as well as a way to observe outside activity.
- Provision of high level openings with

Transporting structures in the Australian bush.



- Roof/skylights over critical treatment areas in the facility.
- Staff management and impact on mechanical services and running costs.
- Dust control.

Health facilities with sufficient natural light have also proved to be more inviting and pleasant for patients, which is important as many indigenous Australians can be reluctant to visit health clinics on a regular basis.

Dust control

Dust is a major issue in many remote communities and has a significant impact on the health of community members.

- Consideration is given to the following: Reducing dust around the perimeter of the facility through:
 - Orientation of building and entry away from prevailing dust-carrying winds.
 - Control of vehicular movement on and around the site including car parking.
 - Surface treatment of driveways, parking areas and footpaths.
 - General landscaping and wind breaks to the perimeter of the site.
- Reducing dust entering the facility through:
- External door and frame detail and construction including all round weather strips/seals.
- High level window openings.
- Construction detailing to ensure external perimeter of the building is sealed, especially wall/floor junctions.



Opening a completed facility.

Passive thermal performance Building design should also be sensitive to the local environment and prevailing climatic conditions to minimise external energy running costs and maximise the comfort of the users of the facility.

Passive design measures employed need to recognise availability of staff time, the training necessary and high staff turnover and expertise with respect to managing any systems. Due to the remoteness of many communities, maintenance contractors and spare parts can take a considerable time to arrive. As such, only systems that are "self managed" should be explored.

- Consideration should be given to: Orientation and protection of the
- building to minimise solar radiation. Orientation, plan form and position of
- opening windows to maximise cross ventilation.
- Thermal mass in construction.
- Thermal insulation of all external walls and roof planes.
- Thermal insulation between air conditioned zones within the facility.

Logistical and seasonal challenges

Perhaps one of the biggest challenges when delivering a new indigenous health facility

comes down to logistics. The majority of indigenous health facilities are outside of metropolitan areas and major town centres, and some are only accessible by barge or plane. This can add a significant amount of cost to capital works projects, as well as increase the operational and maintenance costs.

The location of a community can also reduce the number of quality consultants. contractors and other service providers who are available, and this can also add cost and complexity.

In addition, remote indigenous communities can be cut off during the wet season in parts of the Northern Territory, Western Australia and Queensland. This reduces the window for construction to approximately seven or eight months of the vear.

Progress to date and looking ahead

Since 2000, Arup has completed over 215 indigenous health infrastructure projects around Australia with a combined capital works value of nearly \$200 million. These projects have ranged from feasibility studies to staff housing to primary health clinics. The improved health infrastructure, combined with continued Commonwealth funding and support for dedicated indigenous health programmes, has helped to improve the lives of indigenous Australians.

Fiona Lynch, former assistant secretary, Department of Health and Ageing, said: "Arup's work is an excellent demonstration of how it is possible for Australia to deliver a built environment that meets the challenge of the nation's changing demography through interdisciplinary collaboration between governments, professions and health service organisations.

There are still, however, dozens of communities around Australia that are in need of improved health infrastructure. The Australian Government is continuing to tackle health problems around the country through a combination of health infrastructure projects, improved health programmes, and education and training for indigenous Australians.

Conclusion

The Australian Government is committed to closing the gap in health outcomes between indigenous and non-indigenous Australians. Arup's involvement, ensuring the delivery of new and improved health infrastructure that represents value for money and meets community needs, is a key element of this process.

'Consultation with the community during the early design phase of a project not only helps the consultant ascertain the needs of the community, but it also helps to create a sense of ownership among the indigenous community.



Arup, as a firm, has a commitment to communities and sustainable development. Good infrastructure undeniably improves lives, and good, sustainable infrastructure goes one important step further. It shows how we can improve lives in the future, as well as today, helping to create a positive legacy for generations to come.



'Cultural factors vary substantially between communities across Australia.'

Acknowledgements

The body of knowledge utilised by the authors includes the facility design guidelines for indigenous health infrastructure that were developed by Arup for the Australian Department of Health and Ageing. A number of individuals contributed to the guidelines, including health facility planners, architects, Dramatic Australian landscapes.

anthropologists, indigenous health workers and government officials. Without their input to the facility design guidelines, this article would not have been possible.

References

2

- 1 Australian Bureau of Statistics.
 - Published in MJA, August 2006.
- 3 National Aboriginal Health Strategy Working Party.
- 4 Shannon C., Carson A., Atkinson R.C. 2006. The Manager, *Medical Journal of Australia* 184 (10) p531.



ARUP

Do single patient rooms reduce infection risks?

Government guidelines for new build hospitals in England and Wales currently state that 50% of patient bedrooms should be single rooms.

Ysbyty Aneurin Bevan, in Gwent, South Wales, is the first general hospital in the UK hospital to have 100% singlerooms and there are other new builds in theUK following suit.

There is an ongoing debate among healthcare professionals regarding the benefits of single rooms. Some research has shown that patients received better care while housed in single rooms coupled with greater privacy and reduced noise which leads to lower stress levels. Other research states that nurse walking times are greater in single room accommodation which could affect patient care. Building costs are higher for single room accommodation compared with multi-bedded wards. There is also some supposition on various aspects of patient care in single rooms with regards to cleaning and reducing the spread of infection. Although some evidence exists, more research is needed to investigate patient safety in single rooms, particularly with regards to reducing the risk of cross-infection by other patients and staff. Ultimately, the aim is to create an optimally comfortable and safe environment for patients.

In an attempt to clarify some of these issues, a research study was undertaken to investigate the effect of hospital ward activity on microbiological load in multi-bedded wards and how the chain of infection might be broken.

Infection transmission in hospitals

Microorganisms follow certain paths of transmission which start with an infectious source (animate or inanimate) and transmit to a susceptible host. The transmission stage from source to host depends on various factors relating to the infecting microorganism, the environment to which the microorganism is exposed, and the effectiveness of the transmission route. Therefore, it is important to identify this transmission route at the onset of an outbreak as it is often the most effective way to break the chain of infection. The last link in this chain of infection is the host, which in a hospital environment will be human. The susceptibility of that host to infection is dependent on his or her immune responses which will be affected by age and immune system suppression.¹

The main transmission routes of microorganisms in hospitals have been identified as contact, droplet, airborne, common vehicle, and vectorborne.² The World Health Organization (WHO) identifies that contact, droplet and airborne are the most important of these transmission routes in hospitals and that additional safety measures must be considered to prevent the transmission of infections in healthcare facilities.³

The main transmission routes associated with infection spread in hospitals can therefore be described as follows:

- Contact spread: there are two main types of contact spread – direct person-toperson contact and indirect contact.
- Direct contact spread involves the physical transfer of microorganisms between a susceptible host and an infected or colonised person via direct body surface to body surface contact.² This may involve transmission through an open wound or sore, or vulnerable body opening such as the mouth, nose or eyes.⁴ Hospital activities that may be associated with this mode of transmission include patient washing, dressing and moving.
- Indirect contact spread occurs when a susceptible host comes into contact with a contaminated intermediate object or surface such as hospital equipment, beside tables, door handles or contaminated hands.⁵
- Droplet spread: droplets (typically larger than 10 microns in diameter) are generated from people coughing, sneezing or talking. These particles only travel short distances, usually 1 m or less. Transmission between source and recipient persons therefore requires close contact.²
- True airborne spread: this route includes droplet nuclei from evaporated droplets and dust particles which may harbour

'Microorganisms follow certain paths of transmission which start with an infectious source and transmit to a susceptible host.'

microorganisms (typically 1-5 microns in diameter) transmitted over long distances borne on convection currents.

A recent document published by the Centers for Disease Control and Prevention has expanded the traditional transmission routes to further define the airborne transmission of infectious agents.6 These guidelines describe the transmission of small particle aerosols over short distances which originate from patients during a specific activity, such as endotracheal intubation. A new term "aerial dissemination" is defined to describe this mode of transmission. The route involves particles entering the air for a short time (i.e. some minutes), and then falling onto exposed surfaces. Particles may become disturbed via various hospital ward activities such as floor polishing or bedmaking. When these particles land they can either infect patients directly or indirectly through the contamination of clinically important surfaces. The study undertaken here was

Katherine Roberts

Katherine Roberts is a graduate engineer working in Arup's environmental physics team, London. She obtained a Masters in the Built Environment from the University of Leeds and a Ph.D. doctorate (investigation of the aerial dissemination of Clostridum difficile in the clinical environment.



particularly interested in the aerial dissemination route of microorganisms.

The main aim of the study was to investigate the relationship between ward activity and bioaerosol production. Regular microbiological and particulate (0.3 - 5 microns) sampling of the ward air was undertaken, together with an observational study of ward activity. Results for microbiological sampling have been published elsewhere^{7.8} and are not presented here.

Observational survey

Throughout the study a number of ward activities were observed. It was decided that during times when several activities occurred at the same time, analysis of individual activities would not be possible. These periods would therefore be defined as high activity periods, defined specifically as times when four or more people (excluding patients and researcher) are undertaking two or more activities in the bay area. Activities undertaken during these high activity periods could include bedmaking, ward rounds, cleaning, serving of food and drink, drug rounds, opening and closing of bed curtains and helping patients to wash and dress. There are also numerous occasions when activities occur in the wards at times of low activity. These periods of low activity are defined as times during the day when three or fewer people are in the bay area undertaking only one activity at a time. Other activities which are identified include bedmaking, floor sweeping, floor mopping, general cleaning, commode use and nebuliser use. At these times no other activity was being undertaken in the bay area. General cleaning could involve the wiping of surfaces, cleaning the toilet or dusting of surfaces.

Particulate air sampling

Airborne particulate data collected throughout the study suggest that the greater than five microns (>5 μ m) particulate data correlates very strongly to ward activity. Data for this particle range were therefore analysed to establish if a significant relationship exists between ward activity and peaks in particulate counts. All ward activities observed during the study were defined according to their onset and duration in relation to peaks in particulate counts. Particulate count data were measured over

'Aerosol particles are frequently liberated within the clinical environment as a result of specific ward activities.'



Figure 1: Average increase of particulate counts during ward activities.

five minute time periods correlated to events occurring within this time. A total of 316 ward activity events were observed during the study. The amount of particulate increase occurring during an activity was calculated by taking the difference between the lowest value recorded at the start of the activity and the highest value recorded during the activity.

Figure 1 shows the average percentage increase of particulate counts >5 μ m for all ward activity. Particulate counts that decreased during an activity were treated as zero increase. The greatest increase in

particulate counts was seen during periods of high activity where particles were found to increase up to 471%. The activities most often undertaken during these times included stripping beds of dirty linen and helping patients to wash and dress, which often involves curtain movement. During times when bedmaking occurred independently from other activities, particulate counts for the >5 μ m data had an average increase of 181%. Cleaning was also shown to significantly increase particle counts. Dry sweeping had an average increase of 165%. Floor mopping in comparison was relatively low with only a 69% increase although it still had an impact. Commode use showed a large average increase of 142%.

