



# Health and Care Infrastructure Research and Innovation Centre

**FINAL REPORT 2014**

## HaCIRIC Partners

# HaCIRIC in figures

**7 Year** Programme

**25** books and chapters so far

**320** conference papers and presentations

**£11.96m**

total EPSRC award

**199** journal papers so far

**£2.1m** in grants from HaCIRIC to **8** other

**£2.92m** initial investment by host IMRCs

universities to build capacity

**£5.5m** leveraged in additional grants

**£3.58m** in kind

additional contributions

**33** PhD students

**60** reports

**35** researchers employed in total

Over **1800** delegates at HaCIRIC conferences, workshops and seminars

Over **140** keynote presentations in UK and abroad

# Contents

|  |    |
|--|----|
| 1. Chairman's Foreword   | 4  |
| 2. Programme Director and Principal Investigator's introduction  | 5  |
| 3. Executive summary   | 7  |
| 4. The HaCIRIC story   | 12 |
| 4.1 Origins  | 12 |
| 4.2 Our underlying research focus  | 13 |
| 4.3 The context for HaCIRIC's work – evolution since 2006  | 14 |
| 4.4 HaCIRIC and the global healthcare infrastructure market  | 17 |
| 4.5 Beyond HaCIRIC: the Healthcare Infrastructure Forum (HIF)  | 18 |
| 5. The HaCIRIC Programme   | 19 |
| 5.1 Development and management of the programme  | 20 |
| 6. HaCIRIC's impact – knowledge development and insights and significant achievements                                  | 30 |
| 6.1 Key insights. The impact of innovation in healthcare infrastructure  | 32 |
| 6.2 Key insights. Modelling and simulation tools   | 33 |
| 6.3 Some of HaCIRIC's key impacts on policy, industry and practice   | 34 |
| 7. Impact case studies   | 36 |
| 7.1 New models for service delivery and infrastructure procurement   | 36 |
| 7.2 New approaches to healthcare acquired infection  | 40 |
| 7.3 An assurance based regulatory framework for NHS asset management   | 43 |
| 7.4 Improving urgent and unscheduled care delivery systems   | 46 |
| 7.5 Mainstreaming remote care  | 49 |
| 7.6 Benefits realisation   | 52 |
| 7.7 Modelling, simulation and visualisation to deliver enhanced performance and value of healthcare built environments | 56 |
| 7.8 Whole-system, service and asset evidence-based planning and design   | 60 |
| 8. Enhancing the impact – communications and knowledge transfer  | 64 |
| 8.1 Our Strategy   | 64 |
| 8.2 The website and newsletter   | 64 |
| 8.3 Conferences and other events   | 65 |
| 9. Gearing of EPSRC funds  | 68 |
| 10. Capacity building  | 69 |
| 11. Locating the Centre within the Institutions  | 70 |
| 12. Appendix 1 - HaCIRIC Researchers   | 71 |
| Appendix 2 - Journal Articles  | 74 |
| Appendix 2 - Book Chapters   | 79 |
| Appendix 2 - Reports   | 80 |
| Appendix 2 - Research Collaborators  | 82 |
| Appendix 2 - Principal Research Projects   | 84 |

# 1. Chairman's Foreword

HaCIRIC – the Health and Care Infrastructure Research and Innovation Centre – was the last, and arguably the most complex, of the national centres of excellence established by the Engineering and Physical Sciences Research Council (EPSRC) in the early 2000s under their Innovative Manufacturing Research Centre programme. Its competences are grounded in engineering science and management, with the provision of healthcare defining both the boundaries and the outputs necessary for innovative improvements in patient outcomes.

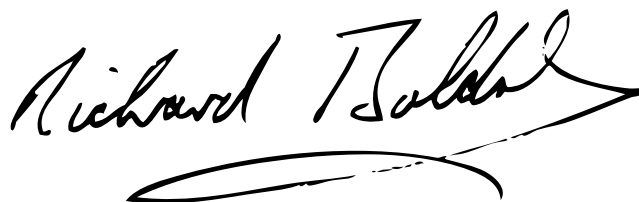
HaCIRIC has been a multi-institutional Centre involving the universities of Loughborough, Reading and Salford together with Imperial College in London, all of which already had well established track records in innovative research. The creation of HaCIRIC was a focused initiative to establish a more strategic, integrated, and multidisciplinary approach to improving the contribution of the health and care infrastructure for the benefit of patients. It was established to deliver an internationally recognised and respected centre for basic research and knowledge, supported by evidence, to help improve health and care infrastructure. Its programme aimed to be sustainable through the training of an alumnus of well qualified researchers and teachers. HaCIRIC was designed to be strategic in the focus of its research on policy issues of national importance, but also practical in assisting solutions for issues of the day. It also ensured the application of competences existing in the wider academic community, all aimed at improving value for money outcomes by working closely with patients, healthcare providers and commissioners, and supply chain companies.

The HaCIRIC team has achieved considerable success in meeting its targets, and is recognised as being unique internationally in the breadth of its contribution to health and care infrastructure research. Their work is detailed in this report, and can also be found on our excellent website ([www.haciric.org](http://www.haciric.org)). We have also learned a lot about how to create a single, focused centre from staff and researchers originating from four quite diverse institutions and cultures. The Executive group are to be congratulated on their significant achievements. Constant communication, enriched by regular workshops where researchers from all four geographical locations could meet to challenge and support each other's programmes, has been key to the success of HaCIRIC. The diversity of these activities has been considerable.

We have been particularly fortunate in having the wise guidance of a highly experienced Steering Committee with a variety of backgrounds as clinicians, health providers, supply chain companies, and international academics. I am extremely grateful for their unstinting support, and the considerable personal time that they have committed to ensure the success of HaCIRIC, helping the Executive and researchers to develop their ideas, test proposals, and focus on the important issues.

I would also like to thank all those companies, public and private, who provided considerable support, both financial and in kind, and guidance for our work.

Whilst the funding from EPSRC has come to an end, the legacy of HaCIRIC will be developed through the establishment of the Healthcare Infrastructure Forum which will seek to provide a vehicle to carry forward the existing work and also help to provide solutions for the considerable challenges facing all providers and commissioners of health and care in the years to come.



**Professor Richard Baldwin**

Chairman of Steering Committee

## 2. Programme Director and Principal Investigator's introduction

From a standing start, in seven years, HaCIRIC – the Health and Care Infrastructure Research and Innovation Centre – grew to become the largest coordinated programme of research on the relationship between three core, yet under-researched, elements in healthcare systems: infrastructure, technology and services.

Our work has shown that the target of substantial productivity improvement in healthcare is impossible without a complete rethink of service delivery enabled by technology and infrastructure redesign.

This is a radical conclusion. Organisations faced with this challenge will have to fundamentally change. The solutions are not simple. They involve a complex interplay of technology, service redesign, infrastructure rebuilding, organisational change and cultural change all focused on better patient services.

Since 2006 HaCIRIC investigated the strategic and the operational steps that leading healthcare organisations from around the world have been taking to address future healthcare needs. Our programme has resulted in significant new knowledge. So far we have published some 196 peer reviewed journal papers, 25 books and book chapters, 60 reports and over 300 conferences papers, including 140 keynote and invited speeches. We have brought together over 1500 experts from around the world in our own annual conferences and over 300 UK experts in our seminar series.

Knowledge translation is key to HaCIRIC's mission. We started by engaging with 70 companies and healthcare providers in the design of our programme – this has grown to a collaboration in our projects with over 200 partners from the UK and internationally.

Recognition of our work can be seen in our leverage of £5.5m additional funding, as well as around £3.5m in in-kind contributions. We have an established mailing list with over 2000 users and our website ([www.haciric.org](http://www.haciric.org)) is regarded as one of the best and most influential in this field. In the last three years more than 100,000 pages were viewed, with around a quarter of users from outside the UK.

Our aim beyond HaCIRIC is to continue our work through the Healthcare Infrastructure Forum and through our community of 68 'HaCIRIC alumni', our research staff and PhD students who have secured positions both in the UK and overseas. They, along with our successor body, the Healthcare Infrastructure Forum, will help us continue this work as the international centre for research and debate on the redesign of healthcare systems and infrastructure.

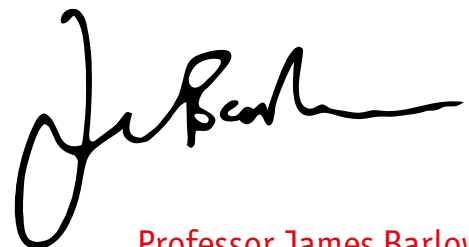
We are immensely proud of our achievements across such a diverse and complex field, across disciplines, and across the world. It has been a collective effort and the HaCIRIC team has been a real pleasure to work with and learn from.

The investment by EPSRC has been significant in enabling us to bring together this disparate field, understand the needs and dynamics at many levels and to produce a structured approach to enable healthcare organisations, facing enormous practical challenges, a way ahead.



**Professor Colin Gray**

HaCIRIC Programme Director



**Professor James Barlow**

HaCIRIC Principal Investigator

**With the HaCIRIC Directors: Dr. Chris Harty, Professor Michail Kagioglou, Professor Andrew Price.**

## THE NATIONAL CONTEXT

- » **Impact case study 7.3:**  
An assurance based regulatory framework for NHS asset management

**Example Project:**

- [An evidence and model supported approach to Strategic Asset Management](#)

- » **Impact case study 7.8:**  
Whole-system, service and asset evidence-based planning and design

**Example Project:**

- [Effects of the built environment on health](#)

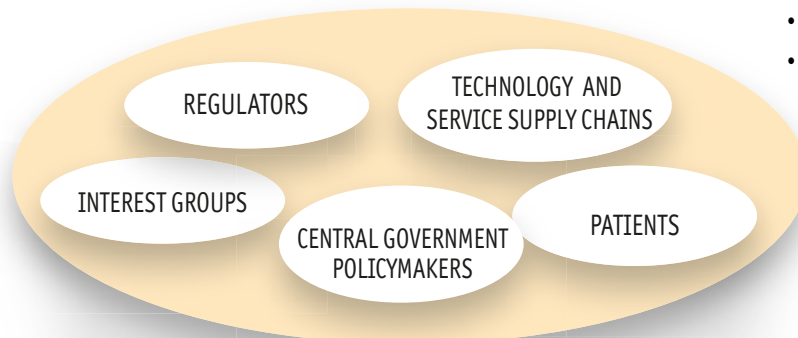
- » **Impact case study 7.5:**  
Mainstreaming remote care

**Example Project:**

- [Innovations in stroke care delivery](#)
- Whole System Demonstrators programme
- [Innovations in renal care](#)

**Policy reports:**

- [NHS 2030](#)
- [All change please](#)



## THE LOCAL CARE SYSTEM

- » **Impact case study 7.4:**  
Improving urgent and unscheduled care delivery systems

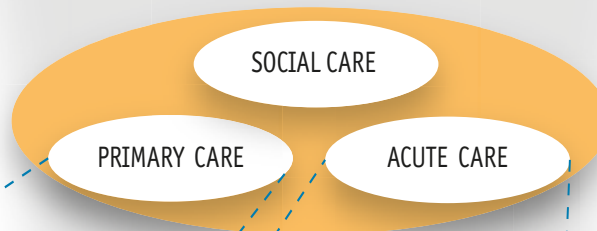
**Example Project:**

- Unscheduled care as a complex system

- » **Impact case study 7.1:**  
New models for service delivery and infrastructure procurement

**Example Project:**

- European Healthcare PPPs



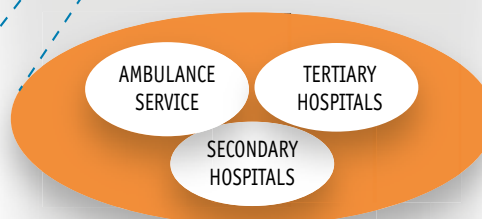
## HOME AND COMMUNITY SYSTEM



**Example Project:**

- [Open Planning for Healthcare Infrastructure](#)

## HOSPITAL SYSTEM



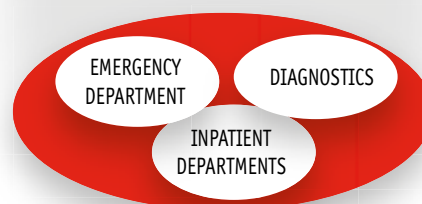
- » **Impact case study 7.6:**  
Benefits Realisation

**Example Project:**

- [Quantifying the Benefits of Healthcare Infrastructure Development](#)

- [Benefits Realisation](#)

## HOSPITAL SUBSYSTEMS



- » **Impact case study 7.2:**  
New approaches to healthcare acquired infection

**Example Project:**

- [Objective assessment of hospital ward cleaning](#)

**Example Project:**

- [The implementation and use of BIM tools and processes in the design and construction of two hospitals](#)
- [Future-Proofing Scenarios in Healthcare Conceptual Design Using BIM](#)

**Example Project:**

- [Monitoring indoor environmental parameters to investigate from health impacts](#)
- [The feasibility of natural ventilation in healthcare buildings](#)

- [The environment and users' behaviour and how these relate to the acquisition of hospital acquired infection](#)



## 3. Executive Summary

### Our Mission

“ *Getting the relationship right between healthcare infrastructure, technology and services.* ”

Improving healthcare, while containing costs, demands sophisticated understanding of three core elements in healthcare systems: infrastructure, technology and services. Their tripartite relationship is extremely complex, not least because the pace of change for each is different. That creates considerable challenges in planning for future needs and makes the management of innovation and change difficult.

Take, for example, the UK's National Health Service. In the 'years of plenty' during the first decade of this century, its hospital sector underwent a large and expensive rebuilding programme. Much of the estate needed modernisation. However, even during the programme, it was becoming clear that more attention should have been paid to diverting activity towards integrated service provision and away from expensive acute sector provision. In short, recent infrastructural and technological investment, costing billions of pounds, is probably in the wrong place and it does not address the future needs of the population.

This is just one instance of how imperfect understanding and poor management of the relationship between the three core elements can lead to waste and diminished outcomes. On the positive side, however, if we get the relationships right, there can be major benefits for the users and the funders of healthcare systems.

“ *From scratch, in seven years, HaCIRIC grew to become the world's largest single programme of research on healthcare infrastructure systems.* ”

Optimising this tripartite relationship lies at the heart of the mission pursued by the Health and Care Infrastructure Research and Innovation Centre. HaCIRIC was created from the ideas of over 70 organisations from UK healthcare, who helped us identify the key challenges and research themes. From scratch, over seven years, HaCIRIC has grown to become the world's largest single programme of research on healthcare infrastructure systems and a global leader in thinking on issues that have huge implications for governments and societies across the world.

The investment by EPSRC has enabled us to bring together a disparate field, and understand different needs and interactions at many levels. This understanding offers healthcare organisations, facing enormous practical challenges, a way ahead. We are now in a position to guide and to advise, as well as to structure, appropriate future research in this very complex field.

The need for change in how and where we deliver healthcare – and how to manage it – remains pressing and growing. The NHS and social care now cost about £125 billion a year, slightly more than education, defence and the police combined – and by 2015/16, it will account for nearly one third of departmental spending. Much further research is needed to support the NHS as it shifts its business model from a focus on acute care delivery to prevention and community based care, with significant implications for infrastructure use and future development.

Therefore, we regret that EPSRC funding for an integrated approach has ended. However, we are pleased to announce our development of a successor think tank - the Healthcare Infrastructure Forum - to retain and disseminate HaCIRIC's knowledge.

Seven years of research in a field whose horizons are still being scoped has produced impressive impacts on policy and practice at all levels in government, industry and healthcare as well as in enhancing the UK's international reputation. It has built valuable partnerships; leveraged considerable funding in addition to original grants; and trained a skilled cohort of researchers who will have continuing influence. We will detail all these later. Crucially, we have learned a lot.

# Some highlights from our programme

## 1. Building the evidence on what works best

What have we learnt? First, we have taken important strides in understanding and quantifying what works best, by strengthening the evidence base for planning and designing a good quality built environment. By making this knowledge accessible, we have helped to support good choices and create 'expert clients' in, for example, the new decentralised NHS.

So, we have built tools – based on our research – to help enhance the healing environment, optimising variables such as lighting, heating, ventilation, room size layout, location and access, infection control and energy efficiency. We have done this by observing how people actually used buildings, so our observations are rooted in reality, not just theory.

Our research has, for example, helped to improve natural ventilation in hospital wards for patient welfare. We've modelled lighting needs, particularly of elderly people, to help reduce falls and reduce length of stay in hospital. We have shown that providing outdoor views cuts patients' length of stay, on average, by 18 hours.

We can now anticipate some of the infection risks of particular hospital designs, thanks to comprehensive research and modelling. We have shown how the physical design of healthcare facilities can influence the movement of people and how altering design can help reduce the spread of infection. We are beginning to understand the relative importance of movement compared with cleaning, so we can advise on where best to focus scarce resources.

In a continuing project, we are working with the National Nursing Research Unit at King's College London and the University of Southampton to conduct the most detailed study to date on the impact of single-room accommodation on patient safety and other outcomes.

“ *We can now anticipate some of the infection risks of particular hospital designs thanks to comprehensive research including modelling.* ”

“ *We have created models of decision-making so that evidence reaches decision-makers when they need it and when it can make a difference.* ”

## 2. Supporting better decision-making

We know that generating better evidence is not enough. Organising good processes for tackling complicated issues around technology, services and infrastructure is also vital to ensure that decisions reflect the latest learning.

We have created tools for decision-making about estate planning and facilities so that evidence reaches decision-makers when they need it and when it can make a difference.

We have built and applied a comprehensive benefits realisation process for healthcare infrastructure and service development (BeReal). BeReal highlights project benefits right from the early strategic stages and helps to ensure they are deployed, managed and traced through a project to maximise outcomes. This is already being used in major healthcare development schemes in the UK.

Good decision-making means making sure that the right people are involved in discussions at the right time. So we have researched where public and patient involvement falls down on infrastructure development. And, in a unique study, we researched what happens when services and infrastructure undergo fundamental change at the same time, comparing the experience of three hospitals in the UK, US and Canada.

Our stream of simulation and modelling work has helped inform the development of the Cumberland Initiative, a major new national programme devoted to extending the use of simulation, modelling and visualisation in healthcare ([www.cumberland-initiative.org](http://www.cumberland-initiative.org)). It could be vital as the NHS and social care systems are reimagined in the coming years.



“ *We have used simulation and modelling as a way of uncovering the potential effects of innovations in stroke care.* ”

### 3. Managing innovation and change

HaCIRIC has taken a realistic view of what makes change happen in the areas of infrastructure and service delivery. It's not a simple line of causality between evidence and action. Often, the biggest issue is ensuring that innovations are taken up and spread. Much of HaCIRIC's work has therefore sought to understand better how to overcome the barriers to innovation and change in complex innovations.

We have examined difficulties in adopting and embedding innovation in a variety of contexts. We have found, for example, that a key impediment to the adoption of innovation is often not a shortage of evidence but a lack of trust in those disseminating good practice. Crucially – given the likely shift of care from hospital towards home – we have collected the most comprehensive data on factors that influence the adoption of ‘remote care’ (telecare and telehealth). We have been able to show how the vision is often lost twice in translation, from leaders to middle managers and from middle managers to front-line staff.

We have also studied how to compare the value that stakeholders place on many different benefits coming from a health facility, including accessibility, aesthetics and working conditions. This is helping us to advise on optimal combinations. Our tools are helping planners to strike the right balance of values in developments – for example, good attention to building standards is valuable but can lead to over-prescriptive solutions. Likewise, there is a balance to be struck with stakeholder consultation, which, though valuable, can lead to a loss of control, extra cost and time over-runs.

Understanding how complex healthcare innovations might impact on economic, social and clinical outcomes is essential for good decision-making about whether or not to proceed. This requires methods to capture impacts at different scales, from individual hospital departments, to hospital trusts and the wider local care system. For example, we have used simulation and modelling as a way of uncovering the potential effects of innovations in stroke care, showing how service and infrastructure changes could greatly reduce long-term disability and costs to the health system by ensuring speedy access to thrombolysis.

Finding efficient ways of stimulating organisations to take up innovation is essential. One approach has been to use different methods of procurement and financing, embracing financial and other incentives. As well as reviewing the performance of UK's Private Finance Initiative programme for hospitals, we are looking to Europe to find examples of new public-private partnership models that align incentives across supply chains and may respond better to evolving health service need.

### 4. Planning for the future

Healthcare systems need to build future flexibility into infrastructure, ensuring that facilities are as ready as possible for the unexpected needs of the coming decades. Our research into ‘open scenario planning’ has provided tools for infrastructural developments that, with a little additional expense, could suit a number of different scenarios. This increases life expectancy of a facility and reduces the costs of possible future reconfigurations.

This work has also led us into research that should increase the resilience of health facilities to natural disasters. We have shown the importance of strengthening hospital relationships with suppliers of power, telecommunications, water, gas and other essential services as well as ensuring that hospital access can be maintained for staff and patients during disasters.



# Our Impacts on Policy, Industry and Practice

Over the last seven years, HaCIRIC has played an important part in supporting policy makers, businesses and healthcare practitioners in the development of new thinking.

“*Our findings formed a basis for a new government initiative to increase the level of remote care and were launched by the Prime Minister in 2011.*”

“*Our findings resulted in a change in hygiene monitoring behaviour and clinical practice in a number of hospitals.*”

## 1. Policy

### Remote Care

Our work on remote care has had a major policy impact. We were invited to form a consortium to evaluate the Government's Whole System Demonstrators programme, and conducted the world's largest randomised control trial of remote care services. The findings formed a basis for a new government initiative to increase the level of remote care and were launched by the Prime Minister in 2011.

### Government briefing

HaCIRIC research on PFI, benefits realisation and barriers to innovation has resulted in invitations to brief the House of Commons Treasury Select Committee, the Treasury's Cooperation and Competition Panel, the Office of Government Commerce, the Darzi Review of NHS innovation, Ofcom, and others.

## 2. Industry

We have worked on specific projects with industry partners including Nightingale Associates, Arup, Skanska UK and HOK Architects, Tunstall and BT. Our work on the impact of technology on future trends in healthcare has led to numerous briefings to industry, including leading global companies such as Microsoft, AECOM and Laing O'Rourke.

We identified the key science and technology areas in need of research for the next generation of remote care for the Technology Strategy Board and the then Department of Trade and Industry, prior to their launch of 38 industry-led projects worth £47.1m. We recommended more research on social and business aspects of remote care which subsequently led to a £10m TSB / Department of Health / ESRC research programme.

## 3. NHS Practice

HaCIRIC's work has influenced NHS practice. For example, prior to our research, most existing work on the transmission of health-acquired infection was laboratory-based. We conducted the first study of a live ward under live operational conditions. This resulted in a change in hygiene monitoring behaviour and clinical practice in a number of hospitals.

We have worked with the NHS to redesign services, at regional (e.g. Leicestershire) and hospital (Barts and Royal London) levels, within hospital wards (Great Ormond Street) and across care pathways (e.g. stroke care in Scotland). From this we have established the importance of getting the infrastructure right to support better healthcare delivery.

Our BeReal tool has been used in capital development programmes by Brighton and Sussex University NHS Trust, NHS Stockport and NHS Lothian. It has informed policy, with the team being invited to join the review panel for the Office of Government and Commerce's Managing Successful Programmes. The BeReal approach was also highlighted in the Treasury Investment Manual, 2009.

We have had an important impact on standards. Work on unscheduled care has influenced the development of a new guidance document on emergency department design as well as College of Emergency Medicine guidance. HaCIRIC has also helped revise the World Health Organisation's Hospital Safety Index, expected to be implemented globally to improve the resilience of healthcare facilities.

The Department of Health commissioned HaCIRIC to develop better ways to strategically manage healthcare assets by improving their existing NHS Premises Assurance Model to broaden its user base and integrate existing standards and toolkits. This means that there is now, for the first time, a single nationally consistent and aligned methodology.

“*HaCIRIC’s global reputation means we have hosted international delegations from health authorities, government bodies, industry and academia from Europe, Canada, Japan, as well as numerous visits by individuals from across the world.*”

#### 4. International influence

HaCIRIC’s position as a global leader in this field is reflected in our influence on international policy and practice. Our contribution to an EU review of the Structure Fund Programme resulted in an invitation to support the Hungarian Ministry of Health in shaping its agenda for Hungary’s Presidency of the Council of the European Union in 2011.

Work for the European Investment Bank on the impact of the built environment on health outcomes has helped to provide evidence to the bank for assessing the potential health gains from investment in different types of healthcare facilities.

We have collaborated in presentations to health ministries, investment banks and healthcare providers as far afield as Kazakhstan and Moldova, and are currently advising the Slovak government in the development of its healthcare strategy and a new teaching hospital in Bratislava.

HaCIRIC’s reputation has meant that we have hosted international delegations from health authorities, government bodies, industry and academia from Europe, Canada, Japan as well as numerous visits by individuals from across the world. Our annual international conferences and seminar series have been attended by over 1800 internationally respected academics and by companies with global reach.

As well as our work on emergency care planning in disaster zones for WHO (see above), we have also led an international team from Japan, Italy and Turkey to investigate the impact of earthquakes on healthcare facilities.

We conducted a tour of Japan, partly organised by UKTI, to make a series of presentations on UK trends in remote care technology to leading Japanese companies and healthcare providers.

“*We have created a much-needed successor organisation, the Healthcare Infrastructure Forum, to lead independent and informed debate, deliver research consultancy and develop our knowledge base.*”

#### 5. Building the field

Our goal at HaCIRIC has been not only to research the field, but also to establish a coherent multi-disciplinary research agenda and the capacity to take our work forward. We have developed partnerships with other universities and have supported a skilled cohort of academics. In all, we have worked with many other universities from UK, US and across Europe.

We have funded 11 other Universities in collaborative projects. We have created a community comprising 35 alumni – former Research Associates and Fellows – most of them continuing our work elsewhere, in the UK and abroad, and 33 PhD students.

We have run six international research-led conferences, attended by 1,500 experts from around the world, and brought together over 300 UK experts in our seminar series.

We have bolstered the academic field, so far publishing 196 peer reviewed papers, 60 reports, and 25 books and book chapters. We have contributed to over 300 conferences.

Our success in consolidating this field of research, and recognition of the quality of our programme, is demonstrated by the fact that, as well as managing the £12m investment from EPSRC, HaCIRIC has raised £5.5m in additional financial contributions and at least a further £3.5m in-kind contributions.

#### Taking HaCIRIC’s work forward – the Healthcare Infrastructure Forum

We have created, as a successor organisation, the Healthcare Infrastructure Forum. HIF is a collaboration between HaCIRIC’s founders and additional partners. It will lead independent and informed debate, deliver research consultancy in the UK and internationally, and translate our knowledge base for a wider user community.

## 4. The HaCIRIC story

### 4.1 Origins

HaCIRIC's work responds to a national agenda that seeks to achieve value for money healthcare, while improving patient safety and experience. Our tool is state of the art infrastructure. We focus on the crucially important, but widely neglected, role that can be played by technological and built infrastructure systems for healthcare.

Healthcare is the largest single spending commitment for governments across the developed economies. There is constant pressure to improve patient services, safety and experience while meeting growing demand and reducing costs. Consequently, healthcare infrastructure is under enormous pressure to enhance its contribution to these multiple goals.

However, research into healthcare infrastructure and its potential contribution has traditionally been a neglected and highly fragmented field. The overwhelming bulk of research effort has been directed at healthcare technology – its development and use – with growing attention to organisational and service issues over the last decade. Yet, while infrastructure clearly both enables and constrains the evolution of healthcare services, in 2004, when HaCIRIC was first mooted, the dynamics of the relationship were not clear.

Our second starting point was the major healthcare infrastructure investment programme that the UK had embarked on in the late 1990s, in the form of the Private Finance Initiative (PFI) for new hospitals and, subsequently, other initiatives including the Local Improvement Finance Trust (LIFT) programme for all forms of primary care multi-use facilities.

As well as renewal of the ageing built environment, there was also very considerable investment at that time in the NHS information and communication technology (ICT) infrastructure, in the form of the National Programme for Information Technology (NPIIT). The scale of these capital investment programmes – many tens of billions of pounds – meant that it was very important to understand what was being planned, how it could be efficiently delivered and whether it would be fit for purpose in the future, especially given the speed of technological and policy change in healthcare.

We developed the HaCIRIC concept over a 12 month period. We engaged the healthcare community – the NHS, government departments, the private sector supply chains and academia – to explore their perceptions of future challenges in delivering healthcare infrastructure. We held two independently facilitated workshops in London, each attended by around 70 delegates. From this we built our proposal to EPSRC. In this sense, the HaCIRIC agenda has been truly user-driven, capturing and responding to the needs of the healthcare infrastructure communities and, we believe, leading the agenda in this under-researched domain.

In doing this, we answered EPSRC's aspirations for research centres<sup>1</sup> that would grow the UK's research capacity in areas of key strategic importance such as healthcare. There was also a concern to overcome the fragmentation of effort across large numbers of independent and relatively small projects. EPSRC wished to establish coherent programmes of integrated multi-institutional and cross-disciplinary work where academia, together with all the stakeholders in the healthcare sector, could combine to make a real difference.

<sup>1</sup> – The Innovative Manufacturing Research Centre (IMRC) programme.

“

*HaCIRIC brought together four acknowledged international centres of excellence to create a new national and international capability that built on significant existing research programmes.*

”

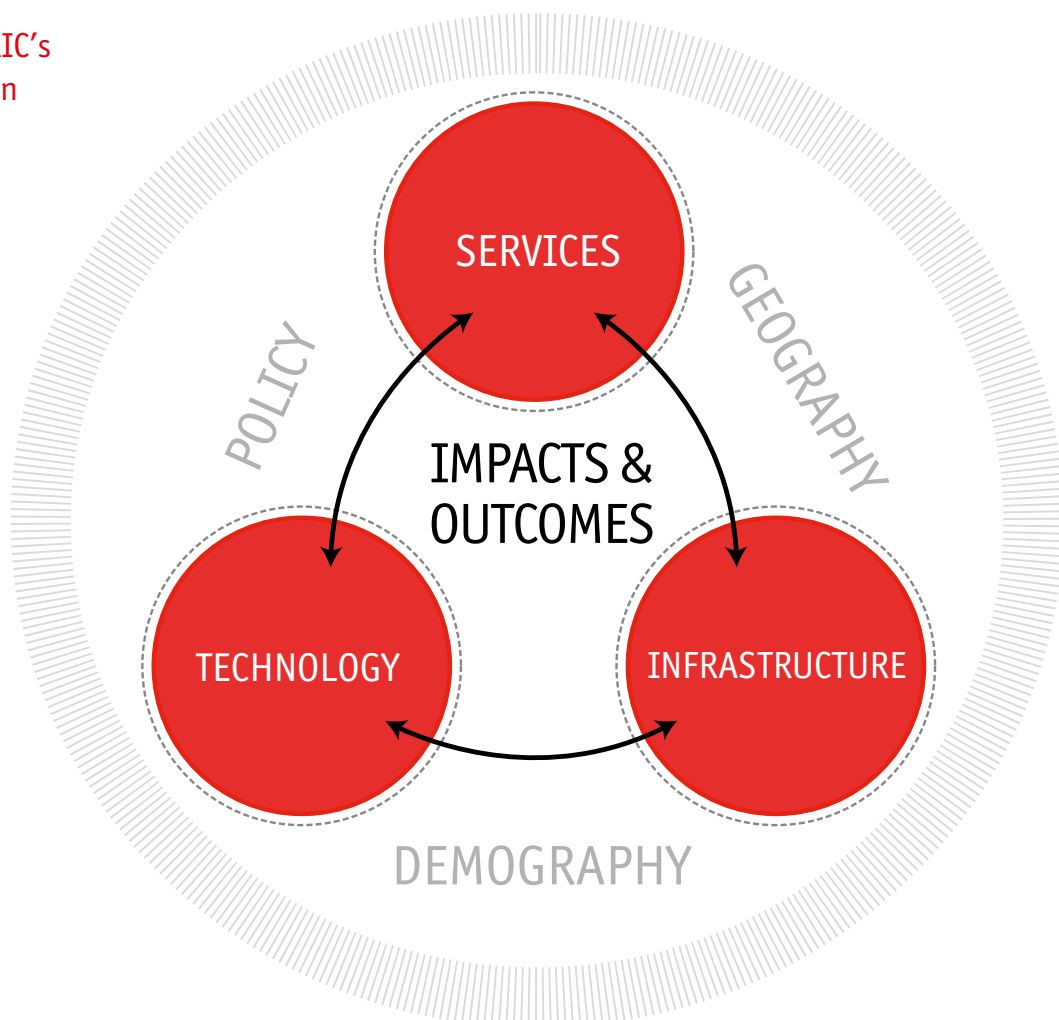
HaCIRIC therefore brought together four acknowledged international centres of research excellence, also supported by EPSRC, to create a new national and international capability. By building on existing centres and their research programmes, HaCIRIC was better able to 'hit the ground running', achieving critical mass from an established portfolio of related projects and a strong skills base. From this grew an integrated research programme, bringing together a user community and academic researchers in a hitherto neglected – but critically important – domain.

At its launch in June 2006, HaCIRIC was therefore well positioned to make significant contributions to performance improvement in an area of significant national importance. As described below, our research has subsequently responded to an evolving national context. Its importance has grown as the cost of healthcare provision has risen inexorably against ever-tightening budgetary constraints and growing attention to patient safety and experience.

## 4.2 Our underlying research focus

Throughout HaCIRIC's history, our focus has remained on understanding the inter-relationship between healthcare services, technology and infrastructure (see Figure 1). In other words, our focus has been on systems rather than on standalone technologies: our innovations are ones that, unlike a simple new drug, require embedding in a complex organisational environment.

Figure 1. HaCIRIC's research domain



“

*A key issue for research, practice and policy in our field is planning and coordinating healthcare innovation where the pace of change across different parts of the system is mismatched.*

”

We also make a distinction between ‘hard’ technologies – physical artefacts – and the ‘soft’ organisational and policy structures within which they are embedded. Understanding the relationship between both has been of equal importance to HaCIRIC’s mission. Clearly, such distinctions in healthcare are not always hard and fast, but the notion of systems and ‘systems-of-systems’ has underpinned much of HaCIRIC’s thinking.

As our initial work began, we identified that a key issue for research, practice and policy in our field is the problem of planning and coordinating healthcare innovation where the pace of change across its system is mismatched – the pace of technology innovation often outstrips the ability of users to adapt the way healthcare is delivered, making it hard to future-proof infrastructure. Particularly important here is the longevity of large scale fixed capital infrastructure – both physically and from a financial investment perspective – compared to the rapidity of change in technologies and, to a lesser extent, services. Shedding light on the dynamics of these relationships has been a core challenge in HaCIRIC’s mission.

The need for innovation – radical and incremental – has been a central principle for HaCIRIC’s work, although we do not see innovation on its own as intrinsically good. It must contribute to problem solving and lead to performance improvement. It is much more than creating new healthcare technologies or physical infrastructure. It is essential to embed these in mainstream practice.

Often, the biggest issue in healthcare is applying innovations that are known to work, perhaps from other health systems or industries, but which have failed to spread. A range of technology and innovation management issues has thus formed a strand through much of HaCIRIC’s work, to understand better how to overcome the barriers to change in complex innovations and to generate the new ideas which could lead to future improvement across the care system.

## 4.3 The context for HaCIRIC’s work – evolution since 2006

The complex relationships between technology, services and infrastructure and the whole process of innovation management have been further complicated by a changing policy and practice environment.

Healthcare is never stable. It is continually changing through progress in its underlying science and the introduction of technological innovation. It is highly politicised, with new governments usually seeking to renew the organisational and economic fabric. Organisations involved in the delivery of healthcare rarely remain stable for more than a decade. The institutions involved in ‘healthcare’, including university researchers, therefore need to be flexible and responsive. The speed and extent of change means that a programme with HaCIRIC’s ambition – focused on the complex interactions between technology, services and infrastructure – will always be needed.



The last ten years have been no exception. During its life, HaCIRIC has been subject to a major evolution in its user organisations, from NHS trusts and their supply chains to central government institutions governing the overall system. Change has happened around us and we have been proactive in bringing in new research partners and responding to new research needs. The original group of over 70 stakeholders, with which we started, has evolved and, from many perspectives, become increasingly fragmented, due to policy changes impacting on the delivery of healthcare. Whilst branded the 'National Health Service', different strategies concerning organisation, procurement and delivery are pursued in England, Northern Ireland, Scotland and Wales, and indeed locally. Of the four countries, England has seen the largest number of policy and organisational changes (see Box 1). These and other policy changes have impacted on the notion of a centralised NHS and the nature of its supply chains and capital investment strategies.

For example, successive reforms have reduced the number and responsibilities of Primary Care Trusts (PCTs), eventually replacing them entirely with new Clinical Commissioning Groups. Another fundamental change was the introduction and growth of NHS Foundation Trusts, which reduced the role and coverage of the Strategic Health Authorities before they also disappeared completely in 2013. The change to Foundation Trusts gave NHS delivery organisations increasing autonomy in the design of service delivery and the design and procurement of the infrastructure needed to deliver patient care.

The encouragement of private sector involvement in the provision of healthcare has also fluctuated over HaCIRIC's lifespan. The framework for private involvement in funding health infrastructure has changed with a move from the original form of PFI to a new variant. There has also been a slowdown in capital funding, despite the fact that much of the NHS estate remains ageing – with increasing costs of backlog maintenance – as well as functionally unsuitable, inefficient and in need of significant investment (box 2).

Changing views about the use of the independent sector have affected diagnostic and treatment provision. There was a major expansion in use, then rapid curtailment, followed by some revival in slightly different guises.

“

*A period of considerable rapid change has required HaCIRIC to be highly responsive, quickly taking on new and emerging research challenges whilst maintaining a core theme-led programme.*

”

## Box 1. Some major policy and organisational changes in the NHS in England

- 2005 'Commissioning for a Patient-led NHS'
- 2006 'Our Health, Our Care, Our Say'
- 2008 'Transforming Community Services'
- 2008 'High Quality Care for All'
- 2010 'Equity and Excellence – Liberating the NHS'
- 2011 'National Programme for Health IT' scrapped
- 2011 'Quality Innovation Productivity and Prevention' programme to deliver £20bn savings for reinvestment over a four-year period
- 2011 'Innovation, Health and Wealth'
- 2012 'The Health and Social Care Act'

## Box 2. The condition of the English NHS Estate in 2011

### The English NHS estates data returns indicate that:

- The estimated replacement cost of the English NHS hospital estate is circa £80 billion
- 36% of the building stock predates 1965
- 20% of the building stock predates 1948
- 35% of the building stock has been constructed since 1995
- 12% of the building stock is functionally unsuitable



*Working closely with our sector partners on a highly applied research programme – during a period of extensive rapid change in the NHS – has required HaCIRIC to be highly responsive.*



While our mission (box 3) has remained constant, the scale of these changes has inevitably impacted on the context within which our work was taking place. We have had to quickly take on new and emerging research challenges whilst maintaining a core themed programme. Our user community has evolved continuously, presenting HaCIRIC with challenges in maintaining continuity of collaborating organisations and individuals. Nevertheless, our recognition as an internationally leading research centre has afforded us considerable opportunity to engage with new organisations as they have emerged.

The challenges we have tackled in HaCIRIC will endure beyond the current policy and organisational changes to UK healthcare. Given the pace of change and financial stringencies, government, healthcare organisations and firms need, more than ever, to work together to break down the barriers to innovation. They need to create a culture which strives to ensure continuous improvement in processes and outcomes as well as to create infrastructure that is fit for purpose.

Much remains to be done in the UK. The devolution of infrastructure procurement has led to a decline in the local knowledge base for planning and implementing infrastructure investment. At the same time, decisions need to be based on evidence of their potential benefits. Often, this does not exist or it is hard to interpret within the highly complex environment of healthcare. The need to renew and adapt the built infrastructure for healthcare remains a challenge for policy makers and the healthcare sector. Research is still required to provide the evidence and tools that can minimise the political influence on key decision making. We are taking steps to continue addressing this agenda, securing funding for new research proposals where possible, and establishing a new ‘think tank’ – the Healthcare Infrastructure Forum (HIF) – to act as a forum for debate (see Section 4.5).

### Box 3. HaCIRIC vision and mission

EPSRC’s investment in HaCIRIC created a unique opportunity to develop a fully integrated programme of work to understand the changing relationship between services, technology and infrastructure in healthcare systems. Our interest and focus has been on the relationship between technological innovation, service delivery and fixed capital infrastructure.

#### The vision

HaCIRIC is a world-class resource delivering the critical appraisal and evidence to support better healthcare through better infrastructure. Our ambition is to be the first call for evidence-based analysis, research and help and advice by organisations closely involved in the redesign of their healthcare infrastructure, both in the UK and internationally.

#### The mission

To provide analysis and the evidence to support better decision-making so that international health systems and infrastructure can be sustained in the changing global context by:

- providing patient-centred facilities with a clean, safe environment and a good patient experience;
- changing the relationship between home and hospital;
- modelling and simulating the complex decisions about new service and infrastructure forms and their impacts; and
- understanding the implications of new funding models of capital and infrastructure investment.

## 4.4 HaCIRIC and the global healthcare infrastructure market

HaCIRIC's activities are relevant globally. The challenges we have addressed are found across the world and are becoming increasingly acute as healthcare systems modernise and the financial burden escalates.

Across the world, healthcare infrastructure spending is estimated at \$300-\$400 billion annually<sup>2</sup>. While this only amounts to perhaps five per cent of overall healthcare expenditure, the proportion varies from country to country. A higher proportion needs to be spent in countries making the basic investment in new built facilities.

The concerns of governments and healthcare organisations over what kinds of healthcare infrastructure to build, and how to pay for it, are not just a UK phenomenon. Developed economies are struggling with increasing expectations for the highest quality care, against a backdrop of an ageing population. Many of them also need to replace an ageing healthcare infrastructure and adapt newer infrastructure to new models of healthcare, driven largely by technological innovation. Containing the escalating cost of their healthcare systems, while maintaining quality, is paramount.

In much of the low- to middle-income world, there is a need for the establishment of the basic infrastructure for healthcare. The challenge here is not to replicate outdated models from the developed world such as building inflexible large hospitals that cannot be adapted to new demands or the new opportunities presented by technological innovation. Indeed, the way some countries such as India are leapfrogging 'old' models of healthcare – and its underlying infrastructure – is potentially offering important lessons to the UK and other developed health systems.

Over its lifespan, HaCIRIC has paid increasing attention to developments outside the UK, with comparative research projects being conducted on healthcare infrastructure issues in other countries (see Section 5.1.6). As the only research programme of its kind in the world, most of HaCIRIC researchers have been invited to present their findings around the world, not only at academic conferences, but to policy and practitioner forums.

“  
*Countries such as India are leapfrogging 'old' models of healthcare – and its underlying infrastructure – potentially offering important lessons to the UK and other developed health systems.*  
”

2 – *Build and Beyond: the (r)evolution of healthcare PPPs.*  
PWC, Health Research Institute, December 2010.



## 4.5 Beyond HaCIRIC: *the Healthcare Infrastructure Forum (HIF)*

The problems are not going away – and policymakers need solutions from academia. Hence our establishment of a new think tank – the Healthcare Infrastructure Forum.

Estimates of the NHS funding gap by the early- to mid-2020s – available resources compared to needs – vary widely depending on the assumptions<sup>3</sup>. If NHS funding remains flat in real terms, the funding gap would amount to £44 to £54 billion in real terms by 2021/22. Even if the four per cent a year efficiency savings under the QIPP programme and beyond are achieved, the shortfall would still be £28 - £34 billion by 2021/2022.

Healthcare therefore needs to continue to look for radical new solutions, as well as ensuring that acknowledged best practice is taken-up. These factors continue to underline the importance of rethinking how we use healthcare infrastructure.

Although the funding from EPSRC to support HaCIRIC has come to an end, we have established the Healthcare Infrastructure Forum (HIF) as our successor organisation. The Forum will be, as HaCIRIC was, unique as the only centre dedicated to improving healthcare delivery by focusing on infrastructure. It will provide vigorous, independent and informed debate, as well as access to high level research and policy review.

Building on the programme of work and community created by HaCIRIC, HIF's research expertise and networks span key infrastructure disciplines including design, construction, technology, planning and finance. It will act as a forum for short to medium term strategy debates on the issues of the day, provide input into the policy process and into scenario and horizon scanning activities, deliver international research consultancy, and enable the underlying knowledge base of HaCIRIC to be developed by the partner universities.

We are launching our activities in early 2014 with a series of discussion events on key issues of the day, informed by our research.

3 – Sally Gainsbury, 'Saving £20bn is only half the story', *Health Services Journal* (21 March 2012); Crispin Dowler, 'Monitor issues fresh warning on NHS funding gap', *Health Services Journal* (10 July 2013); James Illman, 'Kelsey: NHS faces £30bn funding gap by 2030', *Health Services Journal* (5 July 2013); James Illman, 'Exclusive: NHS faces £60bn funding gap by 2025', *Health Services Journal* (11 July 2013).

4 – Adam Roberts, Louise Marshall, Anita Charlesworth, *A Decade of Austerity?* Nuffield Trust, December 2012.



## 5. The HaCIRIC Programme

### Box 4. Creating a healthcare infrastructure research community

Our work has bridged the gap between academic research, pragmatic policy, and industry guidance and needs. The reach was considerable, embracing policy makers and health service supply chains not only within the UK but internationally. Its significance is attested by:

- The importance of the problem – value for money healthcare delivery is a first order issue for public policy and industry.
- The scale of engagement – deep, long-term interactions with government, NHS and private sector.
- Repeated invitations to contribute to solving the next set of policy challenges.

The quality of our research is attested to both by the calibre of journals in which it has been published and by the additional peer-reviewed, competitive research funding that we have secured for related projects (see section 9).

In a short time, and from a standing start, HaCIRIC forged a single entity from the cultural and disciplinary diversity of the four, parent institutions. It has directly funded another nine Universities and engaged with hundreds of other key national and international stakeholders. Finding the right calibre of researchers was always a challenge, but we successfully recruited 35 Research Assistants and 33 PhD students. Other RAs were recruited on projects funded by HaCIRIC but carried out at other universities. These represent our 'HaCIRIC alumni' and they will play an important part in taking forward the message of the research programme.

We have created an international academic body of key stakeholders that is focusing research activity in key areas as identified by HaCIRIC. We have completed around 40 projects, involving teams from the four core universities with the strong collaboration of a significant part of the user community and other partner universities. These represent our 'HaCIRIC alumni' and will form an integral part of the development of the Healthcare Infrastructure Forum (HIF) and its influence internationally.

The concern of the Steering Committee and our stakeholders is that the HaCIRIC programme is coming to an end at exactly the time when it is most needed. Fundamental change is now being recognised as the only way forward for healthcare but it is not clear how to this change will be achieved. Because EPSRC curtailed the IMRC programme early, HaCIRIC had three years less than other IMRCs to complete its original planned programme. This limited the collection of much of the evidence base to support necessary changes to service delivery and the supporting infrastructure.

Our successor body, HIF, is being established in an environment where its insights are needed more than ever. By engaging with the CLARHCs and with the new AHSNs, HIF will provide the forum for bringing together evidence and debate around healthcare infrastructure. The fear is that, without the support of EPSRC and others, research funding may return to the fragmented model of the early 2000s.

## 5.1 Development and management of the programme

The HaCIRIC programme was initially funded for five years with a review by an EPSRC appointed panel of international experts in the third year. Despite reviews that the work was at the highest international level, HaCIRIC was only funded for seven years in total. This was contrary to our expectation and planned programme at the beginning, as the other IMRCs received funding for ten years. The reduction in time was due to the curtailment of the overall IMRC programme funding, so that it could be administratively completed in 2013. This has inevitably curtailed the depth and breadth of our subsequent research programmes.

### 5.1.1 Inception

HaCIRIC was the last of a series of centres established by EPSRC, funded from their platform grant for Innovative Manufacturing Research Centres (IMRCs). The greater majority of these were single institution awards. EPSRC were keen to expand their model into a new multi-disciplinary and multi-institutional Centre that could cope with the complexity and diversity of healthcare infrastructure. To create the HaCIRIC programme, three existing built environment IMRCs (at Salford, Reading and Loughborough universities) were brought together with the Innovation Studies Centre IMRC at Imperial College Business School. Together, these could provide experience and resource, human and financial, to help launch the more ambitious and complex HaCIRIC programme.

During HaCIRIC's first phase (2006-2011), each IMRC contributed aspects of their programmes – for example Salford's work on lean thinking in healthcare – as well as equal additional financial contributions. This amounted to around 40 per cent of the total funding. It is also important to note that 20 per cent of all funds associated with the initial EPSRC award were reserved for the participation of other academic institutions in order to provide the opportunity for others to participate in the overall HaCIRIC programme of research.

### 5.1.2 Organisational and management aspects

We put together a management structure that was collaborative and sought to avoid the pitfalls of previous inter-university projects. We placed great emphasis on the need to ensure that HaCIRIC built on the particular strengths of the four member universities. We also put in place mechanisms to ensure that researchers were supported in developing their skills and experience, and the research conducted was of the best possible standard. Finally, we drew on a highly experienced Steering Committee to help provide direction and governance to the overall programme. The management structure and process is described in figure 2.