'More research is needed to investigate patient safety in single rooms.'



Conclusions

This study found that aerosol particles (including bioaerosol particles) are frequently liberated within the clinical environment as a result of specific ward activities. Ward activity was found to increase particulate counts significantly, especially during high activity periods, bedmaking, dry sweeping and commode use. The aerial dissemination of infectious particles could have detrimental effects on the health of susceptible patients through particles being redistributed into the patients' immediate environment. This will therefore increase the risk of infection to susceptible patients via hand contact of contaminated surfaces. The contact route of transmission for many hospital infections may still be the most important transmission route but it is supplemented by the aerial dissemination route as aerosolised infectious particles will land on surfaces and be transmitted to susceptible patients. Ward activity in single rooms will likely be reduced assuming only low activity events occur due to a reduced number of people present compared with the high activity events which occur daily in multi-bedded rooms.

These findings highlight the importance of using single rooms by creating physical and psychological barriers to reduce the transmission of hospital-acquired infections. Staff and visitors are more likely to wash their 'Staff and visitors are more likely to wash their hands when patients are housed in single rooms as these create physical barriers which serve as reminders.'

hands when patients are housed in single rooms as these create physical barriers which serve as reminders. This hand washing, of course, relies on the location of basins in single rooms and would ideally benefit from basins being easily accessed near the door so staff and visitors can wash their hands before having contact with the patient.

Acknowledgements

This work was completed as part of my doctorate undertaken at the University of Leeds alongside the Pathogen Control Engineering Institute (PACE – www.engineering.leeds.ac.uk/pace) and the Bradford Infection Group. The hospital study was undertaken at Harrogate District Hospital and supervised by the Infection Control Team.

References

- 1 Mims C. *et al.* Chapter 13: Entry, Exit and Transmission, in *Medical Microbiology*. 2004, Elsevier Limited: London. p. 123-142.
- 2 Garner J. S., Guideline for isolation precautions

in hospitals. Part II. Recommendations for isolation precautions in hospitals. *American Journal of Infection Control*, 1997. 24 (1): p. 32-52.

- 3 World Health Organization, *Practical guidelines* for infection control in health care facilities 2004. p. 1-103.
- 4 ASHRAE, Chapter 4: Overview of health care HVAC, *in HVAC Design Manual for Hospitals and Clinics*, Geshwiler M. Editor. 2003. W. Stephen Comstock p. 27-45.
- 5 Garner J. S. Guideline for isolation precautions in hospitals. Part II. Recommendations for isolation precautions in hospitals. *American Journal of Infection Control*, 1997. 24 (1): p. 32-52.
- 6 Centers for Disease Control and Prevention, Guideline for isolation precautions: preventing transmission of infectious agents in healthcare settings 2007. 2007, CDC: Atlanta, GA.
- 7 Roberts K. et al. Aerial Dissemination of Clostridium difficile spores. BMC Infectious Diseases, 2008. 8: p. 1-7.
- 8 Roberts K. et al. Bioaerosol production on a respiratory ward. Indoor and Built Environment, 2006. 15: p. 35-40.

ARUP

Façade-led upgrades revitalise older buildings

The economic downturn in many countries has effectively put construction of new healthcare buildings on hold. In the UK, the feasibility of upgrading a number of existing hospitals has been explored.

Solutions have been sought that represent more than just running repairs and doing the bare minimum. We aim to prepare buildings for the next 30 years and exceed current requirements. This article focuses primarily on façades as these are often key to unlocking the future of buildings. 'Façade-led upgrades' are promoted.

The most pressing requirement and indeed opportunity is to upgrade buildings that are between 30 and 50 years old. Economic necessity demands that we look at how these can be adapted and upgraded in order to meet the needs of 21st Century healthcare. In doing so, one must first take a holistic approach by business case modelling, examining space planning requirements, and considering potential advances in medical technology and likely changes in patient needs. A design team may then consider how requirements and constraints can be applied to the physical reality of the buildings available. Taken into consideration are the fabric, structure and services of the buildings, and the people, equipment and activities accommodated.

The business case model may be complex if it is to include all relevant factors: CAPEX and REVEX, energy savings, running costs, value gained if floor plates are extended, revenue from shedding space released, and even potential new income streams from the revitalised hospital building. The model may need to look far beyond just the immediate

'A particular issue is the need for accurate energy modelling in order to inform decision making.' costs associated with the particular building. Projects should not be considered in isolation. There needs to be an overall strategy. Programme management techniques can consider the best sequence.

Rigorous feasibility studies are required to investigate whether major intervention is possible with the attendant disturbance that this brings but potentially greater benefit gained, or whether an incremental approach can be pursued instead to bring about the change progressively while delivery of healthcare services continues.

Drivers for upgrading façades

As part of the PFI initiative in the UK, there is a shedding of the very oldest buildings but the immediate problem lies in what to do with the buildings that are between 30 and 50 years old. In fact, 50% of the UK's healthcare estate predates 1985.¹

Two particular items on the current national healthcare agenda are to:

- Provide more efficient healthcare in a smaller estate.
- Improve patient privacy and dignity.

This raises an apparent conflict between shrinking the estate and a need for greater area per patient in order to improve privacy through the introduction of more single patient rooms with en-suite bathrooms. However, both these aims can be achieved in many of the 30 to 50 year-old buildings given their flexibility and robustness by:

- Converting inefficient space into space that is better suited for future needs.
- Creating new space by grafting additional floor area onto the building allowing functions to migrate from less well suited space elsewhere on site. The less suitable space may then be shed.

Other topical issues that may drive a façade-led upgrade are:

- The carbon agenda. Improving the building envelope will act to reduce energy consumption.
- A desire to create amenity space and family accommodation.
- Quality accommodation comparable with hotel standards. Both the decorative order

inside the building and external appearance are functions of façades. This is particularly pertinent given the prospect of patients' rights to choose their hospital, and any results-based payment mechanism. It may also assist in attracting and retaining a skilled workforce and bring improvements in staff productivity and reduction in absenteeism.

- Infection, control of pathogens, and significant reduction of healthcareacquired infections. The internal surfaces of the façades must be cleanable.
- New diagnostic equipment and its requirements for dedicated treatment suites. There may be challenges of simply moving equipment into buildings; and there could be requirements for heat dissipation, floor strengthening and vibration control. The building façade can play a key role in providing access for new equipment.

What are the 1960s-1980s buildings?

Typically, many UK city hospital sites consist of buildings of various ages and designs that have gradually agglomerated together in an ad hoc manner over many decades. The spaces between buildings will have been progressively consumed by interfaces between them. There will be convoluted circulation and building service routes, some now obsolete but too difficult to remove. Storage areas will be at a premium and in the wrong places and there will typically be a multitude of different ground and building floor levels. Some buildings may have become

Philip King BSc (Hons) MRICS MCIOB MSFE

Philip King is an associate director and founder member of Arup Façade Engineering, part of the Arup organisation specialising in design of the building envelope. He has a particular interest in upgrading existing buildings, and points to how a substantial positive impact on overall energy consumption can be achieved. He is currently involved in a number of healthcare projects including the upgrade of Guys Hospital tower. London.





Figure 1: Exemplar retrofit window. The actual window is at Altnagelvin Area Hospital, Northern Ireland.

locked in on their site by adjacent development.

Many of the 30 to 50 year-old buildings are concrete structures with either precast or brickwork cladding, typically up to 10 storeys in height and with flat roofs. In keeping with healthcare design philosophies at the time, there was an emphasis on maximising sunlight, fresh air and cross ventilation through the façade. Moderation of a reasonably constant comfortable internal climate from the external weather conditions prevailing at different times of the year was addressed by heating, and by opening or closing windows and blinds. Control of the environment rested with ward staff rather than patients, and was generally never completely successful in achieving comfort.

Mechanical air handling systems became more prevalent in the late 1960s. Sealed façades replaced natural ventilation. It was later realised that poorly maintained air conditioning brought with it risks of Legionella contamination. By the 1970s, changes in UK's economy and industry changed the nation's healthcare requirements. A new generation of buildings emerged, often lower rise with pitched roofs and less institutional in appearance. Internal atria began to feature in designs. A particular landmark came with the 1973 oil crisis. However, designers did not immediately improve the energy consumption performance of buildings and it was not until the late 1970s that insulation began to feature much in façade designs. These lower rise buildings may currently have less obvious need for façade upgrading. However, these buildings may have a greater façade area for the floor area contained and thus arguably present opportunity for achieving greater impact in energy improvement terms.

Upgrading

There are typically a number of ways that the façades of the buildings being considered are challenged to serve current purposes:

- The windows were simple designs by current standards with single clear glazing and without thermally broken frames. This creates high heat gains and losses.
- Mechanisms and ironmongery were prone to jamming. Windows became troublesome and draughty due to poor fit.
- Spandrel panels lack insulation and have poor insulation values.
- Concrete elements may be spalling due to low reinforcement cover and carbonation, or suffering other causes of deterioration. Such problems lead to an ongoing cost for regular descaling of loose material and a persistent risk exposure that debris could fall causing death or injury, damage to property, or adverse publicity.

- Asbestos is often present in the building envelope.
- There may be many building service penetrations and interfaces added to the façades.
- The façades may contain a number of dirt traps which are impossible to clean.
- The façades may create difficulties in controlling the presence of airborne and surface pathogens.
- Maintenance and replacement of components may be challenging. Gaskets and seals may have deteriorated with age. Components may no longer be available. Maintenance staff may need to attend frequently both inside and outside the building which is disruptive to healthcare activities within the building.

Overcladding and recladding solutions

Overcladding and recladding schemes have been introduced for hospital buildings. Many aspects of the façades' design and performance need to be considered together. An engineering-led approach is essential in order to optimise design. Without calculation and simulations, there is considerable danger that the end result will be less than wholly successful despite considerable investment. A particular issue is the need for accurate energy modelling in order to inform decision making. A number of approaches and tools



Figure 2: Impact of improved shading.

are suited particularly to modelling existing buildings. These models are also important later for clearly demonstrating improved performance through monitored data.

A group of objectives concerns the façade's ability to moderate the internal environment from the range of external conditions that prevail throughout the year. The façade can control the passage of water and air, light, heat loss and solar gain, glare, and noise to achieve occupant comfort and energy efficiency as well as afford the patient, carers and staff the ability to visually engage with the external environment, a key component of the therapeutic space.

A lesson learned is that after the façade has been improved the building services must be re-tuned. Previously, controls may have been set to compensate for considerable air and heat loss, which will no longer be the case. If this re-tuning is not done, occupant discomfort will follow and expected reductions in energy expenditure will fail to materialise.

In a number of cases examined, buildings had suffered from extensive leaks and draughts. Overcladding or recladding had

Concrete cladding elements may often lose integrity. Overcladding can secure loose material and slow deterioration.



addressed weather-tightness problems.

A new façade may incorporate significantly more insulation, reducing the amount of heat lost from the building.

The glazed areas of the façade raise a number of issues. The colour and type of glass must be selected to admit the complete spectra of visible natural light. Suitably designed shading can have a substantial impact on energy consumption, as shown in Figure 2. Solar selective glass allows natural light to be admitted while, to a large extent, excluding solar gain. Another option is the installation of a brise soleil. However, use of a brise soleil may raise concerns about the obstruction of views from the building and complications for window cleaning.

In the evening and early morning, daylight admittance needs to be controlled in order that patients may rest. Screening is also required for privacy. It is possible to integrate suitable blinds into the façade. However, usually they are located inboard of the façade.

The controlled use of natural ventilation can improve patient comfort. Passive ventilation of large parts of a building may be achievable with a suitable façade design and sufficient building mass, although some localised heat loads and high dependency areas may still require mechanical cooling and ventilation. Future cooling loads can only be estimated. Climate change and the prospect of new equipment and occupancy level are factors.² By using CFD airflow modelling techniques, air movements can be simulated in order to reduce draughtiness, as shown in Figure 3.

Façade designs that buffer the external air can, for taller buildings, permit natural ventilation in moderate winds. Internal air distribution and movement should also be considered, particularly where there is a deep floor plate design, an open plan, or high internal leakage through shafts and risers. Other considerations when designing 'The most pressing requirement and indeed opportunity is to upgrade buildings that are between 30 and 50 years old.'

windows concern security against intruders, smoking infringements, suicides and the possibility of people throwing objects out maliciously.

Façades present the opportunity to incorporate energy-generating technologies. There has been little adoption of this to date. In the UK climate, solar heated water may have potential.

The objective of facade-led refurbishment is to provide a building that can be run efficiently, requires little maintenance and allows healthcare to be delivered in a sustainable manner over the next 30 or more years. There are various sustainability rating systems, both existing and in development.3 Selection of components can encompass looking at impacts during their material extraction, manufacture and transport phases. Do components consume unsustainable natural resources, require large amounts of energy, generate pollution or involve exploitive labour? The construction process is examined to see whether the façade can be built in an energy efficient manner with waste minimised. Also considered should be the in-use life cycle impact, including benefits the façade may provide in other aspects. Such benefits include reduced overall building energy consumption, less maintenance, and a longer period until replacement. Finally, the end-ofuse impact must be considered - can materials be recycled or turned into energy, and will their disposal cause pollution?

Structural analysis and testing may be required in order to assess if there is capacity for the additional loads of the new cladding system and also the temporary structures

Windows may often have become dysfunctional, beyond economic repair and have poor energy performance.





CFD study of single rooms with en-suite and natural ventilation at high and low level.

such as mast climbers that may be needed to install it.

The challenges of working around continuing treatment and healthcare delivery are significant. Dust and noise must be controlled. Delivery routes and storage will be limited. Highly accurate and rapid LIDAR type geometric surveys permit off site prefabrication, especially as the base level interfaces are often highly irregular. Crane and site handling limits may dictate panel sizes and weights. The number of fixings should be minimised in order to avoid structure-borne sound disturbing occupants, or vibration affecting sensitive equipment.

Most cladding systems require vertically sequenced installation. This may be incompatible with floor by floor horizontal availability from the building users' viewpoint. Construction solutions exist which can reconcile these opposing requirements.

Another key aspect to be considered is the means of undertaking future maintenance and window cleaning. In addition to the needs of the façade itself, it is also a feature of healthcare buildings that their floors require periodic refurbishments and it is always a challenge to segregate contractor access on higher floors from healthcare delivery on lower floors. The new façade might therefore incorporate provision for this in future by having a permanent location that can provide a contractor compound and external hoist when required. The façades can also be used to improve building services flexibility and distribution.

Pods

The limitation of the overcladding approach is that it does not address additional space needs, particularly in response to the privacy and dignity agenda. Explored has been a more powerful approach involving grafting prefabricated, fully serviced and fitted out pods onto the outside of existing hospitals. These permit floor space to be extended for showers and WCs or amenity space. They can also provide opportunities for distribution of building services, soil and waste, medical gases and logistical deliveries up and down the building via the façade zone.

A key technical challenge is the structural support requirement. The pods must either be standing on foundations beneath or hang from a transfer structure at roof level. One must therefore consider ground level

'Passive ventilation of large parts of a building may be achievable.'

availability for foundations or spare load capacity in the building's structural columns. Building service connections and viable uses at the bottom and top where the new structure may not adjoin ward space are also issues. Fire safety and planning regulation compliance may arise. Provision for receiving links from future adjacent buildings is also a useful feature.

Conclusion

Buildings between 30 and 50 years old within our present healthcare estate are fundamentally versatile and adaptable. Upgrading their façades can bring about performance improvements and unlock their future. The façade design, with its multiple elements of thermal efficiency, natural daylight, ventilation, heating elements, shading, views and associated safety issues, is probably the most important engineered system in the built environment.

We cannot imagine what impact the next 30 years' developments will have on illnesses and medicine, healthcare technology, and economic, social and transport requirements. Developments from the genome are with us and the impact of nanotechnology is on the horizon. Perhaps the age range of our healthcare estate may be one of the things

that remains constant but how we use these buildings will change radically. In 30 years it may then be time to shed the buildings that are the subject of this article (which by then will be 60 to 80 years old) as we are currently doing with our pre-World War II buildings. Our most recent generation of metal and glass clad buildings will require upgrading as their cladding will have reached the end of its service life. Our successors in the field of healthcare estate management will probably face similar challenges to those we presently encounter. It will be invaluable if we have rehearsed and developed sound decision making models for them, and built and upgraded our present buildings wisely in order to leave them a less problematic legacy. To do so we must behave now with vision, invest in long-term planning and value good design.

References

- 1 ERIC (Estates Returns Information Collection), 2007-8 returns from NHS. Department of Health Estates.
- 2 TM48: The use of Climate Change Scenarios for Building Simulation: the CIBSE Future Weather Years. CIBSE. 2009.
- 3 BREEAM Healthcare XB, BREEAM 2009.







Towards merging Chinese and Western medicine

Over the past 10 to 15 years there have various concerns raised by those interested in the planning of future healthcare facilities in the West. Two of these concerns are the diminishing standards of healthcare due to lifestyle changes, and the increasing awareness of the benefits of Eastern therapies that rely on natural remedies and a stress-free environment.

The concept of the healing properties of the natural environment, together with the principles of individuals taking a holistic approach to their own healthcare, is gaining wider acceptance not only in the East but also in the West, and some hospitals are now offering traditional Chinese medication to supplement Western treatment.

These gradual changes in the medical system will have an impact on the design of future healthcare facilities. It is therefore essential that planners and designers should start gaining some knowledge of the traditional Chinese medical system so that they are able to understand the needs of the type of facility in which Chinese medicine can be provided. Traditional Chinese medicine has a history of over 4,000 years and has been adopted as an effective treatment in China and elsewhere in the world. As many research studies on combined Chinese and Western medical treatments pointed to satisfactory results, a combination of the two approaches is increasing in popularity, particularly in Asia. To address the increasing demand for traditional Chinese medicine, specialised hospital planning and engineering design are required.

Chinese traditional approach

Ancient Chinese society was developed with reference to everything in nature. In martial arts, for example, practitioners emulate some animals both in posture and movements. Similarly, caring for the human body is related to the traditional five basic elements in nature, namely Metal, Wood, Water, Fire and Earth. This is called the Five Element Theory.

Chinese medicine practitioners use the Five Element Theory to help ascertain the causes of diseases and associated symptoms to particular organs and so on. The Chinese believe that all things in nature are interlinked to one another. Everything must

Figure 1: Relationship between the five elements and nature.						
Five elements	Emotion	Colours	Flavours	Seasons		
Metal	Sadness	White	Spicy	Autumn		
Wood	Anger	Green	Sour	Spring		
Water	Fear	Black	Salty	Winter		
Fire	Happiness	Red	Bitter	Summer		
Earth	Spirit	Yellow	Sweet	Late summer		

Figure 2: Relationship between five elements and human body parts.

Five elements	Yin Solid organs	Yang Hollow organs	Sense organs	Tissue
Metal	Lungs	Large intestine	Nose	Skin
Wood	Liver	Gall	Eye	Tendons
Water	Kidneys	Bladder	Ear	Bones
Fire	Heart	Small intestine	Tongue	Blood vessels
Earth	Spleen	Stomach	Mouth	Muscles

therefore be in balance so that a healthy nature can be achieved. By applying the same theory to the human body, it is the Chinese belief that each of the five main body organs not only promote each other but also restrain each other so that a balanced and healthy body can be maintained.

In the Five Element Theory, the elements interact using four main cycles:

- Generating cycle.
- Controlling cycle.
- Overacting cycle.
- Insulting cycle.

A good understanding of these cycles helps Chinese medical practitioners diagnose symptoms and provide the appropriate medicine/treatment.

- There are also four methods of diagnosis:
- Observing the face colour.
- Smelling.
- Asking detailed questions.
- Feeling the patient's pulse.

Alice Chow

Alice Chow is a director in Arup, leading the company's delivery of programme and project management services in East Asia. She joined Arup in 1988 and has civil and structural engineering background. Alice Chow has spent most of her career in providing programme and project management services in projects of different scales and functionality — projects such as those



for airports, hotels, and schools as well as hospitals.

Alice Chow's "back to the basics" experience in setting up medical treatment facilities has been gained during her voluntary relief work with MSF in Afghanistan, Ethiopia and Banda Aceh. She also managed process-driven industrial projects such as those for breweries and aluminum plants where functionality drives the project and not the building form. Her insight on the future of traditional and modern health facilities is therefore based on these experiences.

Elise Chan

Elise Chan is a senior project manager in Arup's programme and project management team. She started her career as a structural engineer and joined the company in 2007. Elise Chan has been involved in managing various types of projects including those for the functional buildings of healthcare, hotels, schools and data centres.





The Hong Kong Anti-Cancer Society Jockey Club Cancer Rehabilitation Centre.

Chinese medicine concentrates on repairing and stimulating body functions by strengthening main organs to self-regulate, relieve symptoms and remove diseases. For example, if the kidneys are diagnosed to be unhealthy, treatment of the kidney must include strengthening of the spleen because the two organs are interlinked.

The relationship between the five elements and nature are shown in Figure 1, and the relationship between the five elements human body parts are shown in Figure 2.

Contrast

Western medicine has reached a high degree of technological advancement with medications, diagnosis and treatments being continuously updated as a result of well-funded medical and pharmacological research, and clinical studies, around the world. Western medicine is reliable, scientifically based, and has the advantage of being able to treat emergency conditions. However, its drawback is high cost, limited access, and side effects with chronic degenerative disease or lifestyle-induced illness.