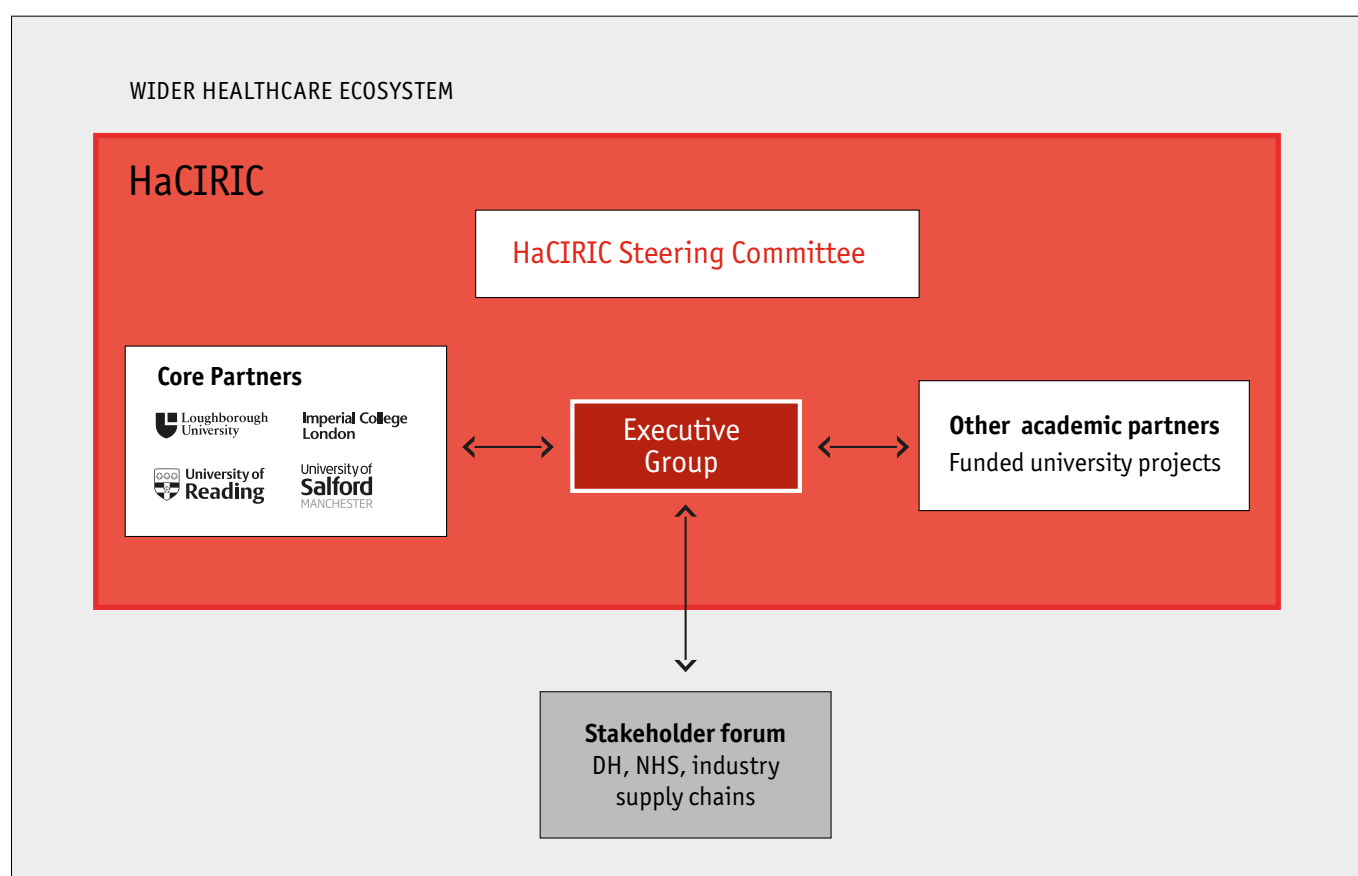
“

*We put together a management structure that was collaborative and sought to avoid the pitfalls of previous inter-university projects.*

”



Figure 2. HaCIRIC Organisational Structure



“  
Our work has bridged the gap between academic research, pragmatic policy, and industry guidance.  
”

## Executive Group

The Executive Group comprised the Principal Investigator, the Programme Director and the Academic Directors from the partner universities (box 5). It was the principal accountable body for the overall direction and operational management of HaCIRIC.

The role was to work collaboratively and provide the leadership of the programme, maintain the vision, adapt the programme and ensure excellence in project delivery. The Executive Group met monthly or more frequently as required, with the Chairman of the Steering Committee in attendance.

## Steering Committee

The Steering Committee (box 6) was chaired by Professor Richard Baldwin and had a non-executive role. We were lucky to be able to draw on a very experienced group from across the healthcare sector. The Committee was representative of its key communities, ensuring our work remained relevant and objective, and membership was refreshed at the start of phase 2 of HaCIRIC in 2011.

The Committee was actively involved throughout HaCIRIC's life. Members attended workshops and away days, helped develop ideas for research, attended 'peer assist' meetings where projects were discussed (see below), and provided encouragement to our researchers. Members also gave generously of their time outside the Steering Committee meetings to assist the Executive in developing the strategy and implementation plans for HaCIRIC during critical periods in its evolution.

The Steering Committee also had a governance role in ensuring that HaCIRIC funds were disbursed with probity. Beyond HaCIRIC, Steering Committee members have been keen to remain involved in the development of its successor, the Healthcare Infrastructure Forum. As well as the Steering Committee members, all members of HaCIRIC's Executive were represented, along with an EPSRC representative.

### Box 5 Executive Group members

**Prof. James Barlow**, Imperial College Business School (Principal Investigator) (2006-13)

**Prof. Colin Gray**, University of Reading (2006-13, Programme Director 2008-2013)

**Prof. Andrew Price**, Loughborough University (2006-13)

**Prof. Michail Kagioglou**, University of Salford (2006-13)

**Dr Chris Harty**, University of Reading (2011-13)

**Mr Oliver Wells**, Programme Director (2006-08)

**Prof. Will Hughes**, University of Reading (2009-2010)

**Prof. David Williams**, Loughborough University (2006-2007)

### Box 6 Steering committee members

**Prof. Richard Baldwin**, Chairman (previously Chairman, Community Health Partnerships) (2006-13)

**Prof. Tom Allen**, Howard W. Johnson Professor of Management, Emeritus, MIT Sloan Business School (2006-11)

**Dr Mike Burrows**, Chief Executive, NHS, Greater Manchester (2006-13)

**Dr Vanya Gant**, Divisional Clinical Director for Infection, UCLH (2011-13)

**Prof Hans Björnsson**, Professor of Technology Management and the Vice Provost of University of California, Merced (2011-13)

**Ms Patricia Leahy**, (previously Director, National Audit Office) (2006-13)

**Ms Jane McElroy**, (previously Director, YRM architects) (2006-11)

**Mr Joshua Reddaway**, Audit Manager, Corporate Finance VFM, National Audit Office (2011-13)

**Prof. Rob Smith**, University of Salford (ex DH Director NHS Estate Policy) (2006-13)

**Dr Justin Whatling**, Senior Director, Population Health, Cerner Healthcare Systems (2011-13)

**Dr Liam Blackwell**, Portfolio Manager, Built Environment, EPSRC (2006-2007)

**Dr Matthew Davis**, Portfolio Manager, Built Environment, EPSRC (2007-2009)

**Dr Chris White**, Portfolio Manager, Built Environment, EPSRC (2010-2013)

“

*We have had to develop a collaborative work ethic within the people engaged in the HaCIRIC project.*

”

### 5.1.3 Building a shared culture, adding value

In setting up multi-university collaborative centres, EPSRC aimed to leverage added research value from combinations of experience and resources, and target this at strategic problems. HaCIRIC's four core universities each brought particular strengths, and complementary areas of interest and skill sets. The importance of this to the quality of the research cannot be overestimated. The breadth and diversity of the HaCIRIC partners has underpinned our programme of work and – we believe – contributed to outcomes and a wider debate from a far broader perspective than would otherwise have been the case.

It has taken a considerable culture change to achieve this outcome. Bringing together four institutions, with four different organisational systems and different disciplines, to create a shared culture and a coherent identity as a single research centre has not come naturally. We have had to develop a collaborative work ethic within the people engaged in the HaCIRIC project. We have had to align university financial systems. We have had to address different expectations in relation to publishing and career progression. HaCIRIC's executive team have had to take on new skills. These include an ability to coordinate the diverse backgrounds and interests of multi-disciplinary researchers, and establish lines of authority that were not necessarily based around researchers' own organisational structures. Critical success factors for achieving culture change and collaborative working in HaCIRIC are outlined in box 7.

The management structure enabled us to avoid duplicating effort, and encourage collaboration so that aspects of a problem area could be tackled by the best-equipped and most experienced team. This led to efficiencies of effort and resource. We put in place, through a 'peer assist process', a mechanism to support new project development and review proposals for funding. To ensure the quality of the research, this engaged as much of the overall HaCIRIC team as possible in the discussion of research projects, along with external reviewers. The peer assist process also applied to projects by non-core HaCIRIC universities (see table 1). Through the peer assist process, we were able to ensure that HaCIRIC's portfolio of projects was balanced between those which were more adventurous, but with higher delivery risk, and projects which were 'nearer to market'. Not all our projects achieved publishable outputs, but they have, nonetheless, provided useful material for future research and we have learned much from them.

We also adopted a balanced scorecard approach to measuring our performance, reviewed annually by the steering committee, comprising the following four components: increase in number of active non-academic partners, growth in new external funding, learning and growth of research team (e.g. completion of PhDs, publication of papers, presentations at international conferences), and internal business processes (especially project variation in time and costs). We established initiatives by which to achieve each component goal.

We brought the whole of the HaCIRIC team together quarterly for two-day events at which the individual projects were reviewed, progress reported and input sought from colleagues and peers so that each project was enriched by the collective input. We also introduced skill development into these events geared to the transition from PhD student and Research Assistant to Research Associate to academic staff. Half our researchers had moved into academic staff positions by the end of HaCIRIC's funding (see Appendix 1).

“

*We ensured that HaCIRIC's portfolio of projects was balanced between the more adventurous, but with higher delivery risk, and those which were 'nearer to market.'*

”

“

*Continuous engagement with our stakeholders via our regular seminars, workshops and the annual conference enabled us to refresh our ideas.*

”

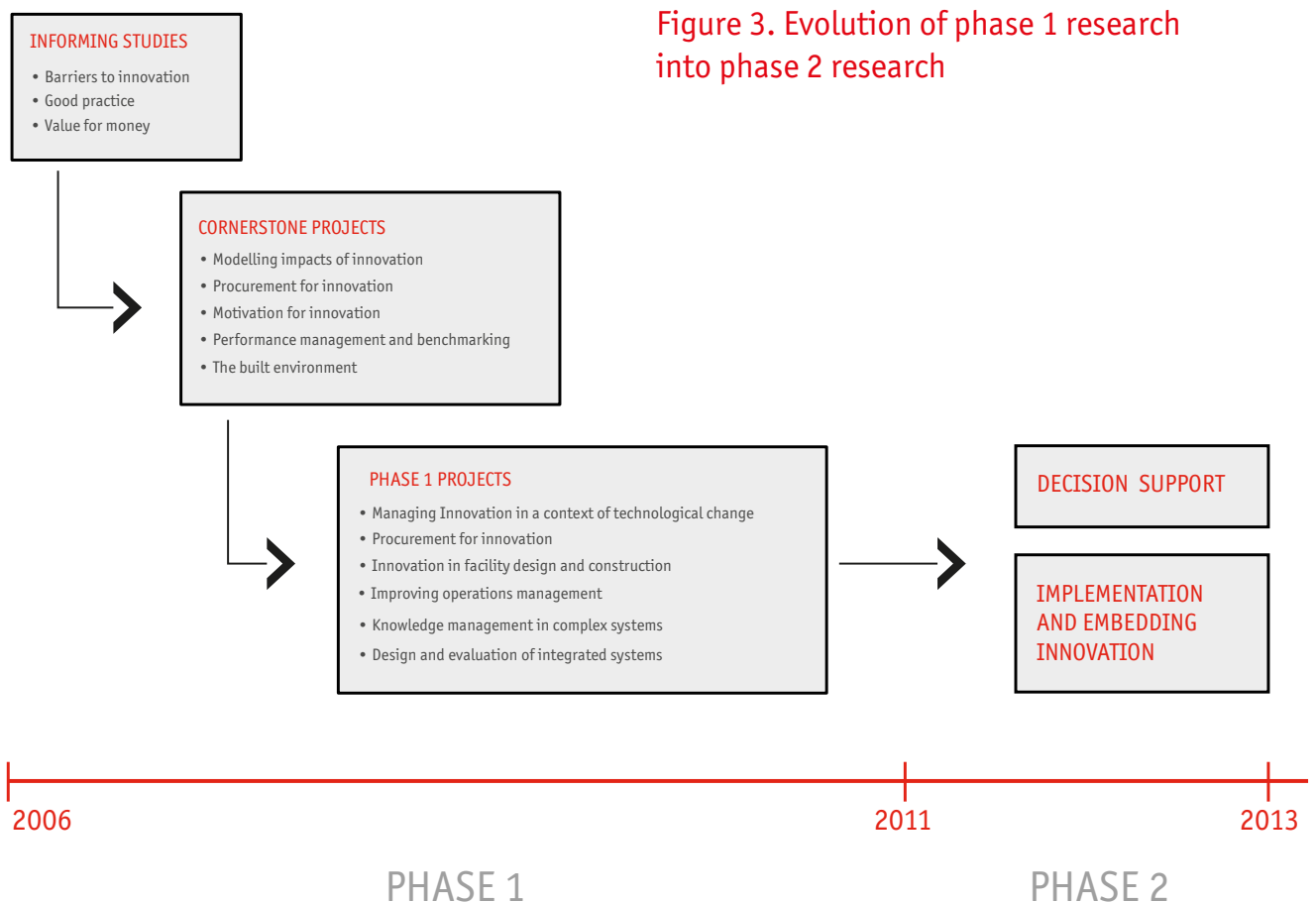
### Box 7. Critical success factors for achieving culture change and collaborative working in HaCIRIC

- Ability of Programme Director and Principal Investigator to hold the overall vision and guide the project integration.
- Creation of a collaborative and supportive working relationship between the members of the Executive that could negotiate flexibly and adjust within a core vision.
- Stability of the Executive team.
- Ability of separate universities to empower directors to work together to create a single research centre.
- Integration of new members to the vision and goals.
- Regular awaydays for the whole team where researchers could develop relationships, share experiences, exchange knowledge and learn new skills and be challenged.
- An annual international conference to provide engagement with researchers worldwide, and regular seminars and workshops that allowed us to collectively remain abreast of changes in the environment for our research.
- A formal project 'peer assist' process to support project proposals from across the team and provide a mechanism to report and monitor progress.
- Clear targets and deliverables for individual researchers and projects.
- A formalised process for monitoring project cost and schedule.
- Centralised processes for external communications, a professionally developed website and professional communications expertise to develop strong branding and industry-facing outputs.
- A central budget but with devolved responsibility for adherence to budget and activity schedules.
- A highly experienced and supportive steering committee.
- A strong interest, and periodic joint support, from the participating academic institutions.
- The creation of a strong HaCIRIC brand.

### 5.1.4 Research theme development

The strategy and initial research targets were developed during two pre-proposal workshops with over 70 healthcare user organisations from local and national NHS and policy levels and industry. This was in order to orientate HaCIRIC to the relevant policy and practice issues.

We started with seven themes, three informing studies and five 'cornerstone projects' (see figure 3). Together, these underpinned and informed the work of the early programme.



Over time, our understanding of the research landscape deepened and we refined HaCIRIC's research focus. Continuous engagement with our stakeholders via our regular seminars, workshops and the annual conference (see section 8) enabled us to refresh our ideas continually. Our aim was to build a programme that made a contribution to meeting the broad challenges facing healthcare infrastructure systems both in the UK and globally. As well as generating rigorous and accessible evidence to show how to use technological and physical infrastructure to support new models of healthcare delivery, we also paid particular attention to the changing environment – the emerging new organisational and funding models for the provision of healthcare services and infrastructure. As the programme developed, and after discussions with the EPSRC third year review panel, we focused our attentions in Phase 2 on two major themes:

## Theme 1.

### Decision support to achieve better health through better infrastructure

(see Impact Case Studies 7.3, 7.4, 7.6, 7.7)

The aim of the theme was to develop and implement evidence and model-supported engineering approaches for healthcare facility planning, design and operation. These approaches aimed to recognise the complexity of the changing external landscape. The theme built on our prior work on strategic asset management and evidence on how healthcare environmental design can improve performance and outcomes. It combined with our work and expertise on developing simulation models of healthcare innovations.

The theme investigated ways of improving planning and infrastructure decision-making through the combination of robust evidence and modelling, simulation and visualisation of alternative service and infrastructure solutions and management of healthcare facilities. It focused especially on the problem of improving urgent and unscheduled care delivery, with projects on analysing health system resilience, scenario planning, and application of simulation modelling to explore options in emergency stroke care.

## Theme 2.

### Implementing and embedding effective and efficient healthcare

(see Impact Case Studies 7.1, 7.5)

The second theme built on our research into the processes underlying successful and sustainable adoption of innovations in healthcare organisations and systems. Previous HaCIRIC projects on the adoption of 'remote care' – telehealth and telecare – and the impact of funding and contractual models on design innovation provided insights into the role of organisational factors such as the use of 'champions', benefits evidence and the difficulties in aligning incentives across complex healthcare systems.

We drew together this research, alongside work carried out as part of the North West London CLAHRC (Collaborations for Leadership in Applied Health Research and Care), and extended it into new areas. Projects were on the impact of new forms of public-private partnerships (PPP) to 'bundle' together infrastructure and clinical services to align risks and incentives; on alternative approaches to managing major hospital infrastructure and services transformation programmes; and on the roles of targets and incentives in delivering innovation in renal care.

## 5.1.5 Funding other institutions from the programme – building UK capacity

As part of Phase 1 of HaCIRIC, 20 per cent of the budget (£1.2m) was allocated to fund eight projects with seven other universities across the UK. This ensured that we were addressing a broad platform of research in healthcare infrastructure requiring inputs of expertise beyond that residing within the core HaCIRIC team (Table 1). Consequently, new initiatives were developed in response to emerging national issues such as healthcare associated infection, where we created three projects engaging three external universities in a coordinated programme of work.

One of these projects was created in a 'sand pit', using the resources of the EPSRC Star Professor at Loughborough IMRC. HaCIRIC provided the context for this work. This is typical of the flexibility that the HaCIRIC programme provided, allowing us to respond to emerging issues and mix blue sky and practice-based approaches.



**Table 1. External university projects receiving HaCIRIC funding**

| Project  | Collaborating university                            | Outcome  |
|--|---|--|
| Hospital acquired infections, review of government cleaning initiative             | London South Bank University (MARU)                 | Pragmatic design and management recommendations for minimising cross contamination in new build designs.   |
| Measuring the built environment factors in hospital acquired infections            | University College London Institute of Child Health | Development of integrated measurement protocol and graphical presentation of high-risk areas for potential contamination zones in operating ward spaces. Review of cleaning systems and cleanliness measurement approaches using Statistical Process Control to advise on cleaning performance.  |
| Design for flexibility and implementation of practice-based commissioning          | Lancaster University                                | Recommendations for GP commissioning suggesting the need for a shift from a 'GP centred commissioning' to 'community centred commissioning' that recognises the key role of GP consortia as facilitators of commissioning networks, but focuses on co-creation as main strategy for service innovation.<br><a href="http://imagination.lancaster.ac.uk/activities/Design_Practice">http://imagination.lancaster.ac.uk/activities/Design_Practice</a> |
| Benefits quantification method   | Heriot-Watt University                              | The team worked with several NHS Scotland Health Boards to develop the method by interacting with live capital investment projects. The resulting method provided initial evidence of economies of scale in the quantification of benefits sought from public good health buildings.   |
| Nurturing and evidence-based learning environment for innovative healthcare design | The University of Sheffield                         | The team worked with Department of Health Estates & Facilities (England), Welsh Health Estates, NHS Scotland/Health Facilities Scotland and Northern Ireland Department of Health Social Services & Public Safety to assemble, collate and critically compare the evidence-based design guidance and tools and strengthen the quality and safety agenda.   |
| Open scenario planning   | University College London                           | New 'open scenario planning' approach to help develop infrastructure solutions that could suit a number of different future scenarios. Collaboration with seven NHS Hospital Trusts and others from across secondary, primary and mental health. The approach was validated in four international road show events in Denmark, Norway, Sweden and the US.  |
| Implementation of single bed hospital design                                       | King's College London                               | Longitudinal analysis of the impact of single-room accommodation in the new Pembury hospital and comparators. Ongoing follow-on work carried out with NIHR-SDO funding showing impact on care processes and outcomes.  |
| Use of simulation tools  | University of Southampton                           | Improved understanding of the use of simulation in healthcare planning practice; conceptual framework describing the roles of simulation models; lessons fed into development of the Cumberland Initiative ( <a href="http://www.cumberland-initiative.org">www.cumberland-initiative.org</a> )  |

“  
*New initiatives were developed in response to emerging national issues such as healthcare associated infection.*  
”

“

*We have collaborated with ECHAA in a series of presentations to health ministries, investment banks and healthcare providers as far afield as Kazakhstan and Moldova.*

”

## 5.1.6 International collaborations

As we have indicated, over time, HaCIRIC became increasingly international in its outlook and activities. Since commencing, over 140 keynote addresses and invited presentations have been made, four seminars held in Europe and two collaborative projects have been developed with non-UK institutions.

### Internationally collaborative research activities

We collaborated on a number of research activities with partners from outside the UK. Highlights include:

- Collaborative work with MIT and Harvard Medical School on disruptive innovation, exploring the potential use of low cost, mobile, ultrasound scanning in hyperacute stroke care.
- International comparative research projects on public-private partnerships and on hospitals' approaches to major infrastructure and organisational transitions, working with partners from the health sector in Finland, Spain, Germany, the USA and Canada.
- Collaboration with University of Minho in Portugal on a methodology for the benefits management of a new hospital development in Guarda. The collaboration introduced HaCIRIC's BeReal methodology to the Portuguese national health service.
- An academic collaboration between HaCIRIC and The Federal University of Rio Grande do Sul, one of the largest federal universities in Brazil. Collaborative activities focused on (1) value management, including visits by three Brazilian PhD students, leading to case studies developed in the UK healthcare sector, (2) waste measurement in construction projects and the role of improvisation as a strategy for coping with ineffective upstream processes, and (3) 'design science', involving workshops with PhD students.
- Collaboration with World Health Organisation (WHO) to integrate emergency planning with daily operations and sustainability with resilience for inclusion in the revised version of the WHO Hospital Safety Index, a global evaluation tool; and develop a curriculum framework for public health risk management.
- Collaboration with the European Health Property Network (EuHPN) and its members including several EuHPN annual conferences to explore the future for strategic planning of healthcare infrastructure.

### International collaborative work with European Centre for Health Assets and Architecture (ECHAA)

The main vehicle for our international work has been the European Centre for Health Assets and Architecture (ECHAA). This was established towards the end of HaCIRIC's first phase as the research arm of the European Health Property Network, with support from the European Investment Bank and TNO (Netherlands). Along with other healthcare and construction research organisations across Europe, HaCIRIC was invited to become a founding partner. Professor James Barlow is Chairman and a Director of ECHAA and Professor Colin Gray is a Director of ECHAA.

ECHAA activity with HaCIRIC includes: a contribution to an EU review of the Structure Fund Programme; work for the European Investment Bank on the impact of the built environment on health outcomes; and support to the Hungarian Ministry of Health while Hungary held the Presidency of the Council of the European Union in the first half of 2011 and beyond. We have collaborated with ECHAA in a series of presentations to health ministries, investment banks and healthcare providers as far afield as Kazakhstan and Moldova. Our work on eHealth and remote care was highlighted in a keynote speech at the Hungarian EU Presidency conference in May 2011. We are currently involved in advising the Czech government on the development of its healthcare strategy and a new teaching hospital in Bratislava. We were invited to conduct a master class on remote care implementation in Lisbon for delegates from across Southern and Eastern Europe. We are continuing to position ECHAA as the leading pan-European source of analysis on PPP financing in the health sector.

Our first collaborative research bid (on integrated care models and the role of infrastructure) with ECHAA for funding from the European Commission's FP7 programme achieved the second round shortlist but, unfortunately, was not selected. However, the development of the ideas for this proposal on integrated care was a useful foundation for work within HaCIRIC and for building closer relationships with European partners. ECHAA's membership is being added to: Semmelweis University in Hungary and Aalto University in Finland joined in 2013.

### **Programme of international visits to HaCIRIC**

We organised a programme of visits by internationally recognised domain experts to establish links with potential future partners and support skills development for our researchers. Some visitors include Dr Henry Feldman (Harvard Medical School, USA), Dr Stan Finkelstein (MIT, USA), Professor Gene Schneller (Arizona State University, USA), Glen Ballard (University of California Berkeley, USA), Professor Franklin Becker (Cornell University, USA), Dr M. Mariappan (Tata Institute of Social Sciences, India), Dr Goran Trendafiloski (World Agency of Planetary Monitoring and Earthquake Risk Reduction, Switzerland), and Professor George Yao (National Cheng Kung University, Taiwan).

HaCIRIC has also hosted international delegations from health authorities, government bodies, industry and academia. These include a delegation to investigate collaborative links with Chalmers University (Sweden) and the Healthcare Architecture Nordic Network, representatives from Ontario Ministry of Health to discuss innovation mechanisms in the NHS, a delegation from Tokyo University and other Japanese organisations to find out about UK policies on the development of innovative medical technologies, representatives from eight Finnish healthcare technology companies to learn about UK healthcare market trends, and a large delegation of Swedish health and social care providers to learn about NHS innovation policies.

### **International visits by HaCIRIC researchers**

As well as presentations at over 140 international conferences, HaCIRIC team members were active in exchange visits to international organisations and partners. Highlights can be seen in Box 8.

## **Box 8. Selected international visits**

- Invitation to join the WHO Global Expert Consultation on Revision of the Hospital Safety Index in Istanbul.
- Leadership of an international team from Japan, Italy and Turkey to investigate the impact of Van and Ercis (Turkey) earthquakes on healthcare facilities, with presentations to over 60 hospital directors and the Turkish National Health Directorate.
- Invitation to join the Emergency Department: Considerations for Innovation & Strategic Design Workshop at The Centre for Health Design and MedStar Institute for Innovation in Washington DC.
- Invitation to join the Japan-UK Joint workshop on Policy Integration between Environmental Assessment and Disaster Management in Ichikawa, Japan.
- Invitation to join consultations on protocols for risk assessment and on developing a curriculum framework for public health risk management in Amman.
- A tour to Japan, partly organised by UKTI, to make a series of presentations on UK trends in remote care technology to Japanese companies and healthcare providers.
- Invitations to facilitate workshops and other events for the healthcare sector, including a TNO workshop in the Netherlands on integrated infrastructure scenario planning; a workshop at Chalmers University of Technology on optimising healthcare infrastructure for emergency care using open scenario planning; and a study visit to St Olavs Hospital (Norway) for emergency department clinicians from University Hospital Leicester.

## 6. HaCIRIC's impact – knowledge development and insights and significant achievements

HaCIRIC's achievements can be viewed on two levels: academic research findings and impact on policy and practice. For selected areas of our work, these achievements are described in detail in the impact case studies. We believe that our body of work has significantly enhanced knowledge of the dynamic relationship between healthcare infrastructure, services and technology. We have greatly increased the evidence base on these relationships, publishing widely in management and practitioner journals.