In contrast, Chinese medicine is focused on strengthening the individual's vital energy (Chi). Its true value is in its power to strengthen a person's ability to recuperate, to enhance immunity and to maintain the maximum level of physical, mental and social functions.

Western medicine is therefore suitable in the treatment of emergencies and crisis situations while Chinese medicine is suitable in strengthening the body to maintain its ability to resist sickness and diseases.

Western and Chinese approaches to diagnosing sickness result in the use of different methods of treatment and medicine administration.

Traditional Chinese treatments and medicines are milder and less toxic, and are based on natural extracts. Western treatments and medicines are based on synthetic or semi-synthetic chemicals with high purity and toxicity. Traditional Chinese medicine involves the use of herbs, acupuncture, fire cupping, gua sha, dietary therapy, naprapathy, recreational tai chi and qigong, rehabilitation and meditation.

Integrated approach

The integrated approach of applying Western medicine to quickly relieve symptoms followed by use of the recuperative effect of Chinese medicine has had positive results in many documented cases.

An integrated approach can help patients to recover with fewer side effects during

'The integrated approach of applying Western medicine to quickly relieve symptoms followed by use of the recuperative effect of Chinese medicine has had positive results in many documented cases.'







Chinese medicine preparation.

treatments, and to be subsequently healthier. Such an approach can be successful with:

- Chronic pain diseases by application of acupuncture, naprapathy and recreational exercises.
- Ailments of the elderly through medicines and recreational exercises.
- Allergies through medicines and external application of paste or washes.
- Cancer treatment through medicines, acupuncture and dietary therapy.
- SARS through medicines and dietary therapy.
- Human swine influenza through medicines and dietary therapy.
- Diabetes through medicines and dietary therapy.

Challenges

Nowadays, Chinese and Western medicine collaboration in hospitals includes the setting up of a Chinese medical ward within a Western hospital. However, since Chinese medicine has more emphasis on the restoration and maintenance of an individual's health instead of curing symptoms when they arise, this type of approach demands more time, space, and Chinese medical practitioners. It is therefore not uncommon that a good Chinese medical practitioner would have a long queue in his or her ward.

As the demand for closer collaboration between Chinese and Western medicine increases, the future trend could involve having Chinese medicine based facilities for healthy people seeking health maintenance management, and equipment for Western medical style check-ups and diagnosis for the treatment of diseases and emergencies. These facilities would require more Chinese medical practitioners which is another real challenge.

In China, a degree of integration between Chinese and Western medicine already exists. A patient may be seen by a multidisciplinary medical team and be treated with radiation, surgery, chemotheraphy etc and, at the same time, with traditional Chinese herbal formulas and treatments. All Chinese medical practitioners in China are well educated in Chinese and Western medical knowledge. However, they have limited professional recognition outside China because their curriculum is totally different from that of Western medical practitioners. Moreover, qualification processes for Chinese medical practitioners in other Asian countries are still at a developing stage.

Operational, engineering and layout considerations

In general, the very basic requirements for hospital designs include the meeting of the highest standard of hygiene, the capability to accommodate future medical technologies, and, most importantly, ensuring the patient is cared for physically and mentally. In fact, there are no major differences in the requirements for Chinese and Western hospitals except where they differ in operation – this affects hospital layout planning. Facilities in which Chinese medicine is practised need:

Large herbal medicine sorting areas for

the pharmacy housing the closets. Many drawers contain all kinds of herbal medicines. The Chinese call such a closet the "Hundred-son Closet".

- Careful planning for waste storage, processing and removal. Herbal medicines are cooked, smelly herbal medicine pastes are prepared, and needles for acupuncture are cleaned or are designated for disposal.
- Naturally ventilated rooms with light pastel colours and large open areas for recreational and relaxation exercises. Air and light are the two basic natural elements that Chinese believe will help the body to recover and maintain balance.
- Single-bed ward rooms. These are recommended as certain treatments such as acupuncture, naprapathy and foot massage can be carried out in bed without moving the patient. Single-bed ward rooms mean the patient's privacy

'With the special characteristics of Chinese medicines, storage design must satisfy different requirements including those relating to air humidity and temperature, access and security, and space for storage.'



"Hundred-son Closet".

can be maintained when such treatments are used.

 Large waiting areas in clinics for scheduled patients as longer diagnosis sessions are required. For these areas, high levels of natural daylight and high quality artificial lighting levels are required as well as high quality acoustics. The environment must be relaxing and stress free.

Some of the important considerations for the planning and designing of integrated Chinese and Western medicine hospitals are highlighted below:

Treatments

- Spatial planning for medical diagnosis and treatment in the same room, for example when acupuncture is used.
- Air quality control with individual ventilation and fire protection systems for treatment rooms associated with odour-causing preparations, smoke and condensation. Odour circulation to other areas must be prevented. Treatments may include fire cupping treatment and a steam bath with Chinese medicine. Room finish materials should be selected on the basis that they may be subjected to condensation.
- Naturally lit and ventilated rehabilitation space for recreational tai chi, qigong and psychological counselling.
- Ambience within, and views from, treatment rooms that invoke a sense of calm during the diagnosis and treatment phases.

Medicine

- Western medicines are all pre-packed and delivered to the hospital ready to use while Chinese medicines require cooking and are individually prepared based on the Chinese medical practitioner's diagnosis. The logistics for Chinese herbal medicines should be carefully considered at hospital design stage. Taken into account should be herb procurement, delivery, allocation, storing, sorting, cooking, packaging and despatching.
- With the special characteristics of Chinese medicines, storage design must satisfy different requirements including those relating to air humidity and temperature, access and security, and space for storage.
- Herbal medicines and non-herbal medicines including dry insects and

ARUP

animal parts require air quality control . Toxic and non-toxic medicines require security controls.

- Pre-packed medicines such as pre-cooked herbal soups and medical paste require large refrigerators.
- Cooked herbal medicines require seven day storage before disposal, for the purpose of tracking should any abnormality arise after the medication. Sufficient space must be allowed for this storage.
- Herbal cooking rooms should have specially designed ventilation and drainage.
- Sufficient outdoor space for drying herbs should be provided.

Facility layout

- In adopting Chinese medicine into Western-style hospital facilities, there are many additional requirements and details that need to be addressed when planning and designing the facility layout.
- Provision must be allowed for warming up herbal medicine in the ward rooms.
- At least two bathrooms per ward should be provided to meet the needs of patients who have taken Chinese medicines.
 Patients may experience some diarrhoea during the course of detoxification, and will need to shower after the application of Chinese moxibustion.

Project experience

Since 2006, Arup has been appointed as the programme and project manager for the Hong Kong Anti-Cancer Society Jockey Club Cancer Rehabilitation Centre redevelopment.

The centre has adopted Chinese medicine for a certain numbers of treatments, and provides a wide range of comprehensive rehabilitation services for patients. Such services span recreational activities, nursing services, interest groups, health talks, and psychological counselling. The centre ensures quality care services are provided for cancer patients and aims to improve their rate of recovery.

People are becoming more health conscious and wish to have comprehensive medical services. There is definitely an increasing demand for the development of integrated Chinese and Western medicine facilities. 'Nowadays, Chinese and Western medicine collaboration in hospitals includes the setting up of a Chinese medical ward within a Western hospital.'

Conclusion

It is essential for hospital planning and engineering professions to understand the demands stemming from today's lifestyles and the benefits derived from therapeutic environments. Arup's knowledge and experience related to facilities which incorporate traditional Chinese medicine will make a positive contribution to healthcare delivery and patients' post-treatment quality of life.

Acknowledgements

The authors of this article would like to acknowledge the following individuals who contributed invaluable information. Without their input, the development of this article would not have been possible.

- Dr Bian Zhao Xiang, associate professor, director of the Clinical Division of School of Chinese Medicine, Hong Kong Baptist University.
- Iris Leung, general manager (administration) of the Hong Kong Anti-Cancer Society Jockey Club Cancer Rehabilitation Centre.
- Dr Chan Pak Ting, Chinese medical practitioner in Hong Kong.
- Michael Mui, Patrick Yung and Reynaldo De-Guzman from an Arup programme and project management team.

References

- Chinese versus Western Medicine www.naturallythere4you.com
- 2 *Healing with Whole Foods* by Paul Pitchford. Part III The Five Element and Organ System.
- 3 Hong Kong Government Press Release: Hong Kong pioneers 'fusion' of Chinese and Western medicines.
- 4 Relationship between Chinese Medicine and Western – www.chinadetail.com

We shape a better world

No walls here – a remarkable vision realised

To "realise the promise of personalised medicine for cancer patients by creating a world-renowned facility, 'without walls', where research findings move quickly into clinical care and clinical challenges drive laboratory research". This was the stated goal of the Garvan Institute of Medical Research and St Vincents & Mater Health Sydney in creating the city's Kinghorn Cancer Centre.

Located within the St Vincent's Research Precinct in Darlinghurst, Sydney, the new cancer treatment facility "builds on a longstanding and well-developed integration of research and clinical care, collaborating to provide national leadership in translational research and the development of personalised medicine approaches to cancer".

Translational research is defined as "research focusing on the bridge between basic laboratory research findings and application to settings involving patients and populations". Personalised medicine, meanwhile, "combines knowledge of the underlying biology of a cancer, and unique physiological aspects of a patient, to determine the most appropriate treatment for that person".

Directly driving laboratory research The Kinghorn Cancer Centre will allow clinical challenges to directly drive laboratory research and enable research findings to be

'Garvan's approach to holistic care removes the metaphorical walls between researchers, scientists, clinicians, patients, families, staff, and the outside community.'



The St Vincent's Research Precinct (SVRP) in Darlinghurst, Sydney.

rapidly translated into clinical applications for the prevention, diagnosis and treatment of cancer patients. The Garvan Institute is helping to generate new paradigms in cancer research that keep pace with the exponential growth of knowledge and current international best practice. This facility is unique in providing a comprehensive "bench to bedside" research paradigm.

The diagnosis and treatment of cancer is quite different from conventional medical approaches. Cancer itself is complex and treatment outcomes are heavily influenced by each patient's unique physiology. Traditional approaches to cancer care in Australia have not widely incorporated the benefits of a multi-disciplinary approach to implementing personalised medicine.

"Personalised medicine relies on the detection of biomarkers to aid patients and clinicians in the process of clinical decisionmaking. These can be biomarkers of the presence of cancer, the likelihood of outcome, or response to therapy. Collectively, these biomarkers are called diagnostics." -The Garvan Institute and St Vincents & Mater Health Sydney.

Unlike a "comprehensive cancer centre", the focus of the Kinghorn Cancer Centre is not on coordinating the care of a large

volume of patients, but on the combination of the fundamental science (molecular biology) of cancer and strong clinical interactions, leading to the development of new diagnostics and therapeutics and the delivery of holistic and individualised cancer care.

Holistic and individualised cancer care balances all aspects of each patient's life in delivering personalised diagnosis, therapy and treatment and providing for the quality of life needs of each individual, both in treatment and after treatment. Patients at the

Georgina James

Georgina James worked for 25 years as an architect before joining Arup in 2010 as an associate of the Programme and Project Management Australasia, Health Facilities and Estates team. She ha led the management and delivery of a wide range of institutional buildings focusing on health projects in Australia and the USA



Her strength in delivering high quality health projects is built on a solid foundation of core health architecture planning and design experience, a strong background in user and stakeholder consultation, an understanding of complex health campuses and extensive experience in the multi-disciplinary design process.



Arup developed a 3D model of the atrium and low-rise wing of the laboratory to investigate the effects, on the indoor environment, of air infiltration when doors were left open, the effectiveness of the spill air approach to cooling the atrium and the potential for heat build-up at the top.

'The Kinghorn Cancer Centre brings together around 250 cancer researchers, clinicians and support staff into a single location.'

Kinghorn Cancer Centre will be directly involved in the research and decisionmaking process. As patients become more informed and aware of the multiplicity of treatment options, this knowledge can be disseminated more widely to families and consumers.

Multidisciplinary teams

At the same time, researcher involvement in multi-disciplinary teams, and more effective links between research and clinical care services, will enable clinical issues to be more rapidly examined in the research laboratories and clinical trials.

The model of care adopted by the Centre promotes "integration and co-ordination across settings, providers, and specialties" and is defined through "an integrated patient journey/continuum of care approach for patients with cancer, and for their families and carers". – NSW Cancer Institute, NSW Cancer Plan 2007-2010, Accelerating the Control of Cancer.

Garvan's approach to holistic care removes the metaphorical walls between researchers, scientists, clinicians, patients, families, staff and the outside community, creating an integrated and multi-disciplinary paradigm. The success of this paradigm is based on its ability to promote "effective partnerships, networking, interdependency, and collective action, between those with the ability to improve cancer results." – NSW Cancer Institute, NSW Cancer Plan 2007-2010, Accelerating the Control of Cancer.

Garvan's approach to the design of this Centre was to emulate its own vision of breaking down the barriers to optimum outcomes for cancer patients. To respond to this, the design team needed a comprehensive understanding of the challenges faced by The Garvan Institute in providing tailored treatment for cancer – i.e. personalised medicine.

A 'holistic approach'

A holistic approach was needed to create designs that achieved optimal outcomes and embodied The Garvan Institute's holistic vision. The optimum design for one particular discipline is not always compatible with the optimum for other disciplines, or compatible with Garvan's vision and goals. The optimum result needed all the team to emulate Garvan's approach and to work in close collaboration toward the same goal.

The metaphorical walls between the many different design disciplines and the client, who was a key participant in the design process, needed to be removed to create the best building possible for the Kinghorn Cancer Centre.

The Centre's key features

The Kinghorn Cancer Centre brings together around 250 cancer researchers, clinicians and support staff into a single location and is a key component of the St Vincent's Research Precinct. The Centre provides over 10,000 m² of research and clinical space, designed specifically to meet the unique requirements of patient-focused research outcomes and incorporating technologies integral to translational research.

The new building is seven storeys high, with an underground car park, roof plant and a roof terrace and garden. Half of the building is dedicated to laboratory spaces. It contains:

- State-of-the-art research laboratories for 120 scientists across several levels.
- Core facilities for molecular genetics and molecular pathology.
- Specific laboratories for development of alternative therapy techniques.
- Purpose-designed clinical data management facilities to provide highlevel analyses of clinical information.
- Specially equipped multi-disciplinary review suites for individual cancer cases and clinical trial coordination to increase participation in clinical trials.

 Facilities for holistic patient coordination and care, patient education and support groups.

'Cutting edge technology'

The Centre incorporates "cutting edge" technology throughout including advanced technologies for microscopy and experimental molecular imaging, all located in dedicated, vibration-free space.

High-end data and video conferencing technologies, with the capacity for very highbandwidth data transmission and high speed data transfer of 10 GB/sec, are other key features. These technologies provide the capacity for outreach and access for clinicians and patients in rural and regional New South Wales.

The overarching requirements of the design were:

- Global best practice in laboratory design. Key features pertaining to global best practice were gleaned from recently completed projects identified through consultation with Arup industry leaders around the globe.
- Potential environmental impact. The mission and values of the founding Sisters of Charity and Sisters of Mercy drive the daily activities and vision of St Vincents & Mater Health Sydney. Following a Vatican conference on climate in 2007, the Sisters of Charity made a firm commitment to sustainability and expressed their desire to reduce the footprint of their buildings through reductions in energy and water use. Comprehensive Environmentally Sustainable Design (ESD) principles, which significantly reduce the carbon footprint of the facility, were incorporated into the design. Arup undertook a review of international case studies and rating tools to aid in the establishment of benchmarks for energy rating in order to understand the system performance in operation. Some of the many sustainable initiatives incorporated into the design are described later in this article.
- Flexibility and future-proofing. The facility has incorporated flexibility as a key overarching driver in its design to address rapidly changing practices, new technologies and new research directions, e.g. greater robotics and automation of research activities. Exemplifying the rapidly changing equipment technologies, sequencing equipment – which sequences the human genome – can now perform in hours what used to take years. Hi-tech equipment such as this uses considerable energy and has a high heat output to be accounted for in future scenario planning.

'Comprehensive environmentally sustainable design (ESD) principles were incorporated into the design.'



The CFD model results indicated that heat build-up at the top of the atrium during a peak summer day, which could begin to impact on the occupied spaces on the laboratory's top floor, would not pose significant issues.

CFD modelling showing peak summer temperatures on the east-west elevation.

Arup conducted carefully considered scenario planning to guide planning for future flexibility. Ultimate flexibility was not the goal, rather a targeted range of flexibility options based on scenario planning. This helped to avoid wasteful spending on overallocation of space, over-sizing system of capacity and added energy, to run larger capacity plant for "just in case" scenarios. Open and collaborative laboratory environments were designed to be sufficiently flexible for a wide range of future uses, equipment and technology.

The cutting edge design of the Kinghorn Cancer Centre reflects the similarly cutting edge technology contained inside. At the same time, however, "looks were subservient" for this building. The focus of the design was to support Garvan in promoting a culture of collaboration in which individuals achieve more through teamwork and "partnerships, networking, interdependency and collective action" (NSW Cancer Institute, NSW Cancer Plan 2007-2010, Accelerating the Control of Cancer) among all those involved in the multidisciplinary teams.

The atrium

The focus of the building is on the patient's experience. An open and welcoming feeling prevails from the moment patients enter the building through to the end of their treatment.

In tune with the Kinghorn vision, conventional separations between the public and Kinghorn staff have been broken down. A pivotal design feature of the Kinghorn Cancer Centre is the strong visual link between the central atrium and write-up spaces, which strengthens the interconnection of activities and promotes awareness for patients and the public. 'Reflecting global best practice and the Kinghorn Cancer Centre vision, walls are removed, and clinical investigators and laboratory-based researchers cross boundaries and interact.'

This open and welcoming feel upon entering the facility has been emulated in the design of the mechanical systems. The quality and performance of the indoor air has been considered just as high a design priority as the relationships between the spaces, particularly in a highly technical and controlled facility with barriers removed.

A 'semi-passive' environment

The atrium is designed as a semi-passive environment with no mechanical air conditioning offering a more natural air quality and reduced energy usage. Computational Fluid Dynamic (CFD) analyses were used to determine the comfort level and performance of the atrium environment and ensure it offered the same comforting and welcoming feel as the physical space. System control hierarchies were employed to control the level of conditioning of the air in the spaces.

The atrium void and landing areas receive sunlight during the day and are not actively air conditioned, but tempered via the relief air from the adjacent conditioned spaces. Being a transient thoroughfare air conditioning was not deemed appropriate, resulting in cost and energy savings. This creates a more natural feel, is more welcoming to patients entering the Centre and moderates the psychological impact of entering a treatment facility.

'All in the air'

As one moves from the warm and welcoming atrium areas to the less informal write-up spaces, and on to the adjacent controlled laboratory spaces, the indoor air performance emulates this transition – from a warm natural environment, to one with floating performance and variable controls, to the highly designed environment of the laboratories. The CFD modelling analysed the impacts of changes in the use of the spaces and how this translated to changes to the indoor environment with appropriate adjustments in the controls.

Promoting the culture of collaboration through removal of conventional separations and boundaries, and metaphorical walls between people and spaces, was extended to workspaces and laboratory areas. Reflecting global best practice and the Kinghorn Cancer Centre vision, walls are removed and clinical investigators and laboratory-based researchers cross boundaries and interact, both formally and informally, on planned and unplanned bases. In the laboratory spaces, this created quite a challenge for the design team.

A first for Australia

In a first for Australia, the laboratory environment employs demand-controlled ventilation to address the complex



In heating mode in an atrium with a door to the outside, there is always potential for downward draughts to create uncomfortable conditions for the occupied ground floor space. This CFD model illustrates that some draughting will occur in a corner of the laboratory's atrium, but would be effectively mitigated by ground floor heating.

ventilation requirements without subdividing the spaces into compartments. There are no walls here to block interaction; everything is controlled by air and highly sensitive air quality sampling systems.

Each laboratory module was provided with a control system that determines the flow rate via supply and exhaust. Some internal boundaries have been eliminated, and additional moderation achieved, via adjustment and supplementation of terminal control units and control system expansion. The laboratory design includes air quality sampling systems integrated with the ventilation control to create demandcontrolled ventilation. This allows air change rates to be based on actual air quality measurement. The addition of a purge function provides full air flow when required and the inclusion of down-draught laboratory benches to remove contaminated air at the source further enhances the air performance.

The facade

The open and welcoming feel of the facility depends heavily on the façade design – a high performance construction designed to moderate the indoor environment and optimise comfort levels for occupants. The façade provides external shading designed to reduce solar heat gain and maximise daylight to interior spaces. Façade optimisation studies underpinned the glare and blind control strategies which were used in conjunction with the façade's detailed design.

Sustainable design

Significantly lower energy requirements will be achieved for this facility through many initiatives for efficiency of energy and water use. These included:

- Energy modelling to create a baseline of performance against which energy efficiency strategies will be measured. Such modelling was performed for the central cooling and heating plant; ventilation and hydraulic systems; laboratory fume hood and exhaust systems; vertical transportation; lighting systems; and, small electrical power loads.
- Daylight and occupancy sensors control lighting while reduced levels of ambient lighting reduce power consumption.
- Variable air volume systems regulate airflow in response to individual room load, reducing heating and cooling loads.
- Dual CO²/VOC monitoring systems regulate return air based on occupancy of non-laboratory spaces.
- Reduced electrical infrastructure based on evidence of current usage, retaining appropriate redundancy using a standby generator for sub-station or network failure.