Some of HaCIRIC's work has been deliberately speculative – projects that were chosen because they encouraged 'adventure' – creating avenues for possible future research. Lessons learned from the evidence base generated by our projects have been applied by the commercial and public sectors.

“

*Of particular importance are the insights HaCIRIC's work has made on the complex relationships between healthcare infrastructure, technology and services – the three core elements making up our domain.*

”

To date, we have published over 190 journal articles in peer-reviewed journals from the built environment, design and healthcare domains, including elite journals such as Construction Management and Economics, BRI, Design Studies, Research Policy, California Management Review, Health Affairs, Social Science and Medicine, BMJ and PlosOne. Several of our papers are highly cited. For example, our systematic review of the evidence base for remote care, published in the Journal of Telemedicine & Telecare (the leading journal in the field) in 2007, is ranked second most highly cited paper ever published in that journal in terms of average citations per year and twelfth most highly cited paper overall from a total of 1810 listed papers<sup>5</sup>.

Of particular importance are the insights HaCIRIC's work has provided into the complex relationships between healthcare infrastructure, technology and services – the three core elements which make up our domain. This is important because the mismatched timescales between technological innovation, changes in service delivery models and fixed capital infrastructure investment make it hard to anticipate and plan for future needs, and manage the change processes (see box 9). We have carried out robust and ground-breaking research to investigate the dynamics between the three elements and use simulation and modelling approaches for improving decision making. This is described in more detail in section 7.3, 7.4, 7.6, 7.7.

As well as generating new knowledge on the impact of innovation in healthcare infrastructure, our work has helped to improve understanding of the difficulties in adopting and embedding innovation in healthcare systems. This has long been recognised as harder in healthcare than other industries for several reasons: the complexity of healthcare systems with multiple stakeholders, different professional, organisational and financial silos, the difficulty of capturing robust evidence of improved benefits, and the highly politicised context at both a national and local level.

<sup>5</sup> –Azam Askari et al. 'The 60 most highly cited articles published in the Journal of Telemedicine and Telecare and Telemedicine Journal and E-health.' J Telemed Telecare 10 January 2014.

## Box 9.

A better understanding of the interrelationships and associated timescales for **healthcare infrastructure, technology and services** has also enabled HaCIRIC to contribute to debates about new approaches to planning and designing the healthcare built infrastructure.

Our research into 'open scenario planning' examines how to develop infrastructure solutions that, with little additional expense, could suit a number of different future scenarios. This increases the life expectancy of a facility and should reduce the costs of possible future reconfigurations. Several UK acute trusts and two EU healthcare providers are working with HaCIRIC to enhance their future-proofing capacities.

Our work on new models for procuring and financing healthcare infrastructure is highlighting why certain approaches have failed historically to deliver the necessary flexibility and adaptability to cope with likely future demands on healthcare infrastructure. This has stimulated interest in the applicability of a new generation of public-private partnership models for delivering infrastructure and services in the NHS (see impact studies 7.1 and 7.7).

In several projects, we have provided new knowledge on why innovations fail to be adopted despite overwhelming evidence for their benefits. We have analysed comprehensive data on factors that influence the adoption of remote care from initial proposal to mainstream implementation (see impact study 7.5). We continue to work with one of the national CLAHRCs (Collaborations for Leadership in Applied Health Research and Care) to understand the organisational barriers and increase the uptake of performance-enhancing innovative healthcare practice across North West London. The key issue appears not to be lack of evidence, but a lack of trust in those who are disseminating the best practice.

HaCIRIC has increased the knowledge base about the role of evidence in design practice in healthcare. Evidence in the past tended to be collected in academic silos and then aggregated when necessary. We have challenged the creation and use of evidence, reviewing the existing theory and practice based tools and proposing a new interdisciplinary approach to co-creating evidence across organisational boundaries.

By drawing together scientific knowledge and practices from economics, social sciences and humanities, we have extended the systemic understanding of healthcare infrastructure evidence from its existing basis in design into early front-end planning. This is helping to ensure that infrastructure design satisfies healthcare service design and operation more effectively. We have also used this knowledge to provide evidence to the Department of Health and the European Investment Bank for assessing the potential health gains from investment in different types of healthcare facilities (see impact study 7.8).

“

*We have challenged the creation and use of evidence, reviewing the existing theory and practice based tools and proposing a new interdisciplinary approach to co-creating evidence across organisational boundaries.*

”

### Box 10 The environmental implications of healthcare infrastructure changes.

A PhD project evaluated the direct and indirect greenhouse gas emissions from 21,000 telemedicine consultations performed over a seven year period in Alentejo, Portugal. Telemedicine has resulted in significant environmental benefits, with a dramatic reduction from over 2.4 million kms to 123,000 kms in the distance travelled in vehicle by patients to appointments. This saved a total of 455 tonnes of CO<sub>2</sub> equivalent.

Two other PhD projects investigated the impact of reconfiguration on NHS staff and patients travel behaviour, using techniques such as Structural Equation Modelling, GIS and multilevel modelling to investigate the socio economic, psychological and situational determinants.

## 6.1 Key insights. The impact of innovation in healthcare infrastructure

Understanding how innovations in healthcare infrastructure impact on economic, social and clinical outcomes requires a wide range of methods to be deployed. Impacts need to be captured across different levels in a health system – from individual departments or wards in a hospital, for example, through individual organisations such as a hospital trust to local health economies – and over different timescales. ‘Innovation’ ranges from the changes in building design to reconfiguration of services across local health systems. This requires the use of quantitative approaches such as simulation and modelling, and qualitative methods. HaCIRIC’s work has helped to extend knowledge in this complex area in several ways.

### Service improvements in hyperacute stroke care

We have been developing simulation models and analytical tools as an aid to decision-making. For example, simulation modelling has been used to develop and evaluate service improvements in hyperacute stroke care, testing the relative impact of different service innovations on proportions of patients receiving thrombolysis in Scotland. This has shown how significant benefits can be achieved from improvements to existing scanning processes within hospitals as well as from more advanced options such as telestroke (see impact study 7.4).

### Improving patient flows through A&E

In another project, University College Hospital London and University Hospital Leicester are working with HaCIRIC to model options for the reconfiguration of services by simulating patient flows through unplanned and emergency activities. (see impact study 7.4).

### Development of ‘natural personalised ventilation’

From our work on airflow (natural ventilation) modelling, we have found limitations in current systems for dealing with the spread of airborne pathogens in hospital wards and the significant heating energy required to keep them thermally comfortable. A direct consequence was the development of the ‘natural personalised ventilation’ (NPV) system which dilutes ambient air through mixing and provides a dedicated supply of fresh air directly over patients (see impact study 7.2).

### Daylight availability and patient recovery

Research involving simulations of daylighting and artificial lighting established the relationship between daylight availability and patient recovery in a hospital setting. This resulted in innovative design of daylight and artificial light environments to promote improvements in therapeutic performance (see impact study 7.3).



### Ground-breaking findings on HCAI

We have collected new evidence on the way the built environment affects the transmission of healthcare associated infection (HCAI). Evidence has been constructed through an exhaustive process of swabbing surfaces and isolating the mix of different infections, while observing the movement and actions of staff and patients to identify correlations. This has allowed potential infection risks of particular configurations of healthcare infrastructure to be modelled and options to be tested before they are put into practice (see impact study 7.2).

### Single-room accommodation and patient safety

Building on an earlier HaCIRIC project, we are currently working in an NIHR-SDO funded project with the National Nursing Research Unit (King's College London) and University of Southampton to conduct the most detailed study to date on the impact of single-room accommodation, including impact on infection control and patient safety, and the economic impacts.

## 6.2 Key insights. Modelling and simulation tools

As well as our research to better understand the impacts of innovations in healthcare infrastructure in different contexts and over different timescales, we have developed improved analytical tools and approaches for capturing both the potential benefits and the costs of such innovations.

### Benefits realisation modelling for healthcare infrastructure and service development

We have developed and applied a comprehensive benefits realisation modelling process for healthcare infrastructure and service development (the 'BeReal' tool). This highlights benefits right from the early strategic stage. Our tool ensures benefits are deployed, managed and traced through the programme. Our research is showing how to quantify and compare the value that stakeholders place on many different benefits coming from a health facility including accessibility, aesthetics and working conditions (see impact study 7.6).

### Simulation tools for planning of healthcare estates and healthcare services

In a joint project with the University of Southampton, we have researched the way simulation tools are actually used in the planning of healthcare estates and healthcare services, and why they are not used when they would bring benefits. This is important because the opportunity for the beneficial application of simulation and other approaches in healthcare has not been fully exploited and is lagging significantly behind other industries. This has provided a better understanding of the role simulation can play in the decision-making processes of healthcare professionals, managers and policy makers.

In another project we investigated tools for estate planning. This work has highlighted that existing tools are not user friendly, with the result that decision-makers are often unaware of their existence, reluctant to pay for them or may not know how to use them effectively. Consequently, we have linked with the Brunel University IMRC (MATCH) and others to develop simulation and modelling via the Cumberland Initiative ([www.cumberland-initiative.org](http://www.cumberland-initiative.org)).

“

*We are supporting the Cumberland Initiative's attempts to develop UK capacity in modelling and simulation of healthcare practices.*

”

“*We evaluated and then shaped policy springing from the world’s largest randomised control trial of remote care services. Launching the next policy initiative, the Prime Minister said: “We’ve done a trial [WSD], it’s been a huge success and now we’re on a drive to roll this out nationwide with an aim to improve three million lives over the next five years with this technology.”*”

## 6.3 Some of HaCIRIC’s impacts on policy, industry and practice

### 6.3.1 Supporting policy development

- **Remote care** In 2007 we were invited by the Department of Health to form a consortium to evaluate the Government’s Whole System Demonstrators programme, including the world’s largest randomised control trial of remote care services. This has informed UK and international policy and practice in this field. Launching the latest policy initiative, the Prime Minister said: “We’ve done a trial [WSD], it’s been a huge success and now we’re on a drive to roll this out nationwide with an aim to improve three million lives over the next five years with this technology.”<sup>6</sup>
- **Effectiveness of public-private partnerships** Our work on PPPs has led to requests to give evidence to the House of Commons Treasury Select Committee on the effectiveness of the Private Finance Initiative (PFI) in delivering innovation in the NHS. We were also invited to organise a special session on PPP at the European Health Forum Gastein, the leading European health policy conference.
- **Advice on NHS innovation** We have provided guidance and advice on NHS innovation processes. We briefed the Treasury’s Cooperation and Competition Panel on NHS innovation and were invited to join the reviewing panel on the new release of the Office of Government Commerce’s Managing Successful Projects. We were invited to lead an inquiry into innovation in the NHS by the Policy Exchange, published in 2008 as ‘All Change Please. Putting the best new healthcare ideas into practice’ to help contribute to debates around the Darzi Review.
- **European infrastructure policy** We contributed to healthcare infrastructure policy at a European level. Our work for the EUREGIO III: lessons learned about improving investment in regional health systems using Structural Funds report helped shape the Hungarian EU Presidency programme content and informed negotiations for the next cycle of EC Structural Funds. We reviewed the evidence for the contribution of healthcare infrastructure investment to health gain for the European Investment Bank. This was circulated to all country lending managers of the EIB to help trigger greater investment in healthcare infrastructure projects.

- In collaboration with the Department of Health Estates and Facilities Division, HaCIRIC has developed a range of tool-based interventions to enable a robust and evidence-based quality assurance approach for the NHS estate. This work has delivered a new strategic asset management approach that draws knowledge from open building, scenario planning, economics and operations management fields. This understanding is being applied across NHS Trust scales, from whole regional systems to specific clinical care pathways and room details within a hospital site, building or department. Additionally, two new regulatory and quality assurance tools to deliver clean and safe environments have been developed.

### 6.3.2 Supporting industry

- **Infrastructure and healthcare trends** Our work on the impact of technology on future trends in healthcare has led to numerous briefing to industry. For example, we were invited to a workshop at AECOM (the leading global design, engineering and infrastructure company), attended by senior managers from AECOM’s health team from UK, USA, Australia. We also held a seminar for senior Laing O’Rourke staff and also contributed lessons from our work on healthcare PFI to Laing O’Rourke’s ‘Leaders of Tomorrow’ executive education programme.
- **Future of remote care** In 2007 we were invited by the Department of Trade and Industry / Technology Strategy Board to conduct a road mapping exercise to support development of the next generation of remote care technology. This led to the launch of 38 industry-led projects worth £47.1m through the ‘Assisted Living Innovation Platform’.
- **Support for business planning** Our remote care research has helped influence industry thinking. For example, Tunstall (market leader in the UK and in several other countries) has stated that its involvement in the WSD helped validate its business approach to remote care.

6 – [www.gov.uk/government/speeches/pm-speech-on-life-sciences-and-opening-up-the-nhs](http://www.gov.uk/government/speeches/pm-speech-on-life-sciences-and-opening-up-the-nhs)

- **User engagement in healthcare design** Our research with Skanska UK and HOK Architects on the development and use of building information technology to deliver large hospital projects has influenced innovation and R&D management within these firms and beyond through activities supporting the use of new virtual reality technologies for user engagement in healthcare design.
- **Standards for waste minimisation** We developed a bespoke lifecycle waste mapping approach, one of the drivers of the development of the new BSI standard on waste minimisation - BS 8895.

### 6.3.3 Supporting healthcare practice

- **NHS business planning** Our innovative BeReal process and methods have been designed to align with other common programmes and project management techniques such as the OGC Gateway Review process, PRINCE 2 and Managing Successful Programmes. This is now being used to support business planning in the NHS. For example, BeReal has been used by Brighton and Sussex University Hospitals Trust, NHS Stockport, NHS Lothian in capital development programmes, and was highlighted in the Treasury Investment Manual, 2009.
- **Open scenario planning** HaCIRIC has developed a new 'open scenario planning' approach, with seven NHS Hospital Trusts and others from across secondary, primary and mental health. The approach was validated in four international road show events in Denmark, Norway, Sweden and the US. This process resulted in sharing and translation of knowledge across the 305 participants from healthcare, and subsequent consultancy work for Trusts applying the principles directly to infrastructure projects.
- **Activity-Acuity-Adaptability-Flow (A<sup>3</sup>F) tool** Through action research we have developed a new methodology addressing the relationships between clinical activity, patient acuity, clinical service systems separation, open building and clinical flow modelling. This takes the form of an Activity-Acuity-Adaptability-Flow (A<sup>3</sup>F) tool. This is being applied in practice through the application of consultancy work, which is resulting in further refinement of the A<sup>3</sup>F tool to create a software prototype.

- **Guidance on emergency department design** The team was involved in the development of a new guidance document on emergency department design (Health Building Note HBN15-01) and in the development of College of Emergency Medicine guidance supporting a policy move away from prescriptive input and output specification.
- **Insights into tensions between targets and incentives** This guidance is radically altering the planning of A&E departments and sets out the strategic background, uncertainties and the evidence-base for key decisions that need to be made in the design. Engagement with Scotland's Unscheduled Care Collaborative Programme provided new insights into the tensions between targets and incentives at different levels in a whole system change initiative.
- **Disaster prevention** Other work on unscheduled care has been carried out to support disaster prevention, through the development of new guidance, and tools and models. We helped revise the World Health Organisation's Hospital Safety Index evaluation tool, expected to be implemented globally to improve the resilience of healthcare facilities. The WHO has acknowledged the significant input of the HaCIRIC team and requested further help for supporting public health risk management. We were invited by WHO East Mediterranean Regional Office to collaborate on developing a curriculum framework for public health risk management.
- **Changes in hygiene monitoring behaviour and clinical practice** Our initial work on the transmission of hospital-acquired infection prompted a Department of Health funded evaluation of the use of ATP-based hygiene monitoring in hospitals. The national study at eight hospitals included ward staff training and feedback and resulted in a general reduction in the median 'relative light unit' levels for a range of high-touch near-patient sites for the majority of hospitals. The impact of the study was a change in hygiene monitoring behaviour and clinical practice in the collaborating hospitals.
- **Analytics support for capital investment decisions** The NHS Premises Assurance Model (PAM), a software-based tool, was developed to provide baseline quality assurance across NHS built assets. The Department of Health commissioned HaCIRIC to develop better ways to strategically manage and assure healthcare assets by improving PAM's functionality, broadening the user base and integrating existing standards and toolkits. This includes more robust analytics for building age, condition and risk-adjusted backlog maintenance, likely to have a significant impact on capital investment decisions in Trusts' asset management plans.

“*HOK are industry leaders in the adoption and use of BIM. The work of HaCIRIC and the University of Reading has made a significant contribution towards our BIM implementation strategy.*”

Andrew Barraclough,  
HOK Director.

## 7. Impact case studies

### 7.1 New models for service delivery and infrastructure procurement

#### Background

This strand of HaCIRIC research (comprising three main projects) investigates the relationship between models for financing and procuring healthcare infrastructure and performance in its delivery. An important consideration is the extent to which different approaches stimulate the innovation needed to cope with future healthcare demands.

This issue is especially important for government health and financial policy. The introduction of private finance into delivery of healthcare infrastructure began in the UK in the late 1990s. This involved considerable investment via the PFI and LIFT programmes, resulting in many new facilities which would not otherwise have been built. However, the introduction of such public-private partnerships (PPP) into the NHS was controversial, partly due to concerns over its long-term cost, and the original PFI model has evolved.

Several new PPP models are now attracting interest both in the UK and worldwide, for example by the World Economic Forum. Emerging especially in continental Europe, these extend the contractual / funding 'envelope' by bundling not only infrastructure but also clinical services. These PPPs range from traditional 'accommodation only' arrangements to full service provision across both primary and secondary healthcare. Significant claims have been made for their benefits, notably the examples in Spain and Finland. There has, however, been very little critical, independent analysis of these PPPs.

Our work builds on an early HaCIRIC project on the UK's PFI programme (2006-07). It also draws on initial HaCIRIC work on the relationship between contractual terms and performance incentives for contractors, subcontractors and suppliers, and on the changing balance of economic and expert powers during infrastructure planning and delivery processes. One of the key areas for further work emerging from these projects was the flexibility of PPPs to cope with future care needs, in the form of design innovation. Despite interest in lifecycle costing, we found the initial PFI schemes in the UK to be inflexible, partly due to issues around risk transfer and alignment of incentives.

We then turned our attention to the newer European PPP models in a HaCIRIC project conducted with colleagues at ECHAA (2011-14). This work is continuing beyond HaCIRIC, but there are preliminary findings on the impact of the PPP and payment models on performance incentives, integration of care, and business and clinical models.

In another project (2009-11) we explored a related concern in research and policy, the use of public sector procurement models to stimulate innovation. The use of European Union Structural Funds for procuring innovative healthcare infrastructure has involved major public expenditure and raises similar research issues to PPPs relating to risk transfer and incentives. We found there were structural barriers to the use of Structural Funds to stimulate healthcare infrastructure innovation, due to similar barriers to collaboration as found in the UK PFI study.

The impact of this body of work has been largely at a strategic policy level. As well as numerous industry workshops and presentations in the UK and abroad, the first project's findings were discussed in the report of the 2011 Treasury Select Committee inquiry into PFI. The European PPP project is ongoing, but early findings were published in the leading US health policy journal *Health Affairs*, attracting feedback from the World Bank. We also presented findings to a special session at 'Gastein 2012' (the leading annual European health policy conference), attracting circa 100 delegates. We are contributing to a report for the European Commission (SANCO) on PPPs in healthcare. The work on the use of the Structural Funds programme helped inform a European Commission report (EUREGIO III) which fed into discussions about the future of Structural Funds for use in healthcare.

## Underpinning research

### 1. Adaptability and Innovation in Healthcare Facilities

(2006-07). This was fully funded via the Howard Goodman Fellowship (supported by NHS Estates, Catalyst, Alfred McAlpine, and St. Bartholomew's and the Royal London Charitable Foundation). The research explored the relationship between the delivery mechanism for healthcare infrastructure (financial and procurement) and the potential to accommodate future changing needs, especially through flexibility and adaptability in the built form. It involved case studies of selected hospital projects from the first wave of PFI hospitals and case studies of pre-PFI hospitals. It drew conclusions on key issues hindering innovative thinking around adaptability/flexibility, including barriers in communication, risk aversion resulting partly from the competitive bidding environment, limited knowledge transfer and learning across PFI projects, and the need to reduce capital costs to match the approved affordability limits.

### 2. European Healthcare PPPs (2011 – 2013 /

ongoing). There is a wide range of PPP models from 'accommodation-only' (such as the UK's PFI) to full-service provision where a private company delivers both acute and primary care for a geographical area from its own facilities. Differences are determined by the degree to which services and facilities are 'bundled' within the contract. The more infrastructure, support services and clinical care services are bundled, the greater the potential for alignment of incentives to improve performance. However, this may be at the expense of increased contractual and financial complexity. We carried out exploratory research on a selection of European PPP healthcare projects to understand the factors which lead to clinical and economic performance. The case studies suggest that, while bundling may well have beneficial implications for performance and integration of care, payment models and ownership structures are potential mitigating factors.

### 3. Demand driven innovation: European Structural Fund supported healthcare projects (2009-11).

While there has been much research on government supply side policies to stimulate innovation (e.g. R&D credits, public provision of research infrastructure, promotion of industrial champions), there is relatively little research on demand side policies. Since 2000, European Union Structural Funds have been increasingly deployed to bring about innovative health infrastructure and associated service delivery. Through case studies of Structural Fund projects in Germany, Greece, Slovenia and Italy, we aimed to understand how their governance, institutional and organisational features were related to innovation outcomes. We found similar problems to project 1, namely hindrance of collaboration and partnering due to positive financial rules, inflexibility in financing arrangements on innovative thinking, and a relationship between clarity of outcome specifications and contractual arrangements and innovative outcomes.

### 4. Associated work. A number of other projects and activities we were engaged in informed our thinking under this theme:

- Research by Roehrich on supply chain management and procurement (see Caldwell et al. Procuring complex performance in construction: London Heathrow Terminal 5 and a Private Finance Initiative Hospital. *Journal of Purchasing and Supply Management*, 2009, 15, pp. 178-186)
- Conceptual research on flow models of capacity planning (see Rechel et al. Hospital capacity planning: from measuring stocks to modelling flows? *Bulletin of the WHO*, 2010, 88, pp. 632–636).
- The EUREGIO III study for the EC included material from Project 3 above (see EUREGIO III: lessons learned about improving investment in regional health systems using Structural Funds, 2012, HCN, ECHAA, EMK-SU, UM, UL, ULSS10 Veneto).
- Project 2 drew on and informed the ECHAA / ECORYS review of PPP projects for the EC (ECORYS, forthcoming, Health and Economics Analysis for an Evaluation of the Public Private Partnerships in Health Care Delivery across EU).

“

*We are generating new findings on the impact of the PPP and payment models on performance incentives, integration of care, and business and clinical models that may shape the way governments invest in capital projects.*

”



## Impacts

The impact of this body of work has been largely at a strategic policy level, with findings being taken up by the UK government in its review of the PFI programme as well as informing European policy around the use of public funds in infrastructure projects and development on PPP models.

## Impact on policy

### 1. Advice to Parliament on PFI and innovation.

Oral evidence was given by Professor James Barlow to the House of Commons Treasury Select Committee on the effectiveness of PFI in delivering innovation in the NHS. The Committee said that it had previously recommended that PFI projects should be monitored for 'innovative approaches' and cites project 1 (above) on the impact of PFI on design innovation. This was reinforced by evidence from the NHS Confederation. Published in House of Commons Treasury Select Committee, Seventeenth Report of Session 2010-12, Private Finance Initiative, HC 1146.

### 2. Discussion of PPPs with key European policy makers.

Project 2 was discussed at a special session on 'Public procurement from the private sector: austerity, PPP and health service innovation' at the 15th European Health Forum Gastein (the leading European health policy conference), 6 October 2012. Discussants included the Chief Economist of Cassa di Risparmio di Venezia, Italian Ministry of Economy and Finance and the Director of the European Observatory on Health Systems and Policies. The session was attended by circa 100 delegates from European health policy and provider organisations.

### 3. NHS Confederation mission on PPPs.

One of the project members (Wright) participated in an NHS Confederation mission to investigate outcomes of Spanish PPPs (published as *The search for low-cost integrated healthcare – the Alzira model*, NHS Confederation / NHS European Office, 2011).

### 4. Review of PPPs for European Commission.

Project 2 drew on and informed the ECHAA / ECORYS review of PPP projects for the EC (ECORYS, forthcoming, *Health and Economics Analysis for an Evaluation of the Public Private Partnerships in Health Care Delivery across EU*).

### 5. Improving investment in regional health systems.

Project 3 findings contributed to EUREGIO III: lessons learned about improving investment in regional health systems using Structural Funds, 2012, HCN, ECHAA, EMK-SU, UM, UL, ULSS10 Veneto. This report helped shape the Hungarian EU Presidency

programme content and a presentation to the informal meeting of EU health ministers (Godollo, Hungary, April 2011). The EU Council endorsed the programme recommendations in the EU Council Conclusions of 6 June 2011, informing negotiations for the next cycle of Structural Funds.

## Impact on industry

### 6. Industry meeting on future of healthcare financing.

With ECHAA, we organized two workshops on the future of healthcare infrastructure finance and PPPs at a time of austerity, held in London and Berlin and bringing together experts from the finance, construction, health and policy sectors, with support from Arup International.

### 7. Presenting to global industry forums.

- International Academy of Design and Health World Congress, Singapore, 24 - 28 June 2009.
- 28th Union International des Architectes – Public Health Group (UIA-PHG), Florence, 23-26 June 2008.
- Conseil International du Batiment (CIB) conference on Revaluing Construction 2007 - Crossing boundaries, Copenhagen, 8-10 September 2007.

### 8. Discussions for global think tank on healthcare infrastructure.

We were invited to participate in a workshop for senior staff from the health team from the UK, USA and Australia at AECOM (leading global design, engineering and infrastructure company) on the healthcare infrastructure challenge. We are now discussing possible future work in the form of an AECOM global think tank.

### 9. Leadership development.

Project 1 and other HaCIRIC work informed the Laing O'Rourke *Leaders of Tomorrow Programme* (2006) (executive education).

## Selected Outputs

1. Barlow J, Köberle-Gaiser M (2008) The private finance initiative, project form and design innovation, *Research Policy* 37, 1392-1402.
2. Barlow J, Köberle-Gaiser M (2009) Delivering innovation in hospital construction. Contracts and collaboration in the UK's Private Finance Initiative hospitals program. *California Management Review* 51, 126-143.
3. Barlow J, Roehrich J, Wright S (2010), De facto privatisation or a renewed role for the EU? Paying for Europe's healthcare infrastructure in a recession, *Journal of the Royal Society of Medicine*, 103, 51-55.
4. Barlow J, Roehrich J, Wright S (2013) Europe sees mixed results from public-private partnerships for building and managing health care facilities and services. *Health Affairs* 32, 146-154.
5. Rechel B, Barlow J, Wright S, McKee M (2010) Hospital capacity planning: from measuring stocks to modeling flows? *Bulletin of the World Health Organisation*, 88: 632-636.
6. Roehrich J, Lewis M (In press) Towards a model of governance in complex (product-service) inter-organisational systems. *Construction Management and Economics*.
7. Barlow J (2010) Delivering innovation in hospital design: finance, contracts and the institutional context. In Caldwell N, Howard M (eds.) *Procuring Complex Performance: Studies of Innovation in Product-Service Management*. London, Routledge.
8. Roehrich J, Barlow J, Wright S (2013) Delivering European healthcare infrastructure through public-private partnerships: The theory and practice of contracting and bundling. In Das T (Ed.) *Managing Public-Private Strategic Alliances*. Information Age Publishing.
9. Barlow J, Köberle-Gaiser M, Moss, R, Noble A, Scher P, Stow D (2009) *Adaptability and innovation in healthcare facilities. Lessons from the past for future developments*. Howard Goodman Fellowship / HaCIRIC. [www.haciric.org](http://www.haciric.org)
10. Barlow J, Roehrich J, Hatzaras K (2012) Impact of EU structural aid on the delivery of innovative healthcare infrastructure and services. Conference on Demand, Innovation and Policy: Underpinning Policy Trends with Academic Analysis. 22-23 March, Manchester, UK.

## Researchers involved

- **James Barlow** (Imperial College London)
- **Christopher Harty** (University of Reading)
- **Martina Köberle-Gaiser** (Imperial College London)
- **Jens Roehrich** (Imperial College London)
- **Kyriakos Hatzaras** (Imperial College London)
- **Stephen Wright** (ECHAA)
- **Anja Kern** (Imperial College London)
- **Lili Kihn** (University of Tampere)
- **Jas Gill** (University of Reading)
- **Sep Arkani** (University of Reading)
- **Will Hughes** (University of Reading)





## 7.2 New approaches to healthcare acquired infection

### Background

Healthcare acquired infection (HCAI) is a serious problem in nearly every developed healthcare system across the world. The studies reported here are an attempt to develop an integrated approach to evidence collection in this complex area and to investigate how management of the built environment contributes to cross infection and potentially the reduction of the spread of HCAI.

Extensive work in the biomedical field has been underway for many years into the actual infections but only limited grounded work has been done to understand how the infections spread. More importantly, little has been done to understand how the facilities in which the care is undertaken contribute to or hinder the contamination and spread of the infections. What work has been done is fragmented and largely anecdotal, although there have been some studies, such as on the location and use of hand wash facilities, that are highly significant.

We undertook a number of studies to examine the problem at different levels of detail. First we examined what NHS Trusts across the UK regarded as their priorities. In 2006/07 the government allocated a grant of £300,000 to every hospital Trust to address their concerns. We explored what they did in relation to the built infrastructure. The most important investment was in improving hand washing facilities, although we show this can be limited in its impact due to the configuration of ward spaces.

Next, we investigated how a facility was being used to deliver healthcare, how people moved around the space, what they touched and how the microbial mix changed through the user interaction with the environment. Thirdly we looked at airflow and its relationship between patient location and movement in the space. Finally we addressed the issue of the effectiveness of cleaning in ward spaces.

Although the studies were looking at different aspects, the pilot stage of each was used to develop consistent research methodologies so that data from culture growth or Total Viable Counts (TVCs) measurements in one location were compatible with the same measures in another hospital or location. In this way, the data being collected in a number of locations and hospitals could be used across the study.

This project was not part of the original proposals for HaCIRIC's first phase, but arose in response to the perceived crisis in HCAI, which was at an all time high in 2007 with *Clostridium difficile* and MRSA cases rising. As the perceived need was to clean the environment and so curb cross-infection, a series of linked and coordinated projects were designed to investigate the role of the ward environment in the spread of infections. The fund set aside for projects in universities external to the HaCIRIC partners was used and this attracted others to align their projects with this programme.

### Underpinning research

#### 1. Evaluating 'Super-clean' initiative (2008-2009).

A review of the Government's Super-clean initiative was undertaken by the Medical Architecture Research Unit at South Bank University. Using a Freedom of Information request they determined how hospital trusts had allocated the funds for cleaning and improvement. This was followed through with a series of structured workshops with key parties in the design and management of ward spaces to learn how current practice was changing and where gains had been made in the control of infection. This informed the next studies in the programme.

“  
*Most existing work is laboratory-based and this was the first study of a live ward under operational conditions.*  
”

“

*Using trend analysis, the objective was to identify high risk sites that might be targeted, for example, by increasing the frequency of the cleaning and/or by changing the cleaning protocols.*

”

**2. Transmission in ward spaces** (2007-2013). A study to investigate how infection was transmitted in ward spaces was undertaken by the University of Reading, UCL and Space Syntax with the cooperation of the National Hospital for Nervous Diseases and Great Ormond Street Hospital. The problem was how to link the source of an infection, its transmission and final location and track the trail from start to finish. Most existing work was laboratory-based and this was the first study of a live ward under operational conditions.

A research protocol was established such that the ward was observed on consecutive days during the busiest periods in the day. The main activities around the beds were recorded, as were the movement patterns, the flora on surfaces at specific locations and levels. Simultaneously the air was sampled and the flora assessed. The air study was done in collaboration with the Civil Engineering Department at UCL, funded separately by EPSRC. A comprehensive picture of activity was obtained. However, the problem of linking cause and effect still remains as the sampling technology is still too slow relative to the speed of patient transfer.

**3. Interactions with patients and implications for HCAI** (2007-2013). A second study in the same ward spaces was commissioned, which focused on the events around a bed space. The Space Syntax methodology was used to observe the interactions with the patient as well as simultaneous monitoring of the flora in the space.

**4. Efficacy of routine cleaning** (2008-2010). We also conducted work to assess hospital ward cleaning using hygiene surveillance and continuous improvement process tools. The principal aim of this was the objective assessment of the efficacy of the routine cleaning currently undertaken in hospital wards with the aim of reducing transmission of nosocomial infections. Cleanliness on hospital wards is currently assessed using subjective assessment methods – primarily visual inspection. The objective of this work was to compare routine subjective assessment with quantitative microbiological data ('total viable counts' for MRSA and *Clostridium difficile*), and use of a hygiene surveillance tool (3M *Clean-Trace*) to evaluate the cleanliness of both high contact surfaces as well as the general hospital ward environment. This enabled the identification of high risk sites to be targeted for increased the frequency of cleaning or changing cleaning protocols.

**5. Ventilation / airflow** (2010-2012). We also undertook research into ventilation and airflow, and its multiple effects on thermal comfort, heating energy and the control of generic airborne pathogens in hospital wards. This involved modelling the performance of existing natural ventilation systems used in single-bed wards. It led to the innovative natural personalized ventilation (NPV) system, primarily aimed at protecting susceptible patients from ambient airborne pathogens. It could provide (personalized) fresh air directly over patients as opposed to windows. Also, unlike displacement strategies, the NPV creates a mixing regime that ensures dilution in the entire space. The mixing characteristics of the system were also found to lower the heating energy required to keep a ward thermally comfortable. Current research is extending the capabilities of the NPV system for existing multi-bed wards as well as for non-clinical spaces.

**6. Modelling ventilation systems** (2012-2013). One study modelled the performance of existing and innovative natural ventilation systems in single-bed hospital wards at Great Ormond Street NHS Trust using four criteria: minimum airflow rates, acceptable thermal comfort, low heating energy and control of airborne pathogens. Models of systems to introduce natural ventilation into refurbished spaces were produced.

## Impacts

We have achieved a better understanding of the relationships between different aspects of healthcare and infection transmission and control. This is helping to improve hygiene and to develop new environmental screening practice in hospitals.

### 1. More hygienic behaviour and clinical practice.

The underpinning research prompted a Department of Health-funded evaluation of the use of ATP-based hygiene monitoring in hospitals. The national study at eight hospitals (January 2010 - April 2011) included ward staff training and feedback and resulted in a general reduction in the median 'relative light unit' levels for a range of high-touch near-patient sites for the majority of hospitals. The impact of the study was a change in behaviour and clinical practice in a number of collaborating NHS hospitals.

### 2. New environmental screening policy.

The research contributed to the development and implementation at Great Ormond Street Hospital Trust of a new environmental screening policy which links validated cleaning techniques, environmental standards and screening techniques for specific organisms in order to ensure a safe patient environment. This policy has been shared with other hospitals including UCLH.

## Selected Outputs

1. Adamu Z, Cook M, Price A (2011) Natural Personalised Ventilation: A Novel Approach, *International Journal of Ventilation*, 10(3), 263-275.
2. Gaudart J, Cloutman-Green E, Guillas S, D'Arcy N, Hartley J, Gant V, Klein N (2013) Healthcare environments and spatial variability of healthcare associated infection risk: cross-sectional surveys. *PLoS One*. 19;8(9):e76249.doi:10.1371/journal.pone.0076249.
3. Malik D (2013) Assessment of infection risk from environmental contamination using rapid ATP surface measurements. *American Journal of Infection Control*, 41(5), 477.

4. Malik D, Patel K, Clokie M, Shama G (2013) On the difficulties of isolating *Clostridium difficile* from hospital environments. *Journal of Hospital Infection*, 84(2), 181.
5. Malik D, Shama G (2012) Estimating bacterial surface contamination by means of ATP: 20 pence short of a pound. *Journal of Hospital Infection*, 80(4), 354.
6. Shama G, Malik D (2013) The uses and abuses of rapid bioluminescence-based ATP assays. *International Journal of Hygiene and Environmental Health*, 216(2), 115.
7. Wojgani H, Kehsa C, Cloutman-Green E, Gray C, Gant V, Klein N. (2012) Hospital door handle design and their contamination with bacteria: a real life observational study. Are we pulling against closed doors? *PLoS One*. e40171. doi:10.1371/journal.pone.0040171.

## Researchers involved

- **Colin Gray** (University of Reading)
- **Nigel Klein** (Institute of Child Health, UCL),
- **Vanya Gant** (UCLH)
- **Hedieh Wojgani** (University of Reading)
- **Elaine Cloutmann-Green** (Institute of Child Health, UCL),
- **Ka-man Lai** (UCL),
- **Pietro Cohen** (UCLH)
- **Serge Guillas** (UCL)
- **John Hartley** (GOSH)
- **Kathryn Harris** (GOSH)
- **Catherine Fusi Ngwa** (NHNN)
- **Phil Astley** (MARU, London South Bank University)
- **Rosemary Glanville** (MARU, London South Bank University)
- **Jacqui McDonald** (Papworth NHS Trust)
- **Karen Sorensen** (Guy's and St Thomas NHS Trust)
- **Danish Malik** (Loughborough University)
- **Gilbert Shama** (Loughborough University)
- **Zulfikar Adamu** (Loughborough University)
- **Malcolm Cook** (Loughborough University)
- **Andrew Price** (Loughborough University)

## 7.3 An assurance based regulatory framework for NHS asset management

### Background

The NHS estate is valued at almost £40bn with £7 billion annual running costs. In the face of financial, capacity and technological challenges and growing incidences of non-compliance with national standards, there has been an increasing recognition of the need for a new quality and safety assurance framework.

To address this, in collaboration with the Department of Health Estates and Facilities Division (DH EFD), HaCIRIC has developed a range of tool-based interventions to enable a robust and evidence-based quality assurance approach for the NHS estate. This work has delivered a new strategic asset management approach that draws knowledge from open building, scenario planning, economics and operations management fields.

This understanding is being applied across NHS Trust scales, from whole regional systems to specific clinical care pathways and room details within a hospital site, building or department. Additionally, two new regulatory and quality assurance tools to deliver clean and safe environments have been contributed.

There has been widespread engagement across the healthcare infrastructure domain in this work, including 23 workshops and numerous steering group meetings involving over 133 participants over a four year period to develop the Premises Assurance Model (PAM), Critical Infrastructure Risk analytics and a roadmap for quality and safety regulation.

### Underpinning research

**1. Strategic Asset Management (SAM) and the Integration of Contestable Health and Social Care Service and Estates Design** (2008-11). The 'SAM' project evaluated existing approaches and developed new theory on optimal decision-making processes and how healthcare infrastructure value is defined. It developed specifications for new knowledge and tools to scale, scope and distribute infrastructure, and for effective stakeholder engagement.

**2. Built Environment Design Evidence Base to Continuously Improve the Delivery of Patient Safety** (2008-11). This project, with additional Loughborough University funding, supported more than 10 PhDs in areas including ventilation, lighting simulation and daylighting. This body of work developed and applied modelling, simulation and visualisation to support the evidenced-based design, policy and assurance of efficient and sustainable healthcare environments that enhance patient safety and experience.

**3. Optimising Healthcare Infrastructure Value (OHIV)** (2011-13). This work developed effective and sustainable evidence and model-supported approaches to healthcare planning and strategic asset management, new theory on the interconnectivity of hospital systems and critical lifelines, and metrics for evaluating the resilience of hospitals to multiple hazards.

**4. Optimising healthcare infrastructure value through enterprise and knowledge transfer activities** (2012-2013, building on an EPSRC KTA grant, 2009-2012]. Through an accurate understanding of the definitions of space, refurbishment and space adaptability, a methodology has been developed to put in place a robust appraisal system to assess space adaptability in existing healthcare infrastructures. Using this system, decision makers, care providers, care commissioners, Trusts, designers and building contractors can review the spatial consistency of a healthcare infrastructure and define whether a refurbishment process is the best option to improve clinical service delivery within a wider regional reconfiguration or national transformation. This included a robust analytical method and an automated tool, based on data envelopment analysis and Social Return on Investment, was developed to measure, compare, benchmark and optimise financial and service value.

## Impacts

### 1. The new Universal NHS New Premises Assurance

**Model (PAM)** is a software-based tool to provide baseline quality assurance across NHS built assets. The Department of Health commissioned HaCIRIC to develop better ways to strategically manage and assure healthcare assets by improving PAM's functionality, broadening the user base and integrating existing standards and toolkits. The PAM tool, released in February 2013, is recommended for use by all healthcare providers in England. The PAM has:

- provided a benchmarking tool which Trusts can use to improve the management and allocation of resources;
- established a consistent multi-criteria asset management software tool for assurance of the premises in which NHS healthcare is delivered, now endorsed by the Institute of Healthcare Engineering and Estate Management (IHEEM) and the Health Estates Facilities Management Association (HefmA); and
- established a basis for National Institute for Health and Care Excellence (NICE), Care Quality Commission (CQC) and Monitor to enforce compliance with national standards and drive premises-related performance improvements throughout the system.

The new PAM applies to all NHS organisations and not just Acute Trusts, as in the initial version. It has also been adopted by NHS Property Services as a common means to manage its asset portfolio. NHS Property Services has confirmed it will adopt the PAM as part of its governance and assurance of more than 3,700 assets in its portfolio.

### 2. Improving national approach to strategic asset management

All NHS trusts report levels of backlog to the Department of Health as a means to monitor the condition of the NHS asset portfolio. HaCIRIC participated in research funded by the Department of Health to explore and understand the causal relationship between built asset portfolio age and year-on-year increases in critical backlog. Robust analytics for building age, condition and risk-adjusted backlog maintenance have been developed by HaCIRIC to support the Department of Health in making capital investment decisions, helping Trusts to agree what levels of capital spending should be allocated in their asset management plans. These new analytics will drive policy decision making to understand the impact of age on national maintenance programmes with regard to risk-adjusted backlog, failure criticality and depreciation.

This work has demonstrated that a smarter national approach to strategic asset management in healthcare infrastructure is required. Trusts need to adopt appropriate levels of continued investment in routine and backlog maintenance to ensure critical backlog is reduced and does not accumulate once eradicated. This research found that Trusts generally need to invest between 0.5 and 1.5 per cent of income to simply maintain critical backlog levels. However few are investing at this level.

“

*With the launch of the NHS PAM, NHS Trust boards have the means for a nationally consistent approach to examining estates condition, performance, and efficiency ... in turn supporting the spread of innovation and best practice.*

**Peter Sellars, Department of Health**

*The unique benefit to providers is that, for the first time, a single methodology exists that is nationally consistent, peer comparable and aligned with the wider NHS management landscape.*

**David Flory, Deputy NHS Chief Executive**

”

### 3. Department of Health Capital Funds for 116 dementia pilot projects – development of a new framework and funding assessment regime.

HaCIRIC has provided national policy support to the Department of Health and contributed to the allocation of £50m infrastructure funding for dementia care by supporting the development of a new framework and funding assessment regime. We are now reviewing schemes to assess their value in terms of social and economic return on investment. To complete this review HaCIRIC with IFF Research has also been awarded £270,000 to monitor the 106 dementia pilot projects.

### 4. Response to the National Institute of Health and Clinical Excellence (NICE) consultation<sup>7</sup>.

The team made recommendations to the Department of Health on the new landscape for healthcare standards and on the role of national healthcare built environment standards during a period of significant policy reform. The underpinning research provided over 500 sources of academic evidence that demonstrated the importance of healthcare infrastructure on patient outcomes. The team also highlighted fundamental failures in the healthcare system reorganisation as part of the consultation. The new regulatory structure included NICE, CQC and Monitor who enforced compliance to national standards. The team organised six round table discussions with leading engineering and architectural representatives alongside the Department of Health, Health Facilities Scotland and Northern Ireland Health Estates to provide evidence on the important role that regulation and guidance play in healthcare building quality assurance.

### 5. Review of Evidence for the Contribution of Healthcare Infrastructure Investment to Health Gain.

This was undertaken on behalf of the European Investment Bank. This report provided evidence to support the bank in ethical lending for hospital projects across Europe and contribute to decisions on what infrastructure scale, scope and distribution delivers the best outcomes. The report provided evidence on the relationship between infrastructure investment and health gain. It was circulated to all EIB country lending managers to help trigger greater investment in healthcare infrastructure projects.

<sup>7</sup> –National Clinical Guideline Centre (2011) *Using Adult NHS Services: Patient experience in generic terms, Clinical Guideline. Methods, evidence and recommendations.*

## Selected Outputs

1. Mills G, Deka L et al. (2014) Critical Infrastructure Risk in Healthcare Trusts in England: Predicting the impact of Trust building portfolio age on the national condition of NHS assets. *International Journal of Strategic Property Management* (in press).
2. Mahadkar S, Mills G, Price A (2012) Stakeholder Consultation Practices within Healthcare Infrastructure Planning: Developing a Strategic Asset Management Approach, *Journal of Built Environment Project and Asset Management*, 2(2).
3. Chen B, Phiri M, Mills G (2011) Design Strategies and Environmental Assessment Methods in Healthcare: lessons from UK's BREEAM. *Architectural Journal (Academic Article Issue)* 6: 159-163.
4. Mills G, Erskine J, Price A, Ricks E, Phiri M, Sellars P (2012) Developing a World-Leading and Smart Regulatory Design Quality Framework for Healthcare Estates in England. *Proceedings, HaCIRIC International Conference. Transforming Healthcare Infrastructure and Services in an Age of Austerity*, HaCIRIC.
5. Adamu Z, Price A, Cook M (2012) Performance evaluation of natural ventilation strategies for hospital wards – A case study of Great Ormond Street Hospital, *Building and Environment*, 56, 211-222.
6. Mourshed M, Shikder S, Price A (2011) Phi-array: A novel method for fitness visualization in evolutionary design optimization, *Advanced Engineering Informatics*. 25(4), 676-687.

## Researchers involved

- **Andrew Price** (Loughborough University)
- **Grant Mills** (Loughborough University)
- **Sameedha Mahadkar** (Loughborough University)
- **Nebil Achour** (Loughborough University)
- **Erica Ricks** (Loughborough University)



## 7.4 Improving urgent and unscheduled care delivery systems

### Background

Unscheduled care challenges are not UK specific. Our research has involved considerable international collaboration. This case study draws together underpinning research from several HaCIRIC Phase 1 and Phase 2 projects which have impacted on the provision of timely and effective unscheduled care – a persistent problem for policy makers and care providers.

Our research has focused on the planning, design and operation of infrastructure and unscheduled care systems from a day-to-day perspective and under special circumstances, e.g. major disasters. There are three main strands to this work.

The first started with a study into 'Unscheduled care as a complex system' which was followed by two projects focusing on 'Innovation in stroke care'. The second focused on the design of A&E Departments, initially through 'Open Planning for Operationally Ready Acute Healthcare Infrastructure' which is continuing through consideration of more detailed design aspects as part of the A3F project. The third strand focused on the resilience and response of healthcare systems to adverse weather events and major disasters.

Unscheduled care delivery has to deal with the complexity of coordinating patient flows across different parts of the care system in a way that avoids bottlenecks and maintains the capacity of the service to cope with sudden surges in need or reduction of resources. The challenge is in aligning processes, targets, incentives and penalties, while continuously maintaining high quality service delivery by a wide range of acute, primary and social care. Infrastructure plays a critical component in this complex relationship because of the need to transport patients and manage 'stocks' and 'flows' in various physical locations. Infrastructure must have the ability to respond to sudden surges in demand or reduction of resources.

Unintended feedback effects may also be present. For example, redesigning patient flows may make the A&E department more efficient, but blockages may simply be shifted elsewhere in the system. The success or failure of A&E can have a significant clinical impact on all other hospital departments as well as urgent and emergency care services outside the hospital.

The research aimed to improve urgent and unscheduled care delivery through evidence and model-supported approaches to service planning and assessment. It comprised three core elements of unscheduled care: infrastructure design, care process design, and integration of processes and infrastructure design.

As well as addressing the routine aspects of unscheduled care through hospital A&E systems, we were also interested in the critical role that healthcare systems play in responding to major emergencies. There are many concerns regarding the effectiveness of emergency responses even when there is a robust management framework in place and resources are not sufficiently available, a fact recognised by the Department of Health and the NHS. We therefore also wished to investigate how different factors such as financial and human resources, communication, conflicts and the predominance of powerful organisations impacted on effective emergency response.

### Underpinning research

**1. Unscheduled care as a complex system** (2006-07). This project was conducted at the request of the Scottish Unscheduled Care Collaborative Programme and with their support. It involved case studies of five local care systems in Scotland, all undergoing a transformation programme to meet the government's four hour emergency care target. The qualitative research focused on the system-wide interactions between local measures / innovations and wider intended and unintended consequences. Subsequent work involved re-evaluating the empirical data from a complexity theory perspective in order to draw out lessons on the impact of different interventions at different scales in the system.

“*The research aimed to improve urgent and unscheduled care delivery through evidence and model-supported approaches to service planning and assessment.*”



**2. Innovation in stroke care** (2006-2009). Building on an earlier Department of Health funded project we modelled the impact of telestroke and investigated the potential of disruptive innovation to speed-up diagnosis to improve stroke care. The initial study used simulation modelling to investigate the potential impact of innovations to redesign stroke care pathways.

The second project focused on the improvement of access to thrombolysis in hyperacute stroke cases. As this treatment can only be given in a very narrow time window, urgent diagnosis is crucial. We worked with colleagues from MIT and Harvard School of Medicine to investigate ways to use cheaper more portable ultrasound (a 'disruptive innovation') in the rapid diagnosis of stroke cases in remote areas. We then worked with colleagues in Scotland to explore the potential impact, using simulation modelling. This indicated that telestroke, combined with improvements to the flow of patients within hospitals could have a significant impact on the number of patients benefiting from thrombolysis in Scotland.

**3. Sustainable healthcare facilities: enhancing resilience of healthcare facilities** (2008-2010). The project explored the vulnerabilities of healthcare facilities nationally and internationally. This led to the development of an integration model for improved sustainability and resilience, and improved knowledge on the relationship between the performance of hospital utilities systems and structural components.

**4. Optimising Healthcare Infrastructure Value (OHIV)** (2011-2013). A subproject within OHIV developed effective and sustainable evidence and model-supported approaches to healthcare planning and strategic asset management, new theory on the interconnectivity of hospital systems and critical lifelines, and metrics for evaluating the resilience of hospitals to multiple hazards. The research investigated international emergency department design and developed a new scenario and flow based approach. This work was translated into the new national Health Building Note (HBN) supported by the Department of Health and the College of Emergency Medicine.

## Impacts

### 1. New guidance on A&E department design.

The team were involved in the development of a new guidance document on Emergency Department Design (Health Building Note HBN15-01) and in the development of College of Emergency Medicine guidance, supporting a policy move away from prescriptive input and output specification. This guidance is altering the planning of A&E departments and sets out the strategic background, uncertainties and the evidence-base for key decisions that need to be made in the design.