Sydney's chronic water shortage has been addressed by using non-potable water, obtained through rainwater harvesting, for cooling towers, irrigation and toilet flushing, thereby reducing potable water consumption.

Some 'unconventional approaches' The breaking of conventions, and the breaking down of walls that hinder the optimum operation of this facility, naturally led to unconventional approaches to other aspects of the design. In an integrated approach to the design of the vertical transport system, the design encouraged walking and using the stairs to promote better collaboration and awareness. Stairs are designed into the atrium as a prominent and highly accessible design feature. Pedestrian movement and vertical transport calculations were adjusted for this with a resulting reduction in energy usage and space requirements.

Staff, of course, need security, but they also want to enjoy getting around with minimum fuss. The design of security systems for the Centre, patients and staff, required an unconventional approach. Interconnecting stairs between the laboratory spaces are highly accessible. Uninterrupted patient services are a feature of clinical areas, the ability to move easily between spaces and maintain appropriate security, were further reflections of the collaborative goals of the Centre.

The Kinghorn Cancer Centre truly embodies the exceptional vision of the Garvan Institute of Medical Research and St Vincents & Mater Health Sydney. The completion of this unique facility is a remarkable demonstration of the inseparable relationship between vision, process and outcome.

• A great deal of background information was obtained from a publication on the Kinghorn Cancer Centre published by the Garvan Institute of Medical Research and St Vincents & Mater Health Sydney. Other information was obtained from interviews with members of the client and design teams, the original design brief and Arup's own design reports.



'The breaking of conventions, and the breaking down of walls that hinder the optimum operation of this facility, naturally led to unconventional approaches to other aspects of the design.'

Pioneering in the 'new' Poland

In 2005, sixteen years down the political and economic post-transformation road, Poland was the state of seemingly endless well-paid opportunities for entrepreneurially minded, educated and eager young individuals.

It had also struggled with the inheritance of a cumbersome, inefficient and expensive healthcare system of the bygone era that the half-hearted reforms to-date had changed very little.

The gap between growing expectations of a wealthier population and the capabilities of the National Health Fund (NFZ) very soon created a booming market for private providers of healthcare services.

Today, close to 100% of Polish dental clinics, 90% of testing laboratories and a large, and increasing, number of outpatient clinics and diagnostic centres are privately owned, either by individuals or by institutional organisations.

In the last four years, the value of the country's private healthcare market grew at the average rate of 10% annually to reach the value of approximately €28 bn in 2009.¹

In this environment creation of a fully private hospital was therefore just a matter of time.

In 2005, Medicover, then Poland's largest private healthcare provider, had a dream: "The Hospital".

An internal survey within the existing client population was commissioned, a business plan was created and, subsequently, the first draft of a medical plan was prepared. The dream began to take "visual, although still virtual, shape. The hospital would be a 180 bed "intimate and private" medical facility, in Wilanow – the south west district of Warsaw that happened to be its wealthiest and, at the same time, the least served medically.

To appreciate the complexity of the task in hand, one has to realise that this was to be Poland's first greenfield major hospital project in approximately 30 years and the first private hospital in 60 years.

Design experience was difficult to find, and Polish healthcare standards were dated



Figure1: Site constraints. Special attention should be given to the "Acoustic protection zone" or "Acoustic triangle" outside which no facilities for medical use would be permitted. Location of non-medical facilities (administration department, technical department etc) would be allowed outside the "zone/triangle". An additional (environmental) constraint was the high water table (at one metre depth) and the stipulation that measures should be implemented in order to allow underground water to flow unimpeded.

and fluid, with changes introduced to them at a monthly rate.

In July 2006 Medicover had appointed Arup as the lead designer, and cost and project manager. Arup would be, effectively, the provider of a "one-stop-shop" service throughout the duration of hospital project.

Arup management and a structural,

Andrew Kozlowski MSc (Eng) CEng MCIBSE MAPM

Andrew Kozlowski is an associate director with Arup and currently works as an office leader in Krakow, Poland. He also leads the Arup Poland Group Healthcare Business, which he established and developed.

Originally a mechanical engineer by training, he has worked in hospital engineering design and, as project manager, in construction of healthcare facilities in Europe, the Middle East and Canada.

Andrew Kozlowski was the project director on Arup Poland's first full multidisciplinary design healthcare project – the Medicover Hospital in Warsaw (2005–2009).

Since then he has been managing four more major hospital projects for private and public clients.

Arup is a global firm of designers, engineers, planners and business consultants providing a diverse range of professional services to clients.

electrical and mechanical (SMEP) design team were provided by its Krakow office and these were complemented at the concept stage by UK-based Tribal's Nightingale Associates architects and medical planning consultants; and by Atelier 7, a Polish architectural practice, at the building permit and execution design stage.



'To appreciate the complexity of the task in hand, one has to realise that this was to be Poland's first greenfield major hospital project in approximately 30 years and the first private hospital in 60 years.'

Site analysis

The hospital site, as selected by the investor, had met all the legal and business requirements – i.e. it was located at the "services area" of an up-market housing estate for 30,000 people, it was included in the local spatial plan (approvals) and had all the necessary MEP services and road accesses. But there were penalties to pay this site was very restrictive, as shown and described in Figure 1.

It is not the author's intention to describe in this article the design process in detail. However, in order to give some idea of the design environment at that early project phase, the risk register from that period is presented in Figure 2.

Will the site, with its known constraints, accommodate THIS RISK REMAINS. the required hospital functions? Are there serious environmental issues that may delay the project? STATUS OUO. AS ABOVE. Utilities - initial information in hand. CONFIRMATION REQUIRED. Timing of decision making – very good so far. However, due to complex nature of the function plan versus design brief, the preparation of the latter is now a: FEW DAYS BEHIND SCHEDULE. Timing and clarity of transfer of standards. OK. **RISK REMAINS HIGH.** Building permit issue (political). Client expectation versus approved budget. VERY HIGH RISK. Market economic fluctuation. VERY HIGH RISK. Medical equipment development. CONTAINMENT POSSIBLE. DESIGN CONSTRAINTS. Quality of design. Quality of construction. MODERATE RISK. HIGH RISK. Programme pressures.

Design phase

The client's initial design brief together with the adoption of NHS standards translated into a hospital with the floorplan area of about 25,000 m².

The available budget would not sustain the construction of a facility of this size and it was intuitively felt that site constraints meant that such a building would not be feasible.

While the medical planners went to work on thorough area checks, comparisons and verification of Polish current norms versus their UK equivalents, it was assumed that the

site should accommodate a hospital having a total floorplan area of 20,000 m² (including future extension space) and several versions of two site arrangements were tested.

Site arrangement – minimum footprint approach

The minimum footprint approach (Fig. 3) was based on a hospital footprint of 5,000 m², and its final version enabled future floorplan extension of 6,000 m² on a 1,500 m² footprint.

However this solution required a fourstorey building arrangement, including semi-

Figure 3: Site arrangement – minimum footprint approach.



'The hospital was developed as a three-storey deep plan building that was most cost-effective as it gave the most efficient plan and a good wall to footprint ratio.'

basement levels – an expensive solution in view of the high water table and a requirement for the natural water system to "free flow".

Site arrangement – maximum footprint approach

The maximum footprint approach (Fig. 4) was based on a hospital footprint of 6,500 m² that allowed a three-storey building arrangement at the cost of compromising some interdepartmental relationships.

Final result

The combined analysis of the optimised medical plan for the hospital and several site arrangements concluded that:

- All hospital functions could be developed within the zone of acoustic protection.
- Three-storey option was the most efficient, low cost development approach.
- Three-storey option required deeper planning, and might compromise departmental relationships.
- Four-storey option enabled a narrow plan, maximum natural light development approach.
- Four-storey option carried higher cost for basement construction.
- Car parking was a key criterion in determining the development approach and for future-proofing the hospital.

Figure 5 shows the final site plan that was approved for further development.

The hospital was developed as a threestorey deep plan building that was most costeffective as it gave the most efficient plan and a good wall to footprint ratio.

Its footprint was also close to the client target of 15,000 m² and provided good options for future expansion as follows:

- Three-storey expansion area to the south of the main hospital street (approximately 3,600 m² available).
- Possible rooftop expansion on level two (approximately 1,000 m² available).

Structural design

Due to the high groundwater level and its impact on load bearing under slab substructure, building foundations in the form of reinforced concrete strip and continuous footing were set at the 0.00 m level.

A system of reinforced concrete columns and slabs, combined with the stiffening effect of the staircase and lift shafts made it possible to avoid the use of beams.

This in turn maximised the use of the permissible building height and increased the flexibility of the building use in respect of current and future medical needs and those of the MEP services.

The adopted grid was: 7.80 m x 7.80 m; while floor-to-floor height was 3.90 m.

For medical equipment, and especially for heavy diagnostic and operating theatre apparatus, very specific requirements were addressed by local increase of slab loads and/or reinforcement.

In addition to the main hospital building, the design included an independent technical building housing the stand-by generator sets, emergency water tank, some cooling equipment, HVAC and water supply equipment, and medical gas manifolds.

A separate two-storey (three-level) car park building of reinforced concrete frame construction was built at the north east corner of the hospital site.

HVAC design

Where applicable, and with the exception of the operating theatre area, the HVAC design was predominantly based on Polish standards and norms in respect of the assumed external temperature and humidity values and the internal environmental requirements (temperature, humidity, air exchange rates and noise levels) for specific medical areas.

However, there were several issues, where decisions had to be made, that were driven more by a marketing plan then by technical standards.

The most important one was the air conditioning of the patient rooms. It could



Figure 5: Final site plan. The hospital at Warsaw Wilanów has 180 beds, five operating theatres, a plot area of 26,200 m²; a footprint area of 6,500 m²; a usage area of 15,900 m²; a three-storey building and plant room; and a three-level 190-space car park.



Front elevation.

have been argued that the Polish climate would enable the designing of wards without cooling: a combination of building orientation, sun screening and wall/window insulation could do the trick. Indeed, most of existing public hospitals did not have any form of mechanical ventilation of patient rooms, not to mention cooling. But our project was for a new hospital and it was private. "New" were also climatic conditions – the global warming being a current global buzz phrase. With several recent extremely hot summers, most of the decision makers intuitively leaned towards the adoption of air conditioning.

In order to give the client an opportunity to make an informed decision, a statistical study was commissioned based on historical data acquired from the Institute of Meteorology and Water Management (IMGW). The formula was: if the total number of hours in the calendar year with temperature equal to and/or exceeding 26°C at the location of the hospital was more than 3% then the some form of cooling should be considered.

The result was 3.26% and the client's decision, strongly supported by its marketing department (the customer/patient expects a vast improvement over public facilities), was to cool all patient wards.

One would think that this was the end of air conditioning design dilemma, but it was not.