### 2. Development of Activity-Acuity-Adaptability-Flow (A<sup>3</sup>F).

Using action research, HaCIRIC contributed to the development of a new methodology that structures the consideration of clinical activity, changing patient acuity, clinical service-systems separation, open building and clinical flow modelling. This understanding is now being applied in practice through consultancy engagements. Further development of the A<sup>3</sup>F tool is planned, to create a software prototype that will structure the consideration of clinical activity (including staff resource ratios), acuity adaptability and lean flows to optimise the development of spatial requirements for new and refurbished emergency departments.

### 3. The World Health Organisation Hospital Safety Index.

We developed models to integrate emergency planning with daily operations and sustainability with resilience and worked with the World Health Organisation (WHO) to ensure that the revised version of the WHO Hospital Safety Index (HSI) addresses these issues. The HSI is a global evaluation tool and is expected to be implemented globally to improve the resilience of healthcare facilities to cope with disasters, a major cause of unscheduled care in certain countries.

The WHO approached the HaCIRIC team to improve its evaluation tool, and broaden its scope away from earthquake risks. The HaCIRIC team led the 'Structural Safety' and 'Critical Systems Safety' sections of the revision exercise, which represent two-thirds of the tool. We introduced several new elements such as the resilience to multiple hazards in design and in operation, integration of sustainability and the proximity of the facility to the source of hazard. The WHO has acknowledged the significant input of HaCIRIC team and requested further integration in other activities, such as a consultation on developing a curriculum framework for public health risk management, which took place in Jordan in November 2013.

“*HaCIRIC has played an important role in shaping College of Emergency Medicine guidance, radically altering the planning of A&E departments.*”

**4. Development of protocol for risk assessment (WHO EMRO).** Our research findings concluded that pre and post disaster evaluation of healthcare infrastructure is a critical component of the safety of patients and continuity of healthcare. However, this still remains a challenge as it is driven by several issues such as the evaluation techniques which are very generic and do not necessarily reflect the complexity of healthcare facilities. We were invited by the World Health Organisation East Mediterranean Regional Office (WHO EMRO) to collaborate with other international organisations to develop a curriculum framework for public health risk management. Our contribution was in terms of integrating the engineering aspects within the curriculum. Subsequently we were requested to develop the protocol report in collaboration with the Centers for Disease Control (CDC, Atlanta, USA).

## Selected outputs

1. Achour N, Miyajima M, Pascale F, Price, A (2014) Hospital Resilience to Natural Hazards: Classification and Performance of Utilities. *Disaster Prevention and Management*, 23(1), 40-52.
2. Achour N, Price A (2011) Healthcare resilience to natural hazards: an achievable target. Editorial in Achour N and Price A (Eds.) *International Journal of Disaster Resilience in the Built Environment*, 2(3), 196-199.
3. Achour N, Price A (2011) (Eds.) Optimising healthcare facilities performance in natural hazards, *International Journal of Disaster Resilience in the Built Environment*, 2(3) [Special Issue].
4. Astley P, Hind R, Mills G, Price A, Mahadkar S, Page M (2013) Open Infrastructure Planning for Emergency and Urgent Care, *Architecture in the Fourth Dimension: methods and practices for a sustainable building stock*, 15-17 November, Boston, USA.
5. Pascale F, Achour N, Price A, Polverino F (2014) Evaluation of factors and approaches affecting emergency department space planning. *Facilities* 32(11/12). [In press]

6. Pascale F, (2011) Issues of functional flexibility of Emergency Department in mass casualty event. Elements of analysis and design, *Proceedings of the IV National Conference of the Italian Society of Architecture and Engineering for Health: Health and federalism: the future of technical areas and renewed commitment to in the ethics*, Naples, Italy.
7. Bayer S, Petsoulas C, Cox B, Honeyman A, Barlow J (2010) Facilitating stroke care planning through simulation modelling. *Health Informatics* 16, 129-143.
8. Dattée B, Barlow J (2010) Complexity and whole-system change programmes. *Journal of Health Services Research & Policy* 15, S2, 12-18.
9. Uzun Jacobson E, Bayer S, Barlow J (2012) The effect of delays for hyperacute stroke in Scotland. *Informa International*, Beijing, 24 June 2012.
10. Feldman H, Uzun Jacobson E, Barlow J, Bayer S, Reti S, Finkelstein S (2011) Disruptive innovation in stroke diagnosis in remote locations: field-based ultrasound, HaCIRIC International Conference, September 2011, Manchester, UK.

## Researchers involved

- **Andrew Price** (Loughborough University)
- **Nebil Achour** (Loughborough University)
- **Federica Pascale** (Loughborough University)
- **Steffen Bayer** (Imperial College London)
- **James Barlow** (Imperial College London)
- **Evin Uzun Jacobson** (Imperial College London)
- **Grant Mills** (Loughborough University)
- **Phil Astley** MARU (Medical Architecture Research Unit), London South Bank University,
- **Andrew Sinclair** (Loughborough University)

## 7.5 Mainstreaming remote care

### Background

The development of 'remote care' – telecare and telehealth – has been driven partly by technological advances in sensing equipment and data processing, policy concerns over the costs of an ageing population and the rise in people with chronic, long term conditions. Additionally there have been growing public expectations – more and more we expect to receive a more personalized package of care at a convenient time and place of our choosing.

The potential of remote care to address these factors is increasingly recognized in health policy in the UK, USA and elsewhere. Its mainstream development appears an attractive solution to growing care demands. Around the world, there have been numerous pilot projects and technology trials. However, adoption has been slow and nowhere can remote care be described as a mainstream, 'taken for granted', part of care delivery.

Building on HaCIRIC members' previous research – partly funded by EPSRC – on the design and implementation of remote care systems, we carried out several projects to collect evidence that establishes how remote care can be sustainably and efficiently embedded into healthcare.

We focused on how organisational and economic factors influence adoption and diffusion, and evaluated the impact on health and social care systems, combining in-depth qualitative research and simulation modelling.

We engaged closely with the policy process, health services and industry. As a result, we were invited to help design and evaluate the Department of Health's Whole System Demonstrators (WSD), the world's largest trial of remote care. As a consequence, the government launched the 3 Million Lives programme, with the Department of Health estimating a potential net benefit to the NHS of £450m over the next 5 years<sup>8</sup>. We were also commissioned to produce reports for the Audit Commission and the TSB/DTI, amongst other bodies.

### Underpinning research

Building on two earlier EPSRC funded projects (2000-2007) which developed and trialled the technology in 'real world' settings, we developed a programme of research designed to address the barriers to scaling-up remote care and its potential impact. Key projects were:

- 1. The role of evidence in remote care adoption decisions** (2006-2008). The research investigated the factors influencing strategic decision making around investment in remote care technologies and services in a range of UK local health and social care authorities. Particular attention was paid to the role that evidence played in shaping investment decisions. This led to an invitation by the DH to conduct a detailed systematic review of the evidence base for remote care. At the time this was the most detailed review that had been carried out to date.
- 2. The Whole System Demonstrators (WSD) programme evaluation** (2008-2012), supported by the DH, in collaboration with Nuffield Foundation and LSE, Oxford, Manchester and City universities. Partly prompted by research carried out by HaCIRIC members, the DH launched a programme to deploy remote care in three regions and use the innovation to redesign services on a 'whole system' basis. This was the most ambitious attempt to trial remote care seen anywhere in the world. As well as supporting the research programme design, the HaCIRIC team was responsible for one of the five research themes, focusing on the organisational and supply chain aspects of remote care implementation.
- 3. Modelling the potential impact of remote care on selected populations** (2006-2011). Several projects, supported by HaCIRIC looked at selected populations (frail elderly, stroke, heart failure). This included a project, funded by the Department of Health on the potential impact of 'telestroke', which was subsequently developed into a joint programme of work with Harvard University Medical School, MIT and the University of Edinburgh on disruptive innovation in stroke care.

“*We were invited by the Department of Health to help design and conduct the £2.5m WSD research programme, to address limitations of the remote care evidence base and stimulate adoption across the UK. Globally, this remains the largest trial of remote care technologies to date.*”

8 –The Times, 6 Dec 2011.

## Impact

Our work bridged the gap between academic research, pragmatic policy, and industry guidance. Its emphasis on translation shaped the climate for adoption of remote care. The reach was considerable, embracing policy makers and health service supply chains not only within the UK but internationally. Its significance is attested by the importance of the problem (ageing and healthcare innovation are first order issues for public policy and industry); by the scale of engagement (from substantial funding to deep, long-term interactions with the Department of Health, NHS, and private providers); and by repeated invitations to contribute to solving the next set of policy challenges (the group has helped supported the launch of the next major UK government initiative on remote care, the 3 Million Lives programme, see below).

## Impact on policy

**1. Department of Health working party on the quality of the evidence base for remote care.** Based on our research on remote care, we conducted work for the Audit Commission<sup>9</sup>, DH, the Care Services Improvement Partnership (CSIP), and the Wanless Commission<sup>10</sup>. This resulted in an invitation to James Barlow to chair a working party for the Department of Health on the quality of the evidence base for remote care. Its findings were disseminated widely via CSIP<sup>11</sup> and subsequently published as Barlow et al. (2007). This is currently ranked as the second most highly cited paper ever published in the Journal of Telemedicine and Telecare (the leading journal in the field) in terms of average citations per year and twelfth most highly cited paper overall<sup>12</sup>.

**2. Developing government policy on telecare.** Our research for the Telecare Policy Collaborative was cited by Liam Byrne - Parliamentary Under Secretary of State for Care Services - in the launch of a major government initiative (the Preventative Technologies Grant, PTG). Mr Byrne said, 'Our policy on telecare has been developed following consultation with a very, very wide range of stakeholders. This included the large numbers of people who have freely given of their time, knowledge and expertise to be involved in the Telecare Policy Collaborative. We just couldn't have done it without you. I'd like to take this opportunity to personally thank all those involved in the collaborative for their role in developing and moving this policy forward', 19 July 2005<sup>13</sup>.

## 3. Design of the Whole System Demonstrators programme (WSD).

We were subsequently invited by the Department of Health to help design and conduct the £2.5m WSD research programme, to address limitations of the remote care evidence base and stimulate adoption across the UK. Globally, this remains the largest trial of remote care technologies to date. Initial research findings were announced by the Prime Minister and Secretary of State for Health on 5 December. 2011 at the launch of the next major government initiative on remote care, the '3 Million Lives' programme (<http://3millionlives.co.uk/>). The Prime Minister said: 'We've done a trial [WSD]. It's been a huge success and now we're on a drive to roll this out nationwide with an aim to improve three million lives over the next five years with this technology. Now this will make an extraordinary difference to people ... And it's not just a good healthcare story; it's going to put us miles ahead of other countries commercially too as part of our plan to make our NHS a driver of innovation in UK life sciences.'<sup>14</sup>

## 4. New thinking on NHS tariff reform.

Our recommendations on the need to reform the NHS tariff to support remote care, from the WSD evaluation and from our previous HaCIRIC work, were taken up in the key government report, *Innovation, Health and Wealth* (Department of Health, 2011, p.20), and the current framework for Commissioning for Quality and Innovation (CQUIN Guidance 2013/14, p.6).

9. Audit Commission (2004) *Implementing Telehealthcare: Strategic Analysis and Guidelines for Policy Makers and Providers*. [www.scie-socialcareonline.org.uk/profile.asp?guid=ca2859ec-aaa0-449b-b1a3-30fc3ac6a865](http://www.scie-socialcareonline.org.uk/profile.asp?guid=ca2859ec-aaa0-449b-b1a3-30fc3ac6a865)
10. Wanless, D. (2006) *Securing Good Care for Older People: Taking a Long-Term View and Telecare for Older People*. King's Fund. [www.kingsfund.org.uk/publications/securing-good-care-older-people](http://www.kingsfund.org.uk/publications/securing-good-care-older-people)
11. DH / CSIP (2006) *Building an evidence base for successful telecare implementation - updated report of the Evidence Working Group of the Telecare Policy Collaborative*. [www.scie-socialcareonline.org.uk/profile.asp?guid=60f39639-99c3-4ed6-8e9f-57354b37e3e5](http://www.scie-socialcareonline.org.uk/profile.asp?guid=60f39639-99c3-4ed6-8e9f-57354b37e3e5). Also see eHealth Insider, 10/8/2007, [www.ehi.co.uk/news/primary-care/2942](http://www.ehi.co.uk/news/primary-care/2942)
12. Azam Askari et al. 'The 60 most highly cited articles published in the Journal of Telemedicine and Telecare and Telemedicine Journal and E-health.' *J Telemed Telecare* 10 January 2014.
13. <http://webarchive.nationalarchives.gov.uk/> and [www.dh.gov.uk/en/MediaCentre/Speeches/Speecheslist/DH\\_4116487](http://www.dh.gov.uk/en/MediaCentre/Speeches/Speecheslist/DH_4116487). Also see eHealth Insider, 15/3/2005 [www.ehi.co.uk/news/ehi/1085/kent-uses-telehealth-for-chronic-disease-support](http://www.ehi.co.uk/news/ehi/1085/kent-uses-telehealth-for-chronic-disease-support).
14. See [www.gov.uk/government/speeches/pm-speech-on-life-sciences-and-opening-up-the-nhs](http://www.gov.uk/government/speeches/pm-speech-on-life-sciences-and-opening-up-the-nhs) (also Department of Health (2011) *Whole Systems Demonstrator - Headline Findings*. [www.dh.gov.uk/health/2011/12/telehealth-trial-early-findings/](http://www.dh.gov.uk/health/2011/12/telehealth-trial-early-findings/) and Public Service, "Telehealth to benefit 3 million NHS patients", 6/12/2011 [www.publicservice.co.uk/news\\_story.asp?id=18224](http://www.publicservice.co.uk/news_story.asp?id=18224)

## Impact on industry

### 5. Identification of remote care implications for industry.

Our impact on industry has been through our collaborations with remote care and telecommunication companies on specific projects, and via engagement with government and regulators. In 2007 HaCIRIC was invited by the Department of Trade and Industry / Technology Strategy Board to conduct a road-mapping exercise to support development of an 'Assisted Living Innovation Platform'. We identified the key science and technology areas in need of research for the next generation of remote care, and supported the launch of 38 industry-led projects worth £47.1m. We also recommended more research on social and business aspects of remote care which subsequently led to a £10m TSB / DH / ESRC research call, with several projects now underway.<sup>15</sup>

### 6. Remote care and UK wireless spectrum allocation.

We contributed to a review for Ofcom of the implications of remote care for the UK wireless spectrum allocation, which identified that changes would not be needed immediately. This was later published as an OFCOM report (*Health Technology Scenarios and Implications for Spectrum*, March 2008).

**7. Help for remote care business cases.** We have supported the development of remote care business cases. Our work on modelling the impact of remote care led to an invitation by the DH to help produce a report on remote care business cases.<sup>16</sup> We have also helped influence the thinking of our industry partners. For example, Tunstall – market leader in the UK and in several other countries – stated that its involvement in the WSD helped validate its business approach to remote care.<sup>17</sup>

<sup>15</sup> Barlow J and Curry R (2007) *Department of Trade and Industry Assisted Living Roadmapping exercise. Workshop Report.* [www.innovateuk.org/ourstrategy/innovationplatforms/assistedliving/assisted-living-innovation-platform.ashx](http://www.innovateuk.org/ourstrategy/innovationplatforms/assistedliving/assisted-living-innovation-platform.ashx) and TSB (June 2010) *Assisted living: Economic & Business Models and Social & Behavioural Studies. Competition for funding*, p.3.

<sup>16</sup> Department of Health, *Strategic Business Case Models*. [http://webarchive.nationalarchives.gov.uk/+/www.dh.gov.uk/en/SocialCare/Deliveringadultsocialcare/Olderpeople/DH\\_4116208](http://webarchive.nationalarchives.gov.uk/+/www.dh.gov.uk/en/SocialCare/Deliveringadultsocialcare/Olderpeople/DH_4116208)

<sup>17</sup> <http://www.tunstallwsd.co.uk/resources/news/telehealth-strongly-validated-by-first-results-from-whole-system-demonstrator>

## Selected outputs

1. Chrysanthaki T et al. (2013) Stimulating whole system redesign: lessons from an organisational analysis of the Whole System Demonstrator Programme. *Journal of Health Service Research & Policy* 18(Suppl. 1) 47–55.
2. Cartwright M et al. (2013) Effect of telehealth on quality of life and psychological outcomes over 12 months (Whole Systems Demonstrator telehealth questionnaire study): nested study of patient reported outcomes in a pragmatic, cluster randomised controlled trial. *BMJ* 346,f653 doi: 10.1136/bmj.f653.
3. Hendy, J. et al. (2012) An organizational analysis of the implementation of telecare and telehealth: The Whole Systems Demonstrator. *BMC Health Services Research*, 2012, 12:403 doi:10.1186/1472-6963-12-403.
4. Sanders C et al (2012) Exploring barriers to participation and adoption of telehealth and telecare within the Whole System Demonstrator trial: a qualitative study. *BMC Health Services Research* 12, 220 doi:10.1186/1472-6963-12-220.
5. Steventon A et al. (2012) Effect of telehealth on use of secondary care and mortality: findings from the Whole System Demonstrator cluster randomised trial. *BMJ* 344, e3874 doi: 10.1136/bmj.e3874.
6. Hendy J, Barlow J (2012) The role of the organizational champion in achieving health system change. *Social Science and Medicine* 74, 348-355.
7. Bayer S, Petsoulas C, Cox B, Honeyman A, Barlow J (2010) Facilitating stroke care planning through simulation modelling. *Health Informatics* 16, 129-143.
8. Bayer S, Barlow J, Curry R (2007) Assessing the impact of a care innovation: telecare. *System Dynamics Review* 23, 61-80.
9. Barlow J, Singh D, Bayer S, Curry R (2007) A systematic review of the benefits of home telecare for frail elderly people and those with long-term conditions. *Journal of Telemedicine & Telecare* 13, 172-179.
10. Cravo-Oliveira T, Barlow J, Gonçalves L, Bayer S (2013) Teleconsultations reduce greenhouse gas emissions. *Journal of Health Service Research & Policy* 18(4):209-214.

## Researchers involved

- **James Barlow** (Imperial College London)
- **Jane Hendy** (Imperial College London)

- **Theti Chrysanthaki** (Imperial College London)
- **Steffen Bayer** (Imperial College London)





*BeReal's tools and techniques have the potential to transform the chances of successful delivery of healthcare infrastructure change programmes.*



## 7.6 Benefits realisation

### Background

Delivery of consistent high quality services and infrastructure through diverse investment models requires a benefits-driven approach. We worked with our partners MaST LIFT (Manchester, Salford and Trafford Local Initiative Finance Trust), Community Health Partnerships, NHS Stockport, and Brighton and Sussex University Hospitals NHS Trust. We have undertaken a major research initiative to develop a comprehensive benefits realisation process for application to investment in the healthcare built environment, from the strategic planning stages to project delivery (BeReal).

BeReal aimed to bring a notoriously fragmented community together through workshops to generate shared aims and vision, and develop benefits realisation management tools and methods that embrace self-checking processes and improve process visibility. The approach focused on how to elicit and prioritise potential benefits with stakeholders at the initial stages, and how to track and manage benefits during the lifecycle of a programme or project. BeReal's tools and techniques have the potential to transform the chances of successful delivery of healthcare infrastructure change programmes.

### Underpinning research

**1. How to improve current best practice.** The BeReal research initially involved identifying current best practice and demonstrating how to improve benefits realisation in healthcare infrastructure provision. This involved an extensive literature review of relevant areas and evaluation of existing models and frameworks.

**2. Developing benefits realisation management tools.** From this we developed benefits realisation management tools in collaboration with industry partners. These were tested and refined in a variety of case and comparator studies, not only to define a business critical process but also to set out an approach which put benefits realisation at the heart of securing collective change. To do this, we had to consider the way the approach could be integrated at both the planning and implementation phases. We also had to consider issues of stakeholder management, knowledge management and communication. An advisory board was set up, including representatives from the National Audit Office, Department of Health, NHS Gateway Reviews, and representatives from NHS hospital trusts, LIFT programmes and private industry.

Two other projects were commissioned by HaCIRIC and informed the development of BeReal:

#### 3. Design for flexibility and change within health

**service providers** was carried out in collaboration with Imagination at Lancaster University. This investigated existing frameworks for Practice Based Commissioning (PBC), in particular the modes of governance and processes through which improved services for patients were being designed and commissioned, and how they encouraged engagement and collaboration. The team also sought to understand if, and how, design and other creative methods and tools drawn from design could support commissioners' activities.

The research included an evaluation of existing PBC structures through case studies, and an in-depth case study with a large medical practice, with design workshops and experimentation with different design tools. The research developed recommendations for GP commissioning, suggesting the need for a shift to 'community centred commissioning', recognising the key role of GP consortia as facilitators of commissioning networks but focusing on co-creation of service innovations.

#### 4. Developing a 'Benefits Quantification Method'

The second project, funded by HaCIRIC, was carried out in collaboration with Heriot-Watt University, Health Facilities Scotland and Davis Langdon LLP. The project worked with several NHS Scotland Boards to develop each part of the method by interacting with live capital investment projects. Healthcare programme performance was characterised using stakeholders' evolving perceptions of tangible and intangible benefit 'worth.'

The project synthesised principles of 'prospect theory', value function use in environmental management, and the accommodation of irrational judgement in behavioural economics to build a method of benefits quantification. This comprised two parts: an initial benefit elicitation, modelling and target setting part; and a periodic performance evaluation part. The method fits into the BeReal process but can also be used in isolation. The resulting method provided initial evidence of demand-side economies of scale in the quantification of benefits sought from public good health buildings. The method was documented in a Benefits Quantification Manual and a supporting spreadsheet tool. It was publicly available on a website for two years after project conclusion.

“

*Benefits realisation has only relatively recently assumed the profile and importance which it deserves ... The benefits realisation methodology developed by HaCIRIC assisted us in the elicitation, through workshops, of the key benefits, ultimately leading to the selection of the preferred option which is proposed to be finally built.*

”

Duane Passman (3TS Programme director)

## Impact

### 1. A healthcare infrastructure focused benefits

**realisation process.** The main theoretical and practical contribution of the BeReal research is the development of a healthcare infrastructure focused benefits realisation process which integrates project management best practices and continuous improvement methods. BeReal has developed significant insights into the processes for defining, measuring, delivering, and evaluating benefits and has produced valuable methods and tools to help achieve improvements.

We developed a collaborative system to help those involved in different roles to identify and manage benefits and disbenefits throughout the life of a programme or project, taking into account the likelihood of change over time in the external environment and internal objectives. This promotes knowledge flow and sharing by managing stakeholders expectations throughout the project lifecycle. The result is a collaborative process that is informed by existing best practice and new research evidence.

The case study work emphasised the importance of viewing benefits realisation as a dynamic process, facilitating adjustments to plans in the light of experience gained and changes in the external or internal environment. This increases the predictability of benefits being realised.

The main outcomes from the research are the innovative BeReal process and methods, combining best practice from a range of knowledge areas and industry sectors. BeReal has been designed to align with other common programme and project management techniques such as the OGC Gateway Review process, PRINCE 2 and Managing Successful Programmes.

### 2. Training and education tools for benefits

**realisation.** A consultative guide focuses on how benefits should be elicited at the initial strategic stages, and how benefits should be deployed, managed and traced along a project's lifecycle (see [www.be-real.co.uk](http://www.be-real.co.uk)) Second, we have developed the conceptual IT toolkit (<http://tool.be-real.co.uk/>) platform, which functions as a training and education tool, implementation guide and knowledge database, along with other training material on how to implement BeReal. The IT platform links the process steps and outcomes in an open public access website and a knowledge database that encapsulates both general and project specific information.

**3. BeReal adopted in NHS.** The main impact of the research can be demonstrated through the adoption of the BeReal process in the NHS organisations. The programme director and the project team in the Brighton and Sussex University Hospitals (BSUH) '3Ts' (trauma, tertiary and teaching) hospital development adopted the BeReal process to monitor the realisation and achievement of expected benefits throughout project implementation, reporting directly to the CEO of BSUH. The data collected and main outcomes were used to inform the compilation of the scheme's business case and justify its potential investment by the Department of Health. The IT platform is being used and will be further developed, subject to funding, in collaboration with the 3Ts development team. According to Duane Passman (3TS Programme director) "The robustness of the work undertaken on this project is being applied across a number of other programmes and projects within the Trust. The ultimate aim is to widen the application of the web-based application to the other programmes and projects which the Trust is engaged in, to ensure that all benefits are tracked clearly across all programmes."



NHS Stockport adopted BeReal as a methodology in developing and informing the outline business case for the St Thomas project. The Gateway review team that appraised the project interviewed the HaCIRIC research team in the gate 3 review of this project, where the BeReal methodology and the outputs of the benefits elicitation workshop were presented. The outcome of the review considered that the methodology followed was robust and recommended that the outputs and findings be included in the St Thomas business case. As a consequence, the Gateway review team involved made a generic recommendation that the BeReal process be adopted when planning for healthcare change programmes, the development of infrastructures or the development of the associated a business cases.

**4. Use by NHS in Scotland.** NHS Lothian used the method developed in Project 2 to populate their Benefits Realisation Plan for the Royal Victoria Building in Edinburgh (Full Business Case submitted to the Scottish Government Health and Social Care Directorates Capital Investment Group, March 2010).