The first proposed solution to cooling (and heating) of patient rooms involved chilled beams and overhead radiation panels. This would have worked well with low windows and would add to the overall flexibility of the facility. However, the health and safety (H&S) authorities, whose obligatory duties were to verify and approve the design principles, were not yet ready to support these solutions. As a result, the "standard" variable air volume (VAV) HVAC model was selected with a perimeter heating system (radiators) to offset the heat loss against the wall/façade fabric.

Air conditioning of the operating theatres presented similar problem: there were simply

no finite Polish standards that would guide the designers and/or guarantee the final approval of the system by the H&S authorities. Fortunately, Poland had just entered the EU, and European standards, even when not fully approved for use, were accepted as guidance. British HTM design guides were found to be "too specific and too generous" (regarding space) – following them would therefore result, with five operating theatres planned, in a significant overspend of the available budget.

Finally, the draft of the German DIN 1946-4 Ventilation – Part 4: Ventilation Services in Hospitals Standard (April 2005) was selected for use.

After consulting the client, all five operating theatres were to be of "Class 1b" that translated into laminar flow ceiling panels having total dimensions of 2.0 m x 2.0 m. These were equipped with class H13 filters and with the total air flow of $3,300 \text{ m}^3$ ensured the air velocity (at the panel level) of 0.23 m/s.

To facilitate the air flow from areas of higher cleanliness class to those of lower classification the recommendations of BS 5295, Part 1 were followed, i.e. values of 15 Pa pressure drop across the partitions between the classified and unclassified areas and 10 Pa between the classified (higher to lower) areas were assumed.

These were specifically adopted in the HVAC design for operating theatres, anaesthesiology and intensive care units, and neonatal and vascular testing departments.

'The effects of lessons learned during the three years of the project development have reached far beyond the client organisation.'

Electrical services

With the absence of relevant Polish equivalents, not unlike the position with HVAC services, the design of electrical services was primarily based on "imported" standards, this time European and British:
IEC 60364-7-710:2002 Electrical

- IEC 60564-7-710:2002 Electrical installations in medical locations.
 Lighting Guide LG2. Hospitals and
- healthcare buildings.
- Health Technical Memorandum 2007. Design considerations. Electrical services supply and distribution.
- Health Technical Memorandum 2011. Design considerations. Emergency electrical services.

The most notable for their "pioneering" role are probably the first two. As far as we know, never before were their stipulations considered in Polish healthcare, and specifically in Polish hospital engineering design.

IEC 60364-7-710:2002 introduces the classification of medical treatment rooms regarding their function and the critical importance of electrical services to the patient's life. Rooms in which the sudden loss of power could subject the patient to mortal danger are classified as Group 2.

The same standard stresses the significance, in Group 2 locations, of the isolated power system (IPS) with dual primary and a secondary supply.

The "revelation" of the Lighting Guide LG2 lies in drawing the designer/client decision makers' attention to the obvious fact that, due to their (predominantly) supine position, the patients are affected by ceiling mounted light fittings in a much different way than their standing/walking companions.

Differing with dated Polish norms, HTMs now superseded by HTM 06-01 were clear in defining the requirements of, among other factors, dual primary and an emergency supply.

Public health services

The public health design requirements were clearly defined by Polish norms and the stipulations of the local spatial plan (50% retention of rain water).

The hospital's uninterrupted water supply of 7.2 l/s was achieved by DN300 primary connection to municipality mains and a secondary water tank of 90 m³ capacity: 78 m³ could maintain the 12 hours emergency supply, required by the norm, and 18 m³ was kept as the fire defence reserve.

Conclusions

The Warsaw hospital was opened in July 2009 and the end result is a modest but elegant, three-storey building with an efficient layout and an interior that resembles a solid hotel rather than a hospital.

Medicover's vision was tested by tough formal, technical and construction realities and survived, and so did its wish, fuelled by the project's success, to build and operate other, similar facilities – as a "learned" and much wiser client.

From the position of an active participant in the Polish healthcare design market, Arup is aware that the effects of lessons that were learned during the development of the Medicover project have reached far beyond the client organisation.

Significantly, the project overcame the initial reluctance, in Poland, to accept the use of non-Polish standards. I am aware of at least three major hospital projects where DIN 1946-4 Ventilation – Part 4 (now DIN 1946-4:2008-12) has been used together with all four of the electrical standards, as mentioned above.

Similarly, the position has changed regarding the use of equipment which, in healthcare, was "not met with enthusiasm of the approving bodies" (e.g. chilled beams, radiating panels) to the considerable cost to the clients. At least one major hospital will utilise chilled beams and radiating panels on a large scale.

Poland is now experiencing growing environmental awareness in its population. Such awareness is present in the healthcare sector, and more often than not even public sector clients are ready to discuss and accept an energy-saving model as the base of the building design and will consider options



Patient room.

such as combined heat and power (CHP) and even tri-generation.

It may be argued that, within the constraints of the Polish healthcare dated norms and those of the construction site and the client's brief, the Wilanow hospital design set new standards for a patient-centred therapeutic environment.

For that reason, this hospital would probably be different, if conceived and constructed today and this, ironically, is the measure of its success.

References

- 1 PMR Private healthcare market in Poland 2009. Development forecasts for 2009-2011.
- 2 Nedin P. Design of the hospital environment to promote staff and patient wellbeing. *The Arup Journal* 1/2010, London.

Acknowledgements

• Figures 1, 3, 4 and 5 courtesy of Nightingale Associates. The two photographs courtesy of Adam Charuk/Medicover.

ARUP

Alisdair McGregor PhD, PE, LEED AP – Arup, San Francisco, USA Afaan Naqvi PE, LEED AP – Arup, San Fransisco, USA Tyler Krehlik AIA, LEED AP – ANSHEN+ALLEN, part of Stantec Architecture, San Francisco, USA

Sustainable health design needs different approach

Sustainability in healthcare has unique opportunities and challenges. The emissions from energy use and construction materials have been shown to have negative impacts on the general population's health. If we follow the principle of "first do no harm", then we should endeavour to eliminate any negative impacts that our hospital designs have on health. We have opportunities to improve healthcare delivery through better design, for example through better access to daylight, reducing the risk of airborne infection transmission, and more therapeutic environments.

We might define a sustainable healthcare facility as one that minimises the negative health impact on the surrounding environment while promoting healthy outcomes for patients and staff. This is a different approach to merely defining sustainability as a LEED rating. The Green Guide for Health Care has gone some way to incorporating the specifics of the healthcare environment into a LEED-like rating system, and this system can indeed give a more appropriate measure of healthcare sustainability than LEED. These different metrics for sustainable hospitals can be confusing, but, as detailed further in this article, we considered all of these measures in the early stages of planning of the UCSF Mission Bay Hospital in San Francisco, and incorporated them into a project-specific sustainability plan.

US hospitals have very high energy use. Data from the 2003 CBECS energy survey shows US inpatient hospitals averaging 250 kBtu/ft²/year. This compares with a rate for typical US commercial office buildings of 93 kBtu/ft²/year. Comparison against hospitals in Sweden, which have energy use around 70 kBtu/ft²/year, shows that we have a long way to go on energy reduction for US healthcare facilities. Although the cost of energy is small compared with staff costs, energy costs are still significant in a low profit margin business. For a typical healthcare provider operating at a 5% profit margin, every dollar of wasted energy cost requires \$20 of new revenue generation.

Dominated by space heating

A deeper review of the CBECS data shows that annual energy use is dominated by space heating. What is surprising is that this heating load does not vary significantly by climatic region. The reason for this anomaly is the extensive use of constant volume (CV) air supply with reheat. This system is common in hospitals as a simple means of achieving the correct pressure differentials between clinical spaces. Reducing the reheat energy is at the centre of all our system strategies for new hospitals.

The design team at UCSF Mission Bay in San Francisco went beyond the usual "green building approach" to materials to examine the impact of building materials on human and ecological health. This process is discussed further in this paper. There is much talk of therapeutic environments in healthcare. The strategy for creating such environments needs to be incorporated at the earliest stages of design so that it becomes an essential component. An example of this strategy is discussed in this paper.

UCSF Mission Bay – an overview

The approach to a sustainable hospital described in this article can be applied to any healthcare project, but we have taken a specific project to illustrate the methodology.

The University of California San Francisco (UCSF) plans to build a 289-bed integrated hospital complex to serve children, women, and cancer patients on its 57-acre biomedical campus at Mission Bay. Upon completion of the first phase in 2014, the 878,000 ft² hospital complex will include:

- A 183-bed children's hospital with urgent, emergency, and paediatric primary care and specialty outpatient facilities.
- A 70-bed adult hospital for cancer patients.
- A women's hospital for cancer care, specialty surgery ,and select outpatient services,

'The engineering, lighting and architectural teams worked closely together to optimise the façade design, collaborating as early on as at the schematic/concept design phase.'

including a 36-bed birth centre. An energy centre, helipad, and parking.

The UCSF Medical Center at Mission Bay will provide a world-class, sophisticated, efficient, flexible, and family-centered healing environment. The hospital complex will provide comprehensive diagnostic, interventional, and support services, and use advanced robotic and imaging technology during surgery in an environment centered around the compassionate care of patients and their families. The hospital's integration with the existing biomedical campus will strengthen collaboration among basic scientists, clinical researchers, and physicians, bringing new discoveries to patients faster. The collaboration of



Tyler Krehlik

Tyler Krehlik, AIA, LEED AP, is an architect and sustainability chair with ANSHEN+ALLEN, part of Stantec Architecture in San Francisco, USA.



Alisdair McGregor

Alisdair McGregor, PhD, PE, Afaan Nagyi is a LEED AP, leads the healthcare business for Arup in North America. He was elected an Arup Fellow in 2004 for his contribution to the development of the sustainable agenda.



Afaan Nagvi







An aerial artist's impression of the development as a whole.

A view of the outpatient building.

multidisciplinary medical specialists will create a rich environment for innovations in the care of foetal, paediatric, maternal, women and cancer patients.

Arranged along wings

The three major hospital patient rooms (Children's, Women's, and Cancer) are arranged along wings facing north and south above a podium containing the diagnostic and treatment functions. This orientation optimises daylighting potential.

A series of workshops were held at the start of the UCSF project to determine the key goals and strategies for the project. These were attended by the full design team, as well as by staff from UCSF representing both operations and clinical responsibilities. This integrated team involvement allowed a complete acceptance of the project goals. A set of guiding principles were derived using benchmarking studies of current best practice, leading edge discoveries from evidence-based design research, LEED, the Green Guide for Healthcare, and the specifics of the site and programme. These can be summarised as:

- Light and views.
- Fresh air.
- Green space.
- Healthy materials.
- Clear wayfinding.
- Anticipatory design (flexible future).

Among the value and benefits derived from following these principles are:

- Improved patient care.
- Improved staff attraction and retention.
- Significant energy reductions.
- Lower operating and maintenance costs.Improved funding ability through donor
- attraction.
- Improved public and community relations.
- Spatial efficiency and adaptability.