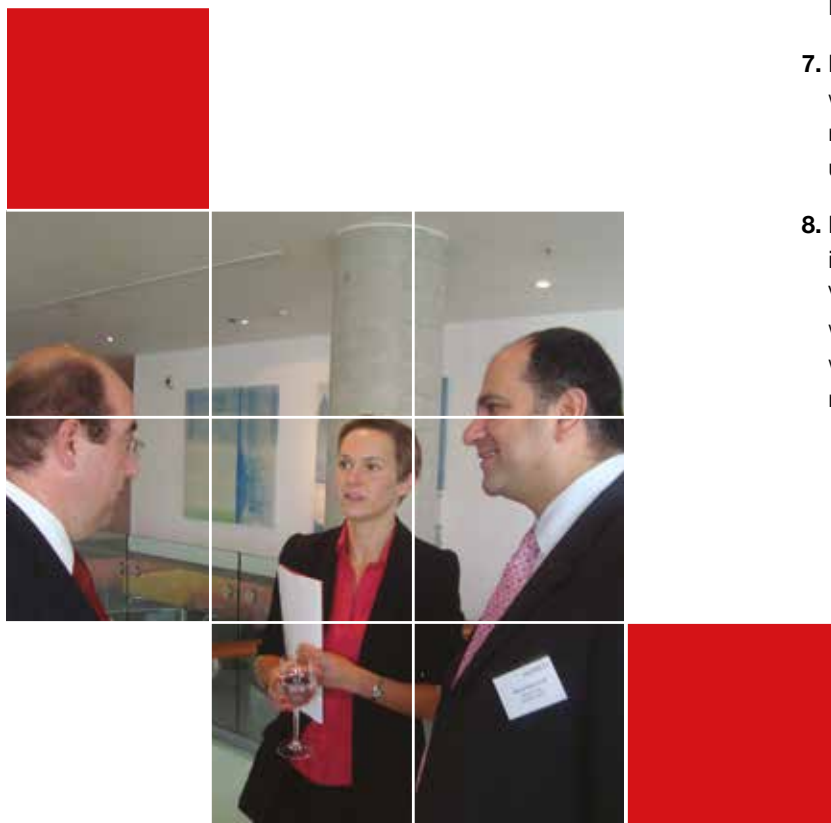
#### **5. Inclusion of BeReal work in government guidance.**

The health sector OGC Gateway Review team and the Cabinet Office identified a common lack of structured focus on benefits realisation in NHS project delivery. This resulted in the inclusion of the BeReal work in the 2009 review by the Treasury of their Investment Manual. However, the remaining review and republishing work was suspended following the 2010 General Election. The need for a further improved focus on benefits realisation in public sector projects and programmes continues to be highlighted by the National Audit Office. The NAO are in discussion with the BeReal team and other parties about how work might be implemented. The BeReal project leader was invited by The Stationary Office (TSO) to assist in the preparation and review of the benefits management chapter within the 2011 edition of 'Managing Successful Programmes'.

**6. Wider work in the NHS.** Project 1 findings were reported in a 'listening' exercise around GP commissioning with Anne Milton, Parliamentary Under Secretary for Public Health. Wider interest in the research created opportunity for further initiatives including 'visioning' work with Bridgewater Community Services NHS Trust and Pathways to Impact Award event involving designers and commissioners (see [http://imagination.lancaster.ac.uk/activities/Design\\_Practice](http://imagination.lancaster.ac.uk/activities/Design_Practice)).

**7. Impact abroad.** The spreadsheet tool on the public website (project 2) has been downloaded by users ranging from academics in Australia to the commercial users from the mergers and acquisitions sector.

**8. Beyond healthcare.** The core method has had an impact beyond healthcare. It was shared with the Valuing Nature Network ([www.valuing-nature.net](http://www.valuing-nature.net)), where its practical approach has been incorporated within the Deliberative Monetary Valuation (DMV) methods of this community.



## Selected outputs

1. Sapountzis S, Lima J, Yates K, Kagioglou M (2011) BeReal: A benefits realisation process, from planning to delivery: effective benefits realization. A Consultative guide, The University of Salford, ISBN 978-1-907842-16-0.
2. Rooke J, Hamblett K, Sapountzis S, Yates K, Kagioglou M, Aouad G (2009) Realising Benefits for Primary Healthcare Infrastructures, *Facilities*, 27 (3/4), 74-78.
3. Tillmann P, Tzortzopoulos P, Sapountzis S, Formoso C (2010) Managing benefits in the design of healthcare facilities in the UK. 'Gestao de beneficios na etapa de projecto em empreendimentos hospitalares do reino unido, *Gestão & Tecnologia de Projetos* 5 (1), 109-132.
4. Rooke J, Sapountzis S, Koskela L, Codinhoto R, Kagioglou M (2010) Lean Knowledge Management: the problem of value, Proceedings of 18th Annual conference of International Group of Lean Construction, Technion, Israel institute of Technology, Haifa, Israel, July 14-16, pp 12-21.
5. Sapountzis S, Yates K, Lima J, Kagioglou M (2010) Benefits realisation: Planning and evaluating healthcare infrastructures and services. In Kagioglou M and Tzortzopoulos P (Eds.) *Improving healthcare through built environment infrastructure*. Wiley-Blackwell, Oxford, UK.
6. Tillman P, Tzortzopoulos P, Formoso C (2010) Analysing benefits realisation from a theoretical perspective and its contribution to value generation. Proceedings of 18th Annual conference of International Group of Lean Construction, Technion, Israel institute of Technology, Haifa, Israel, July 14-16, pp 73-82.
7. Yates K, Sapountzis S, Lou E, Kagioglou M (2009) BeReal: Tools and Methods for Implementing Benefits Realisation and Management, Proc. 5th Nordic Conference on Construction Economics and Organisation, Reykjavík, Iceland, 10-12 June 2009, 223 – 232.
8. Yates K, Barreiro-Lima J, Sapountzis S, Tzortzopoulos P, Kagioglou M (2009) BeReal Benefits Realisation model integrated approach: The Built environment lifecycle and organisational views, 2nd HaCIRIC Symposium, Brighton, April.
9. Sapountzis S, Harris K, Kagioglou M (2008) The need for Benefits Realisation – Creating a benefits driven culture in UK's Healthcare Sector. HaCIRIC Symposium Redefining healthcare infrastructure. Integrating services, technologies and the built environment, 3-4 April 2008, London, UK.
10. Sapountzis S, Harris K, Kagioglou M (2008) The development of a Benefits Realisation Management Process to drive successful programmes and projects. In Pantouvakis J (ed,) Proceedings of the Joint Fourth Scientific Conference on Project Management (PM-04) & the First IPMA /MedNet Conference - Project Management Advances, Training & Certification in the Mediterranean, 29-31 May, Chios, Greece.

## Researchers involved

- **Mike Kagioglou** (University of Salford)
- **Stelios Sapountzis** (University of Salford)
- **Kathryn Yates** (University of Salford)
- **Jose Barreiro Lima** (University of Salford)
- **Patricia Tzortzopoulos-Fazenda** (University of Salford)
- **John Rooke** (University of Salford)



## 7.7 Modelling, simulation and visualisation to deliver enhanced performance and value of healthcare built environments

### Background

Redesign of care services and infrastructure can be difficult and risky. The relationships between technology, services and infrastructure are complicated, with potential benefits poorly evidenced. This makes it hard to develop a case for change or a business case for investment in innovation. The relationships between technology, services and infrastructure are complicated, with potential benefits poorly evidenced. HaCIRIC research has explored how modelling, simulation and visualisation (MSV) can be used to help plan and design healthcare infrastructure innovations at different scales in the system, from the ward to the local healthcare economy.

This impact case study focuses on HaCIRIC activities aimed at the application of MSV to deliver enhanced performance and value of healthcare built environments. MSV has been widely used in HaCIRIC's research and is reported in other impact case studies, notably 'An assurance based regulatory framework for NHS asset management' (case study number 7.3) and 'Improving urgent and unscheduled care delivery systems' (case study number 7.4).

The research teams at Loughborough and Reading Universities drew on their previous research into evidence based design and used Building Information Modelling (BIM) and environmental simulation to improve the therapeutic design of new and existing healthcare facilities. They enhanced the BIM approach by developing purpose-built models and digital mock-ups, helping to reduce the cost and time required for various aspects of healthcare building design and the development process. They modelled indoor built hospital spaces and our work on airflow (natural ventilation) modelling has highlighted limitations of current systems in dealing with the spread of airborne pathogens in hospital wards and the significant heating energy required to keep them thermally comfortable.

As well as HaCIRIC research projects in this theme, an extensive programme of doctoral research was conducted, funded by Loughborough University's Innovative Manufacturing and Construction Research Centre and other Loughborough University funding. Ten PhD projects were supported, predominantly developing and applying MSV tools to support evidenced based design, policy and assurance of efficient and sustainable healthcare environments.

### Underpinning research

HaCIRIC's initial work in this field involved collaboration with the Centre of Excellence in Customised Assembly at the University of Nottingham to explore the role of advanced MSV technology such as BIM and immersive and virtual environments in improving design and decision making process and stakeholder engagement of healthcare facilities. From this we developed a programme of research focused on the following projects.

**1. Use of modelling tools.** This project investigated the use of simulation tools in the planning of healthcare estates and healthcare services, in particular how they are used and why they are not used. This is important because the potential of simulation and other approaches in healthcare has not been fully exploited and is lagging significantly behind other industries. Our work with the University of Southampton provided a better understanding of the factors influencing how simulation models are used in 'real' commercial settings and the role they can play in the decision-making by healthcare professionals, managers and policy makers. We investigated tools for estate planning and for the use of simulation and modelling of care services at different scales in the healthcare system. This highlighted that existing tools are not user friendly, and decision-makers are often unaware of their existence, reluctant to pay for them or may not know how to use them effectively.

**2. Modelling complex urban environments.** This scoping study explored the use of systems dynamics for modelling the interaction and change of systems for the effective delivery of infrastructure and services and the potential applications of complexity theories in strategic decision making. The work addressed issues of integration and connectivity across different spatial and temporal scales within the urban environment, investigating the challenges of integrating social and technical systems and services at appropriate scales. This enabled an improved understanding of different approaches to modelling and predicting urban sustainability. The research was further developed within PHIΦ and OPHI projects to support the rationalisation and effective use healthcare estate, and inform a new strategic planning framework, supported by best practice case studies, for emergency and urgent care planning.

### 3. Improving the Therapeutic Performance of Healthcare Spaces: Modelling, Simulation and Visualisation (MSV) Aesthetics and Lighting.

The concept of designing therapeutic environments which have positive impacts on the occupants is not new, but the relationships between environmental stimulus and response are complex and not fully understood. Well-designed healthcare facilities are delivering positive outcomes, but there is a high degree of complexity involved with many often-conflicting environmental parameters that need to be considered and reconciled. This project demonstrated how innovative design solutions relating to aesthetics and lighting (e.g. the availability of natural light/ day light and use of the arts) can impact on clinical outcomes, staff productivity and facility performance. It developed a parametric environmental design framework to support assessments and improvements within multiple variable parameters. It also explored the potential application of BIM, enhancing this approach by developing purpose-built models and digital mock-ups.

**4. An integrated approach to the design of high quality healthcare space and flexible layouts using MSV.** The Department of Health has recommended that the design of new healthcare facilities and refurbishment of existing buildings should be flexible enough to cope with changing patient expectations, new treatments and medical advances. Physical mock-ups are frequently used to assess different design options, but these tend to be costly, time consuming and difficult to modify. This project developed an integrated approach to the design of high quality healthcare facilities, focusing on acute and community hospitals, using MSV tools. The research developed methodologies to optimise the space layout of healthcare facilities, drawing on evidence based design lessons and considering the factors influencing the hospital space planning and mathematical optimisation techniques in the design decision making process. Two PhD researchers were also recruited to support this work, investigating optimisation of healthcare facility spatial layout and the role of layout and people circulation in hospital nursing staff productivity.

**5. Enhancing performance and value through the application of advanced MSV to the design and operation of healthcare facilities.** In this work Loughborough and Reading Universities aimed to develop integrated approaches using MSV to improve planning, design, construction and management of healthcare facilities. Following work to identify and developed theory on performance indicators, parameters and modelling approaches to be considered during the design of healthcare facilities, subsequent projects included the following.

- Development of a decision support system using modelling and simulation to optimise lighting design of healthcare spaces.
- Investigation of energy and indoor environment of healthcare buildings by monitoring significant indoor environmental parameters and development of a Computational Fluid Dynamics (CFD)-based evaluation method to improve natural ventilation, environmental performance and maintain health without harm in healthcare spaces.
- Exploration of the role of advanced visualisation technologies such as immersive and virtual reality environments in improving design and decision making process, and stakeholder engagement in healthcare space design.
- Investigation of the implementation and use of BIM tools and processes in the design and construction of two major UK hospital schemes.

## Impact on industry

**1. Informed a new strategic planning framework, supported by best practice case studies, for emergency and urgent care planning.** In collaboration with the DH, several PCTs and The Prince's Foundation, the PHIΦ project developed an accessibility model (using factors such as fuel consumption and CO2 emissions) to support the rationalisation and effective use healthcare estate. A follow-on project Open Planning for Healthcare Infrastructure (OPHI) co-produced with eight Acute NHS Foundation Trusts a set of tools to support an open and flexible acute strategic and large site planning response with a focus on with Emergency and Urgent Care. Working closely with a local PCT, a GIS accessibility model was developed and used to assess the potential impact of different reconfiguration scenarios and inform the relocation decision making process during a period of major reconfiguration.

“*The research on the use of BIM in practice helped contribute to Skanska and HOK's understanding of BIM adoption and rollout in two case study hospitals. The research team provided mentoring, training and development and consultancy to support the partners' ICT and innovation strategies.*”

## 2. Improved evidence base for the impact on

**therapeutic healthcare environments.** This HaCIRIC work programme has improved understanding of the therapeutic design of new and existing healthcare environments. The research on daylighting and artificial lighting simulations established the relationship between daylight availability and patient recovery in a hospital setting. The statistical analysis of the collected data shows that while holding the other explanatory variables constant, the provision of outdoor view reduced the observed patients' length of stay by an average of 13.5 hours in total and by 4 hours per 100 lux increase of daylight.

## 3. Novel method for artificial lighting design.

We developed a model-based evolutionary optimisation technique, integrated with RADIANCE computer simulation, and used as a mean to search for new lighting solutions. A novel method for artificial lighting design was subsequently developed taking due consideration of low vision requirements.

## 4. Improved natural ventilation and environmental

**performance.** The use of natural personalised ventilation was shown to be a feasible concept in a four-bed Activity Data Base (ADB) ward as well as a four-bed cruciform ward layout. In both spaces, each patient had a dedicated supply of fresh outdoor air delivered directly above them, resulting in a protected zone of diluted and uncontaminated indoor air. This resulted in the development of a natural personalised ventilation (NPV) system to dilute ambient air through mixing and provide a dedicated supply of fresh air directly over patients. The NPV system was able to deliver fresh air up to distances of about 10m in a multi-bed hospital ward.

## 5. BIM and VR CAVE.

The research on the use of BIM in practice helped contribute to the supply-chain participants (Skanska and HOK) in the two project case study hospitals understanding of BIM adoption and rollout. The research team provided mentoring, training and development and consultancy to support the partners' ICT and innovation strategies. The work is continuing with applied research funding (TSB Rethinking The Build Process, KTP Associate, EPSRC Vacation Bursaries). In collaboration with Skanska and HOK we are developing further computer models and virtual reality applications to help architects and planners to take account of diverse stakeholders, new treatments and medical advances.

## 6. Cumberland Initiative.

As a result of the MSV related research conducted by HaCIRIC, we have joined with the Brunel University IMRC (MATCH) and others to form the Cumberland Initiative. This aims to transform the quality and cost of healthcare delivery through development and use of simulation, modelling and systems thinking. The Cumberland Initiative has close links with industrial partners, including BT Health / BT Global Services and IBM Healthcare and Life Sciences, and healthcare partners from several NHS trusts.





## Selected outputs

1. Joarder M and Price A (2012) Daylight Simulation in Architectural Practice: Shading Design for Hospitals in London. International Seminar on Architecture: Education, Practice and Research, 02 - 04 February, Dhaka, Bangladesh, pp 436-451.
2. Astley P, Bolgar B, Mahadkar S, Mills G, Price, A, Rafor N, Soriano B and Titidez O (2009) *PHIΦ: Planning Healthcare Infrastructure; Implementing the Next Stage Review Healthcare Infrastructure*. Prince's Foundation for the Built Environment.
3. Titidez O, Quddus M, Ison S, Price A (2012) Modelling Transport Accessibility to Healthcare Facilities using Statistical Methods and GIS. *44th annual UTSG conference*, Aberdeen, UK.
4. Mourshed M, Shikder S, Price, A (2011) Phi-array: A novel method for fitness visualization in evolutionary design optimization. *Advanced Engineering Informatics* 25(4) pp. 676-687.
5. Adamu Z, Cook M, Price A (2011) Natural Personalised Ventilation: A Novel Approach. *International Journal of Ventilation*, 10 (3), pp 263-275.
6. Osaji E, Price A, Mourshed M (2010) The Role of Building Performance Simulation in the Optimization of Healthcare Building Design. *Journal of Building Performance Simulation*, 3(3), p.169.
7. Davies R, Harty C. (2013) Implementing 'Site BIM': a case study of a large hospital project. *Automation in Construction*, 30, 15-24.
8. Krystallis I, Demian P, Price A (2013) Supporting Future-proof Healthcare Design by Narrowing the Design Space of Solutions Using Building Information Modelling, *Association of Researchers in Construction Management*, September 2013 Reading, UK.
9. Tutt D, Harty C (2013) Journeys into the CAVE: The use of 3D immersive environments for client engagement practices in hospital design. In: Smith S, Ahiaga-Dagbui D (Eds) *Procs 29th Annual ARCOM Conference*, 2-4 September 2013, Reading, UK, Association of Researchers in Construction Management, 111-121.
10. Bayer S, Barlow J. (2011), Raising the profile of simulation and modelling in health services planning and implementation, *J Health Services Research & Policy*, 16(3): 129-130.

## Researchers involved

- **Andrew Price** (Loughborough University)
- **Mohammed Quddus** (Loughborough University)
- **Stephen Ison** (Loughborough University)
- **James Barlow** (Imperial College London)
- **Steffen Bayer** (Imperial College London)
- **Chris Harty** (University of Reading)
- **Monjur Mourshed** (Loughborough University)
- **Peter Demain** (Loughborough University)
- **Shariful Shikder** (Loughborough University)
- **Jun Lu** (Loughborough University)
- **Ashik Zulfikar** (Loughborough University)
- **Ahmad Makarfi** (Loughborough University)
- **Emeka Osaji** (Loughborough University)
- **Ilias Krystallis** (Loughborough University)
- **Dylan Tutt** (University of Reading)
- **Omid Titidez** (Loughborough University)

## 7.8 Whole-system, service and asset evidence-based planning and design

### Background

This strand of HaCIRIC research contributed new knowledge to expand the creation, maintenance and use of evidence-based design. This approach has grown from the scientific evidence based medicine field and now combines a community of leading academics around the world who apply scientific evidence of clinical and patient outcomes within the building planning and design process.

The challenge lies in the complex interdependencies between infrastructure investment and healthcare outcomes. This relationship is seldom completely causal and is, even now, not fully understood – for example, increasing or changing investment inputs may produce variable outcomes. Furthermore, capital investment is rarely appraised against a robust evidence base.

A combination of HaCIRIC projects progressed the journey to amalgamate and structure fragmented sources of evidence to generate an interdisciplinary system of evidence. We implemented research to establish theoretical underpinnings for evidence based design (EBD), reviewed supporting tools and standards, conducted systematic reviews and created new evidence that is being used to support policy and practice.

The impact of the work developed has been influential at theoretical, strategic-policy and operational levels. We challenged existing organisational structures and shaped new collaborative networks for policy makers, industrialists and academics as a means of addressing complex decision-making, thus contributing directly to policy and expanding the evidence based design field into strategic asset management, operations management, ergonomics, design management and policy / regulation.

### Underpinning research

At its outset HaCIRIC recognised a need for a robust and evidence-based approach to planning and design quality assurance. Teams from Loughborough, Salford and Sheffield Universities worked with many construction practitioner and clients to develop this. Related research projects included:

- 1. Theoretical underpinnings of evidence based design** (2003-2004). Research by SCRI (Salford Centre for Research and Innovation) reviewed the international evidence and developed a new structure to support the creation, capture, storage and retrieval of evidence based knowledge. The research also identified gaps in the evidence base and key unaddressed issues related to the use of evidence by practitioners in the design process.
- 2. The innovative design of well-performing built healing environments** (2007-2009). The research described which characteristics of the built environment have the greatest impact on health outcomes and investigated how the evidence-base could be used to inform designers throughout different project phases. It applied operations management to accelerate innovation, improve performance and align with new healthcare business models and practices. It also explored the use of evidence to support value delivery in operational efficiency, staff performance and operating costs; healing environments, wellbeing and patient recovery; capital costs, sustainability and future proofing, standardisation and flexibility.
- 3. Design evidence base to continuously improve the delivery of patient safety** (2008-2011). Loughborough University funding, including IMCRC funding, supported over 10 PhDs who developed/ applied modelling, simulation and visualisation to support the evidenced based design, policy and assurance of efficient and sustainable healthcare environments that enhance patient safety and experience. This included a PhD student who developed new theory through the exploration of key decision-making processes and consolidation of our research into a framework for evidence based design of healthcare infrastructure.



#### 4 Nurturing an evidence-based learning environment

(2009-2011). The research explored the creation and maintenance of evidence to create a learning quality system between policy and practitioner planning and design supply chains. Prior to this work the University of Sheffield developed the Sheffield Healthcare Environmental Database published by the Department of Health Knowledge Information Portal. Through HaCIRIC's input this database was expanded and made more accessible to a world-wide audience through an interactive online portal.

#### 5 The impact of the physical environment on mental capital and wellbeing

(2007-2009). This research reviewed evidence and predicted the impact of the physical environment on the mental wellbeing of patients and users. The assessment of the scientific evidence showed that poor quality environment is currently negatively affecting mental capital through life, mental health, wellbeing and work and learning and that this trend is predicted to be maintained within 25 year horizon reviewed.

#### 6 Appraisal of Health Infrastructure Investment and its contribution to health gain

(2010-2011). Research funded by the European Investment Bank and Department of Health established an evidence base for hospital infrastructure investment appraisal. This study reviewed the available evidence across diverse fields of social sciences, geography and economics. It evaluated the health and related benefits to be gained from investing in health infrastructure and medical equipment of different kinds and what the potential was for determining an optimum scale, scope and distribution.

Much of this stream of work has provided input into our activity on the use of modelling, simulation and visualisation to investigate integrated approaches to the design of high quality healthcare space and flexible layouts using (impact case study 7.7).

## Impact on policy

### 1. Improved health building standards in the UK.

A HaCIRIC collaborative team supported the development and revision of HBN 15-01 (DH, 2013). This informed the move from prescriptive input statements to desirable beneficial outcomes and process flows. The principles of acuity adaptability, that separates decision making into strategic, site and operating level flows in HBN 15-01, are built from HaCIRIC research.

### 2. Healthcare infrastructure contributions to improved quality and safety outcomes.

We provided evidence showing the relationship between capital investment and health gain. This contributed significantly to DH input into the 2012 NICE consultations, and is integrated into the 'patient experience' domain of the national NHS Premises Assurance Model (NHS PAM). The NHS PAM is a software-based multi-criteria asset management tool, endorsed by the Care Quality Commission and Institute of Healthcare Engineering and Estates Management. It provides a nationally consistent approach to examination of estates condition, performance and efficiency, and board-level quality assurance of healthcare premises. The NHS PAM comprises five domains of national indicators: finance and value for money, safety, effectiveness, patient experience, and board governance. The impact of this research has led to the development of a functionally coherent, responsive and evidence based NHS PAM.

### 3. Future foresight on ageing.

Our research contributed to a wider Governmental Foresight review on Mental Capital and Wellbeing. The research showed very little had been done in relation to the physical environment support the ageing population which resulted in the generation of policy recommendations for improving the physical environment for older people.

## Impact on practice

### 1. At the operational level, data sets were created and new applications for supporting EBD were created.

The work has reached a national and international audience of academics and the healthcare industry, putting the UK in the forefront of research in this area – HaCIRIC's workshops were attended by senior members of the Department of Health, the NHS Estates, and major UK and international design and construction firms.

### 2. The work was presented, by invitation, to the Portuguese Director General of Health, representing the EU High Level Committee on Health, the Health Security Committee and Chief Medical Officers.

At this time Portugal was also leading work for the EU and the World Health Organisation on ageing.

### 3. Within England the work has received the following endorsement from the Department of Health:

*"The evidence-based design work developed within HaCIRIC identified the need for evidence-based models that demonstrate the efficiencies and process optimisations that can be gained in the design of facilities with a large number of user profiles, such as hospitals. The evidenced-based design research has provided new and improved ways for the NHS to approach healthcare infrastructure design in the future."*

Peter Sellars, Director and Head of Profession/Policy, NHS Estates & Facilities England, Head NHS Gateway Reviews & P21+ at UK Department of Health.

### 4. Architectural environmental healthcare reference base.

A freely available online resource was developed in part through funding from HaCIRIC for the Nurturing an Evidence-Based Learning Environment collaborative project between Sheffield and Loughborough University. This database contains around 700 relevant items of research that is used by policy makers, academics and practitioners the world over. The evidence suggests that factors that the designer has control over can make significant differences to patient satisfaction, quality of life, treatment times, levels of medication, displayed aggression, sleep patterns, compliance with regimes among many other similar factors. Taken together then, this new evidence-based approach has the potential simultaneously to improve the quality of patient experience and, in many cases, health outcomes, while also saving time and costs. This database is accessible at: <http://hear.group.shef.ac.uk>.

### 5. Determining the impact of Activity Database on clinical and care outcomes.

Working with Sheffield University, HaCIRIC reviewed the use of Activity Database (ADB) a room-based programming and design system developed in the 1960s to aid the briefing, construction, asset management and alteration of healthcare facilities. This had an impact through involvement of 177 practitioners in workshops and a survey, leading to a future research and development agenda for activity based healthcare outcome specification and evaluation.

### 6. Evidence supporting dementia investment.

This work has led to the formation of the International Dementia Design Network and the Salford Dementia Institute, providing a platform for discussion about the provision of care for people with dementia. It brings together industrialists, carers, communities, academics and people with dementia. Working closely with practitioners, industry and other stakeholders, the Institute provides training and educational material. In addition, the HaCIRIC team at Loughborough is currently supporting the DH in the assessment of the £50m investment made on 116 healthcare facilities being redeveloped to accommodate people with dementia and the needs of carers.



## Selected outputs

1. Codinhoto R, Tzortzopoulos P, Kagioglou M, Aouad G, Cooper R (2008) Healthcare environments and health outcomes: a framework for the built environment, *Facilities*, 27, 138-151.
2. Hignett S, Lu J (2010) Space to care and treat safely in acute hospitals: recommendations from 1866 to 2008, *Applied Ergonomics*, 41(5), 666-673.
3. Hignett S, Lu J, Fray M (2010) Two Case Studies Using Mock-Ups for Planning Adult and Neonatal Intensive Care Facilities, *Journal of Healthcare Engineering*, 1(3), 399-414.
4. Lu J, Price ADF (2011) Dealing with complexity through more robust approaches to the evidence- based design of healthcare facilities (Guest Editorial), in *Health Environments Research and Design Journal*, 4(4), 5-7.
5. Astley P, Hind R, Mills GRW, Price ADF, Mahadkar S, Page M (2011) Open Infrastructure Planning for Emergency and Urgent Care, In: Kendall S (Ed), *Architecture in the Fourth Dimension: methods and practices for a sustainable building stock. CIB, 17th annual meeting of the CIB Commission on Open Building Implementation*, Boston, Mass, USA.
6. Cooper R, Boyko C, Codinhoto R (2009) The effect of the physical environment on mental wellbeing, in: Cooper C, Goswami, U. and Sahakian, B.J. (eds). *Mental Capital and Wellbeing*. Wiley-Blackwell.
7. Adamu Z, Price ADF, Cook MJ (2012) Performance evaluation of natural ventilation strategies for hospital wards – A case study of Great Ormond Street Hospital, *Building and Environment*, 56, 211-222.
8. Mourshed M, Shikder S, Price ADF (2011) Phi-array: A novel method for fitness visualization in evolutionary design optimization, *Advanced Engineering Informatics*, 25(4), 676-687.
9. Joarder M, Price ADF (2012) Impact of daylight illumination on reducing patient length of stay in hospital after coronary artery bypass graft surgery, *Lighting Research & Technology*, 45(4), 435-449.
10. Tzortzopoulos P, Codinhoto R, Kagioglou M, Rooke JA, Koskela LJ (2009) The gaps between healthcare service and building design: a state of the art review, *Built Environment*, 9(2), 47-55.

## Researchers involved

- **Andrew Price** (Loughborough University)
- **Bryan Lawson** (Sheffield University)
- **Mike Kagioglou** (The University of Salford)
- **Michael Phiri** (Sheffield University)
- **Grant Mills** (Loughborough University)
- **Clementinah Rooke** (The University of Salford)
- **John Rooke** (The University of Salford)
- **Jun Lu** (Loughborough University)
- **Nadeeshani Wanigarathna** (Loughborough University)
- **Patricia Tzortzopoulos Fazenda** (The University of Salford)
- **Rachel Cooper** (Lancaster University)
- **Ricardo Codinhoto** (The University of Salford)
- **Stephen Ruddock** (The University of Salford)
- **Phil Astley** (MARU)
- **Simon Austin** (Loughborough University)
- **Federica Pascal** (Loughborough University)
- **Efthimia Pantzartzis** (Loughborough University)



## 8. Enhancing the impact – communications and knowledge transfer

### 8.1 Our strategy

Communications and engagement were a fundamental part of HaCIRIC's mission. Following our third year review, we reviewed our communications strategy, including its objectives and scope, and put in place a number of actions to maximise its impact. These included appointing a professional communications expert to spend 1.5 days per week on HaCIRIC activity, plus additional time as necessary. Our strategy aimed to develop a coherent identity for the centre and project this more effectively to stakeholders. Nearly all projects had local groups associated with them and these were used for workshops to develop the research, provide immediate feedback and evaluation. Regional events were used to introduce the programme to the stakeholder community and to inform the direction of the research.

We also developed a series of carefully planned cross-cutting seminars. These brought together HaCIRIC's research on particular key issues, and other academics and experts, to discuss findings and identify future areas for activity, both research and engagement. Our strategy was generally to publish reports of these events, addressing key questions of interest to our stakeholders. On each occasion, one of our directors wrote a foreword, which drew together the learning and its wider policy and practice significance. These reports were then widely circulated. We also used the events as the basis for articles in the *Health Service Journal*, the key trade publication for the NHS with an average circulation of approximately 15,000 decision-makers and others from the healthcare sector. This ensured that our messages potentially reached a large number of key stakeholders and meant that the learning from the seminar was not confined to those who attended or those who went to the website.

We also developed a second suite of publications – *HaCIRIC Insights* – which made accessible our research by setting it against some of the big issues that our stakeholders cared about. In all, we published three HaCIRIC Insight publications. A foreword to each of these was written by one of our directors, ensuring that as much as possible was gained from the inter-disciplinary, multi-university nature of the work.

### 8.2 The website and newsletter

The website [www.haciric.org](http://www.haciric.org) was established early on to maximise communication of the output from the research. As it evolved, its style was used to develop the corporate identity of HaCIRIC publications. Its design was intended to make it as user friendly as possible, setting out at the home page the issues that were of key concern to our stakeholders – 'safer patients', 'home not hospital', 'better decision making', 'smarter purchasing', 'managing change and innovation'. These lead the reader through to the research projects. All the research is explained within these four narratives. Our corporate brochure, which has also been widely praised for its accessibility is likewise built around these narratives.

From 1 September 2010 to 30 November 2013 more than 100,000 pages were viewed and the site has been widely admired by its users. Most (73 per cent) of our total visitors have been from the UK, followed by the United States and Netherlands.

Blogs have been written regularly on issues arising from the research in response to current questions in healthcare. These are an excellent way of commenting on events from the breadth of HaCIRIC's network. We have turned a number of blogs into contributions to the *Health Service Journal*, further boosting our readership.

The site – and the styling of the communications – was helpful not only for external communications. An easily accessible route to understanding everything happening within HaCIRIC helped maximise internal communication across the partner universities and researchers, and everyone to understand better the collective mission.

Seven editions of an email-based newsletter were published. They have been sent to the whole of the HaCIRIC database which has over 1500 members. This group will be the basis for our alumni, who will become part of the Healthcare Infrastructure Forum.

“

*We used events as the basis for articles in the 'Health Service Journal', the key trade publication for the NHS with an average circulation of approximately 15,000 decision-makers and others from the healthcare sector.*

”

## 8.3 Conferences and other events

### 8.3.1 Conferences

From the outset, we initiated an annual conference to establish the research agenda, its international relevance and provide a context in which new researchers could experience presenting their ideas to a challenging audience. We aimed to 'regionalise' HaCIRIC's conferences as much as possible by rotating them around the UK's countries and regions. Over 1500 people participated in our national conferences and our seminars – not including the many workshops that have been hosted at a university level within HaCIRIC.

Our annual conference was primarily designed to build a national and international research community, although they have also attracted a high level of participation by users and policy makers. Typically, over 60 papers were received from around the world for each conference. Our policy was to accept around 20 papers for presentation at the conference by seeking high quality contributions which were given sufficient time to develop their argument and enable the audience to participate in debate. The final conference in 2013 took a different form and was aimed at practitioners and policy makers. The conference structure was designed to form the future debate and to launch HaCIRIC's successor, the Healthcare Infrastructure Forum (see Section 4.5).

We were also involved in organising or supporting other conferences, with collaborating partners. For example, HaCIRIC co-sponsored and co-organised, with the Rajiv Gandhi Centre at Imperial College London, a conference on 'Innovation for Inclusive Growth – Addressing the Challenge of Improving Healthcare Access' held in 2011. This brought together speakers and delegates to explore new ways of bringing care at a lower cost for socially and economically disenfranchised communities. A report of the conference was published and distributed to a wide mailing list, and some lessons were incorporated in a major report published by *The Lancet* in 2012<sup>18</sup>.

With ECHAA, we co-sponsored and organised two conferences. One of these was on 'Comparative PPP models in a time of recession: the options for decision-makers', held at the Technische Universität Berlin in 2009. Around 40 delegates from banks, healthcare providers and other organisations, the EU and academia came together to explore lessons from different healthcare PPP models. The conference paved the way for a HaCIRIC project. The second conference, on 'Credit crisis or global depression: The impact on capital planning and the health sector' was sponsored by Arup International and held at their offices in London in 2009. This attracted over 50 delegates.

18 Technologies for Global Health. *The Lancet Commissions*.  
[http://dx.doi.org/10.1016/S0140-6736\(12\)61127-1](http://dx.doi.org/10.1016/S0140-6736(12)61127-1)

“

*The final conference in 2013 was designed to inform the future debate and to launch HaCIRIC's successor, the Healthcare Infrastructure Forum.*

”



### 8.3.2 Seminars and workshops

In 2008 we initiated a series of breakfast meetings, sponsored by Mace, the international consultancy and construction company. These were targeted at an invited audience from policy and practice and designed to stimulate debate about key issues addressed within our work. A further programme of four events, sponsored by Willmott Dixon Construction, continued in 2009-10. These meetings were on (1) evidence-based design: the way forward, (2) strategic master planning and asset management, (3) innovative ways for procuring healthcare infrastructure and (4) innovation in healthcare: too much or too little? Subsequently these developed into a series of debates led by practitioners at the centre of the changing healthcare scene so that we could tease out the future research questions. These were written up and published.

In 2012-13, we launched a number of dissemination events aimed at current high profile concerns in healthcare. These drew on findings from HaCIRIC research projects and involved other academics, policy makers and industry practitioners.

These events took the format of short presentations followed by debate, and were on:

- **‘New learning on controlling healthcare acquired infection’.** The event explored research on the movement of microbes as well as on routes of transmission and contamination in healthcare settings, modelling the effectiveness of cleaning agents and techniques, and new work to control Norovirus. Following this event an article was published in the *Health Service Journal*.
- **‘Recent advances in improving healthcare delivery using modelling and simulation.’** The event brought together a range of speakers from HaCIRIC and the simulation industry to debate the guidelines to ensure wider adoption of simulation and modelling by healthcare decision makers. This event also led to an article in the *Health Service Journal*.
- **‘Fresh thinking on managing unscheduled care.’** This event explored experiences in implementing more streamlined emergency care. It reflected on the challenges of whole systems working, reported on some of the work within HaCIRIC and opened a discussion on the management of unscheduled care in a time where patient demand and the pressure on A&E was growing and when new outcome measures had been introduced to manage unscheduled care.

- **‘Localism and big system change in the NHS.’**

Since 2011, changes in the NHS have resulted in devolution from the centre to hospital trusts and primary care CCGs in a radical attempt to influence service delivery and productivity. HaCIRIC brought together three discussants, former health minister Lord Warner, Director of Greater Manchester NHS, Dr Mike Burrows, and John de Pury, then a senior policy advisor in the NHS Confederation. The subsequent debate helped shape the design of our 2013 conference and a summary of the debate was published, widely distributed, with an article published in the *Health Service Journal*.

- **‘Planning for more resilient healthcare in emergencies under increasing risks and decreasing budgets.’** This workshop brought together a multi-disciplinary group to share their experiences and discuss how the resilience of emergency services to major incidents and extreme weather events could be improved.

- **‘Future directions in lean healthcare – delivering value in planning and design.’** The workshop invited industrialists to join with the research teams to define a future direction for lean healthcare estates planning and design.



### 8.3.3 Dissemination reports and other non-academic publications

Several reports on the 'big issues' facing our stakeholders were produced. These drew together HaCIRIC research to provide a state-of-the-art commentary:

- *Complex Healthcare Made Simpler: Advances and opportunities in improving healthcare delivery using modelling and simulation* (2012).
- *Controlling Healthcare Acquired Infection: New learning on how performance management and design can reduce HCAI* (2012).
- *Remote Care plc, Developing the capacity of the remote care industry to supply Britain's future needs* (2012).
- *Localism and Big System Change in the NHS: Can the new localism in the National Health Service deliver the innovation needed to avert a forthcoming crisis?* (2013).

Some of these, and other, HaCIRIC publications led to extended pieces in the *Health Service Journal*:

- 'Redesigning hospital environments can help tackle infection' by Nigel Klein, Vanya Grant, HSJ, 2 February 2012.
- 'Address the barriers and deliver acute stroke care' by Evin Uzun Jacobson, HSJ, 4 October 2012.
- 'Turn a remote love affair into a long-term relationship', by James Barlow, HSJ, 24 January 2013.
- 'Localism will not fix the bust NHS business model' by Norman Warner, HSJ, October 2013.

We also published three 'HaCIRIC Insights' reports, focusing on some of the best of our research findings and their implications for policy:

- HaCIRIC Insights 1: 'How should we create 21st century healthcare infrastructure to deliver best value?' (September 2011)
- HaCIRIC Insights 2: 'Transforming healthcare infrastructure and services in an age of austerity' (2013)
- HaCIRIC Insights 3: 'Project Findings' (September 2013)

In 2010 we published a textbook edited by Mike Kagioglou, *Improving Healthcare through the Built Environment*. Wiley-Blackwell, Oxford, UK.

Further reports are in the process of publication in 2014 on:

- European PPP models and integrated care.
- Managing major reconfiguration of hospital services and infrastructure.
- Insights into infrastructure and healthcare acquired infection.



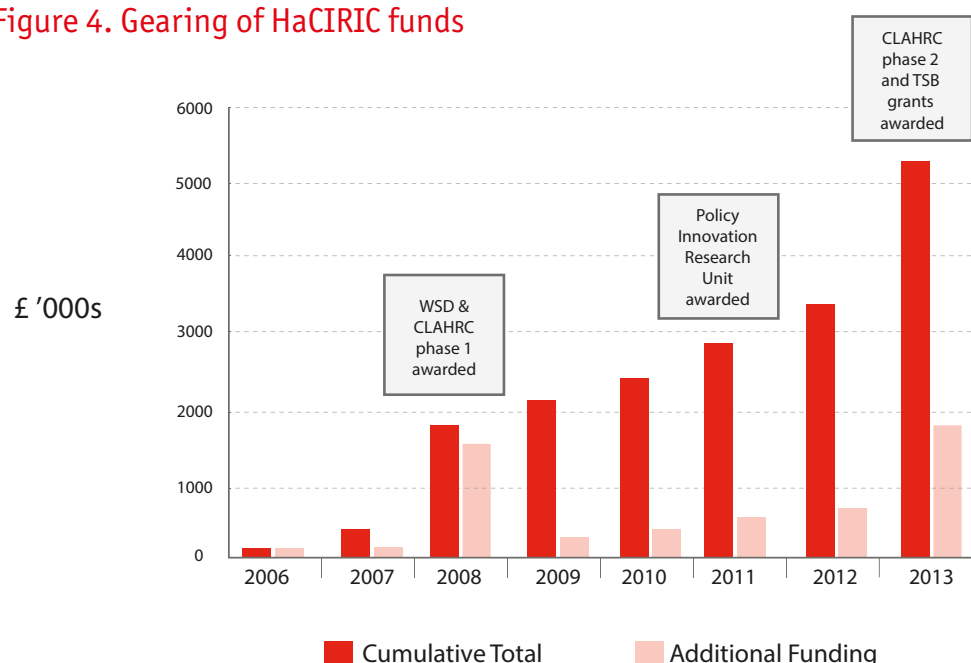
## 9. Gearing of EPSRC funds

As well as the value of in kind contributions from research collaborators, we have been successful in attracting additional funding for HaCIRIC-related work. Since 2006, the four HaCIRIC partners have secured £5.5m in new research grants and other funding (see figure 4). Much of this is associated with larger projects or research centres involving other universities – in total these amount to a further £20.7m, including two NIHR CLAHRCs and the Policy Innovation Research Unit, funded by the Department of Health.

### Highlights:

- Policy Innovation Research Unit (PIRU). Funded by Department of Health, £4.5m (2011-2016). HaCIRIC element - £300,000. Led by London School of Hygiene and Tropical Medicine, with Imperial College London, LSE and RAND Europe.
- Whole System Demonstrators programme evaluation. Funded by Department of Health, £2.3m (2008-2012). HaCIRIC element - £450,000. Led by City University, with Imperial College London, LSE, UCL, University of Manchester, University of Oxford, Nuffield Trust.
- Collaboration for Leadership in Applied Health Research and Care (CLAHRC) for Northwest London. Funded by National Institute for Health Research. Phase 1 £10m (2008-2013), Phase 2 £10m (2013-2018). HaCIRIC element - £1,050,000. Led by Chelsea & Westminster Hospital / Imperial College Health Trust.
- A £300,000 contract from the DH to monitor the £50m DH Dementia Friendly Environment Capital Programme.
- Collaboration with UCL, with a total grant of over £1m from EPSRC, to investigate air movement.
- ESRC Future Research Leaders Fellowship (£227,000) on Designing Healthy Homes for a HaCIRIC researcher.
- Technology Strategy Board Knowledge Transfer Partnership with Skanska UK (£122,000) on infrastructure based knowledge capture.
- Technology Strategy Board (£750,000) for research on Near Site, Off Site - affordable near site assembly in Modern Flying Factories.
- £250,000 from University of Salford for a Chair in Dementia Design.

Figure 4. Gearing of HaCIRIC funds



## 10. Capacity building

A priority for HaCIRIC has been building capacity in healthcare infrastructure research, alongside the Centre's research outputs and impact. This is reflected in the number and breadth of PhDs working within the HaCIRIC community (see appendix 2) and the investment in training and mentoring for post-doctoral researchers. Over 30 doctoral students have been attached to the Centre, either working directly on HaCIRIC projects or on their own research on healthcare infrastructure topics. Eight of these were supported by the Doctoral Training Grant funding.

Over the funding period, we have also been successful in developing and progressing the careers of many promising new academics (see appendix 1, table 1). Destinations for these researchers on leaving HaCIRIC include: National University of Singapore – Duke University Medical School; the Centers for Disease Control in Atlanta; London School of Economics and Political Science, London School of Hygiene and Tropical Medicine, King's College London, University College London, Ahmadu Bello University, Zaria, Nigeria Bangladesh University of Engineering and Technology, University of Nottingham Ningbo China, and the University of Massey, New Zealand. Another researcher has been awarded an ESRC Future Research Leaders Fellowship.

Postgraduate and undergraduate teaching: HaCIRIC outputs have formed the basis for MSc course modules for Imperial College's MSc in Health Management and a new MSc on Built Environment in Healthcare at Salford, as well as undergraduate and postgraduate course material at Loughborough and Reading plus MBA, MSc and Intercolated BSc (Medicine with Management) at Imperial.

Our research has also informed executive education / CPD in the healthcare infrastructure domain. For example: we have run master-classes for European healthcare infrastructure decision makers through ECHAA; we contributed to Laing O'Rourke's 'Young Guns' executive education programme; and we have held tailor-made seminars for senior executives at Merck Sharpe Dohme, AECOM and others.



# 11. Locating the Centre within the Institutions

The total resource available to HaCIRIC was in excess of £14.5m over 7 years. This comprises new funds from EPSRC and the contribution from the four member IMRCs. It had the benefit of a well-considered initial strategy that was developed with the financial support of EPSRC and contributions from the supporting IMRCs. HaCIRIC was therefore independent but embedded in the IMRCs of the supporting institutions and its user community, both financially and in terms of its research programme.

Initially, a number of projects within the supporting IMRCs were 'imported' into HaCIRIC in order to give a flying start to the programme and inform the emerging research programme. In this way HaCIRIC is built on the strengths of the supporting IMRCs and developed its own characteristics and contribution, e.g. MSc courses at Imperial and Salford now include case studies derived from HaCIRIC's research.

At Salford University, HaCIRIC is closely linked to the IMRC Salford Centre for Research and Innovation in the Built and Human Environment. There is joint work and exchange of ideas between HaCIRIC researchers and those involved with the Seamless Delivery of Value theme at SCRI. HaCIRIC has enabled research collaborations and teaching across the wider university, especially with the Faculty of Health and Social Care and the formation of a healthcare environments research group.

At Imperial College London, HaCIRIC has resulted in the development of closer links between the Business School and the Faculty of Medicine. We are a partner in the National Institute for Health Research Collaboration for Leadership in Applied Health Research and Care for Northwest London (CLAHRC), which has recently received funded for a further five years' work. Professor James Barlow is now Associate Director for Research and Evaluation for the newly formed Imperial College Health Partners AHSN, with responsibility for evaluation and innovation issues. We have contributed to a new MSc on global health innovation, run by the Faculty of Medicine, and with the Faculty of Medicine we have been successful in securing NIHR funding for a new research centre on innovation in point of care diagnostic testing to start in 2014.

At Loughborough, HaCIRIC has been an active contributor to cross campus health related research through the Virtual Research School of Health Sciences. HaCIRIC enabled the creation of ten PhD scholarships from funds within their IMRC and the School of Engineering. This has considerably expanded the capacity for research in healthcare and associated fields and consequently we have a high quality cohort of students as potential future RAs. Department of Health funding has enabled the HaCIRIC team at Loughborough to continue its research in dementia friendly environments. Additional funds have been awarded from Loughborough's impact acceleration account has been provided to continue to work with the College of Emergency Medicine, Cambridge University NHS Hospitals and University Leicester Hospitals.

At University of Reading, strong links have been developed between HaCIRIC, and the Schools of Systems Engineering, Psychology and Clinical Language Sciences, Henley Business School and with the Oxford AHSN. Research and teaching collaborations are well established across the university in the healthcare infrastructure area, and the Healthcare Infrastructure Group is one of the School of Construction Management and Engineering's five key research groups. We are currently developing a collaborative proposal with a number of NHS Trusts on understanding the relationships between design, layout, clinical practices and energy demand.

## 12. Appendix 1 - HaCIRIC staffing

### HaCIRIC Academic Staff: Research Associates / Fellows and their destinations

|                                   |   |   |
|-----------------------------------|---|---|
| Inger Abma                        | Sponsored PhD   | University of Nijmegen  |
| Dr Nebil Achour                   | Facilities Manager  | Loughborough University   |
| Dr Zulfikar Adamu                 | Lecturer in Architectural Technology                          | Loughborough University.  |
| Dr Steffen Bayer                  | Associate Professor   | Duke-NUS Graduate Medical School Singapore                                      |
| Dr Theti Chrysanthaki             | Lecturer  | London School of Hygiene and Tropical Medicine                                  |
| Dr Ricardo Codinhoto              | Lecturer in Construction Management                           | School of the Built Environment , University of Salford.                        |
| Dr Richard Davies                 | Teaching and Research Fellow                                  | School of Construction Management and Engineering, University of Reading        |
| Dr Ian Ewart                      | ESRC Future Research Leaders Fellowship                       | School of Construction Management and Engineering, University of Reading        |
| Kyriakos Hatzaras                 | Senior Research Solutions Analyst /<br>Information Technology | King's College London   |
| Dr Jane Hendy                     | Senior Lecturer   | University of Surrey  |
| Dr Ahmed Ibrahim                  | Head of Department  | Department of Quantity Surveying, Ahmadu Bello University, Zaria, Nigeria.      |
| Dr Ashik Joarder                  | Assistant Professor   | Bangladesh University of Engineering and Technology.                            |
| Dr Anja Kern                      | Lecturer  | University of Karlsruhe   |
| Fahmida Khandokar                 | PhD student   | Loughborough University   |
| Dr Therese Lawlor Wright          | Lecturer in Project Management                                | School of Mechanical, Aerospace and Civil Engineering, University of Manchester |
| Dr David Lengu                    | --  | --  |
| Dr Jun Lu                         | Assistant Professor in Architecture,<br>Engineering           | University of Nottingham Ningbo China   |
| Sameedha Mahadkar                 | Strategic Delivery Manager                                    | Nottingham University Hospital Trust  |
| Dr Masoud Malekzadeh              | Research Associate  | Loughborough University   |
| Dr Amanda Marshall-Ponting        | Lecturer in Construction Management                           | School of the Built Environment, University of Salford                          |
| Dr Grant Mills                    | Lecturer in Project Management<br>and Enterprise              | UCL   |
| Emeka Osaji                       | Researcher  | University of Wolverhampton   |
| Efthimia Pantzartzis              | Research Associate  | Loughborough University   |
| Dr Primali Paranagamage           | Lecturer in Design and Society                                | Lincoln School of Architecture, University of Lincoln                           |
| Dr Federica Pascale               | Research Associate  | Loughborough University   |
| Dr John Rooke                     | Research Fellow   | School of the Built Environment, University of Salford                          |
| Dr Stelios Sapountzis             | Lecturer in Project Management                                | Salford Business School, University of Salford                                  |
| Sharif Shikder                    | Simulation Specialist   | Mott MacDonald  |
| Andrew Sinclair                   | Research Associate  | Loughborough University   |
| Dr Danielle Tucker                | Lecturer  | London School of Economics and Political Science                                |
| Dr Dylan Tutt                     | Lecturer  | School of Construction Management and Engineering, University of Reading        |
| Dr Patricia Tzortzopoulos Fazenda | Director of Design and<br>Property Management                 | School of the Built Environment, University of Salford                          |
| Dr Junli Yang                     | Senior Lecturer   | Faculty of Architecture and the Built Environment University of Westminster     |
| Kathryn Yates                     | PhD and PT Research Associate                                 | College of