Furthermore, some of the specific targets that followed from these principles were:

- To create healthy, vibrant habitats that increase biodiversity.
- No irrigation using potable sources.

- To achieve a 50% reduction in energy use, compared with a typical hospital.
- A clear, rigorous protocol for assessing all materials and products.
- All patient, caregiver, and public areas to have abundant access to daylight, fresh air, and green space.
- The remainder of this paper examines how the team has put these strategies into practice.

Optimising façades

The engineering, lighting and architectural teams worked closely together to optimise the façade design, collaborating as early on as at the schematic/concept design phase. Common goals of maximising daylight and views, minimising solar gains, and creating a highly thermally and visually comfortable environment, were established early on, and framed an iterative "optioneering" process whereby various façade designs could be qualitatively and quantitatively assessed and improved.

As the architectural team developed various glazing, shading, and layout options, the engineering team guided their design with a set of peak load "thresholds", each of which, if exceeded, would trigger a more energy-intensive, and physically larger, perimeter HVAC system. The lighting team concurrently tested the options for natural light levels and penetration, further informing the design with indicators such as potential artificial light reductions.

Energy and thermal comfort studies

The engineering team also carried out energy and thermal comfort studies for the various options, the results of which highlighted the lifecycle, economic, and qualitative benefits of elements such as high performance glazing and external shades, allowing the architects to hone in on the optimal solution.

Hospitals are traditionally plug and process load-intensive buildings. Heat gain from these loads affect the sizing and operation of mechanical cooling systems that



Computer model used to optimise the building envelope.

maintain patient and staff comfort, as these loads are utilised over the course of the day. Unlike typical office equipment, diversified load information for medical equipment is not readily available. Therefore, traditional methods of accounting for heat gain from these loads use rules of thumb, with highly conservative safety factors, or a summation of name plate power method. A project the scale of the UCSF Medical Center at Mission Bay would typically follow one of these methods, resulting in unnecessarily large ductwork, excessive and under-utilised airflow capacity, and mechanical systems running primarily at non-optimal, part-load conditions.

Recognising this as an area of tremendous savings opportunity, the engineering team instead studied equipment heat gain using purchase order equipment cut-sheets, coupled with time-of-use, or "concurrent" use, diversity factors. These diversity factors were developed through a series of focus group meetings with end-users of the medical equipment specified for the project. This resulted in a more realistic concurrent peak heat gain estimate, with minimal unnecessary conservatism.

With the heat gain information from cutsheets and true usage patterns per end-user input, the team was able to build up a palette of diversified heat gain load for all plug and process equipment in the project and accurately estimate air flow requirements at each zone.

Analysis of consumption data

The next level of refinement in this area will come from the collection and analysis of
energy consumption data from actual medical equipment in operation at existing facilities, signalling the motivation for sub-metering and monitoring of medical equipment in the future. We are also in the process of quantifying the theoretical energy and cost savings resulting from the ductwork and fan energy reduction realised by the approach highlighted above when compared with a more traditional rule-of-thumb approach – to highlight the benefit of addressing plug and process loads earlier and in more detail during the design phase.

There are two major areas of energy consumption associated with the HVAC systems for typical US hospitals in a mild climate such as San Francisco; fan energy and reheat energy associated with typical CV systems. Three alternate air supply systems for patient rooms were studied:

- Variable air volume with exhaust air tracking to ensure the correct pressure differential to the corridor.
- Constant volume (fresh air requirement only) with chilled ceilings.
- Constant volume (fresh air requirement only) with chilled beams.

All systems studied used 100% outside air, as this had been shown to be cost-effective for other hospitals in the San Francisco Bay Area, and greatly reduces the risk of airborne infection transfer. Each system was analysed with different heat recovery options. Variable air volume with run-around coil heat recovery had the best lifecycle cost performance for the hospital, saving over \$3 million over the presumed 20-year life of the system. The initial investment costs are recuperated within 12.5 years. A fourth option of displacement ventilation was discussed, but not taken forward for the LCCA study.

Energy analysis

As the team set about running energy models, it became apparent that getting an appropriate base case was not as simple as might be thought. The base HVAC system required by the ASHRAE 90.1 protocol that has to be used for the LEED Energy model is a system that is never used in real hospitals in California. We modelled both the LEED base case and the more traditional "business as usual" systems.

The results, shown in Figure 1, demonstrate that for cooling, pump, fan, and heating energy, we were more than 50% better than the typical hospital, and close to 50% better than the LEED model. In terms of systems that we can model with confidence, the energy goals of the project have been met. However, the plug load was kept the



Figure 1: The project team's modelling demonstrated that for cooling, pump, fan, and heating energy, the UCSF Mission Bay facility's sustainability performance was "over 50% better" than the "typical hospital", and "close to 50% better" than the LEED model.

same for every model. The typical hospital model has a total energy intensity of 350 KBtu/ft², which is greater than the CBECS data of 250 kBtu/ft². This implies that we are still being too conservative in our estimates of annual process and plug load. Monitoring of actual plug loads in the completed hospital will provide data for better modelling in the future.

Operable windows

Readers from Europe will be wondering why, in such a benign climate as the San Francisco Bay Area, the patient rooms do not use natural ventilation through operable windows. Current regulations in California do not permit the use of passive ventilation for hospital areas, due to concerns about filtration, temperature control, and infection control. European experience would tend to indicate that passive ventilation systems are not a problem, but it will take a major effort to change minds in the USA.

Renewable energy

Generation of clean energy on-site has been a project goal from the very onset. To that affect, 54 photovoltaic arrays, with a total connected capacity of 500 kW, are currently planned for at the following locations:

- The north patient tower roof.
- The south patient tower roof.
- The outpatient building roof.
- The Energy Centre roof.
- Parking areas.

'The collaboration of multidisciplinary medical specialists will create a rich environment for innovation.' The trellises supporting these arrays have been carefully coordinated around air handling units, exhaust fans, and other major rooftop equipment, such that the project is ready to accept photovoltaic panels during, or post-construction. The PV panels provide a visual screening to the air-handling units as well as shading the roof, which will reduce summer temperatures at the air intakes. Given how quickly technology advances in this field are, leaders of the project will wait as late as possible before settling on any particular technology.

Materials selection

ANSHEN+ALLEN, part of Stantec Architecture, together with William McDonough + Partners, and McDonough Braungart Design Chemistry (MBDC), set about setting material criteria for typical patient rooms. A rigorous filtering process was put in place for typical materials such as floors, walls, paints, ceiling tiles, millwork, and trim and other materials within a patient area. These materials were then passed through the following filters:

- Performance.
- Human health.
- Ecological health.
- Nutrient potential.
- Recycled/renewable content.
- Embodied energy

After putting typically specified materials through the filtering criteria it was found that less than 10% met all the criteria. It is clear that there is much work to be done before we truly have a healthy internal environment for our hospitals. The team's goal was to replace the health hazard exposure warning sign required on public buildings in California with one that celebrated the health benefits of the building. (Fig. 2). Tyler Krehlik describes this process in greater detail in the March/April 2010 issue of *Eco-Structure* magazine in a article entitled: "A Matter of Health, Are Our Buildings Making us Sick?"

Therapeutic design and roof gardens

Ongoing research into the health impacts of access and exposure to gardens and outdoor areas is showing substantial therapeutic benefits. Therefore green spaces at urban hospitals have become increasingly important. Terracing the building, and providing this outdoor access at every floor of a multi-storey building, maximises this benefit. In a typical hospital, many of the patient rooms look out onto roof areas, and these roof areas are typically filled to the brim with mechanical equipment. Converting these roof spaces into rooftop gardens improves the view, but complicates mechanical designs by creating large areas of "off-limit" roof areas. At UCSF, the extent of rooftop green space at the hospital complex will be among the highest of any urban hospital in the US. Twenty-four separate gardens and outdoor areas of respite are included in the hospital project plans for a total of 187,000 ft² of green space; there are 60,000 ft² of green space on the roofs alone. That is more than 1.1 acres on the roofs and 3.2 acres on the ground. The most important



An illustration of the scale of emission reductions at the UCSF Mission Bay Hospital.

aspect of these roof gardens is accessibility. At a paediatric hospital, providing respite for the parents is especially important. Typically, getting a breath of fresh air would involve leaving your child's hospital room, walking down the unit hall, getting into an elevator, travelling down several floors, walking through the lobby, and finally stepping outside. For most parents this is an unacceptable distance to travel away from your sick child. Remedying this, UCSF has integrated gardens and outdoor areas of respite at almost every nursing unit at every floor, allowing for that therapeutic breath of fresh air for the parents just steps from their child's room.

Adding therapeutic garden spaces does have one negative impact, and that is increased potable water use. In locations with adequate rainfall or consistent rain throughout the year, rainwater collection strategies are



Twenty-four separate gardens and outdoor areas of respite are included in the hospital project.



Figure 2: One of the team's goals was to replace the health hazard exposure warning sign required on public buildings in California with one "celebrating" the building's health benefits.

adequate, but in dry climates, or climates with long dry seasons (such as that in San Francisco), rainwater collection becomes untenable due to large tank requirements. Other sources of non-potable water need to be investigated. In the case of UCSF, we utilised the cooling tower blowdown as an irrigation water source, with minimal extra filtration and some dilution, saving almost 3.5 million litres of potable water per year.

Planting the roofs with gardens also has the added benefit for stormwater treatment. Studies have shown that stormwater draining from a green roof has higher water quality than that coming out of a typical on-grade bioswale. In addition, the flow of stormwater from the roof gardens is slowed, reducing the impact on the city stormwater system.

Conclusion

The value of setting integrated sustainability goals with input from the whole has been shown to be of great value. For a large and complex project such as the Mission Bay Hospital, most of the sustainability goals have remained. The project is currently on target for LEED Gold Rating. As of July 2010 the project is going through the OSHPD review process.

The project has adopted an Integrated Project Delivery process, with the contractor and sub-contractors intimately involved in the detail design. The entire team of owner, designers, and contractors, are co-located on site developing a fully integrated 3D model of the building. That is the subject of other papers. However, the sustainable outcome of this project is due to the efforts of many people working in a team environment. Listed below are only the principal team players, but there are many more that space restrictions prevent us from listing:

- UCSF.
- ANSHEN+ALLEN, part of Stantec Architecture.
- Arup.
- Cambridge CM.
- DPR Construction.
- William McDonough + Partners.

Rutherford & Chekene.



We shape a better world



Medicover Hospital, Warsaw, Poland



Laguna Honda Hospital, San Francisco, USA



Tseung Kwan O Hospital, Hong Kong, China



Ysbyty Aneurin Bevan, Blaenau Gwent, UK



University College Hospital, Macmillan Cancer Centre, London, UK



Cairns Base Hospital, Queensland, Australia

Whether we are creating comfortable environments, flexible integrated building solutions or sustainable business packages, Arup adds value to our global healthcare clients while ensuring a high level of quality on which they can rely.

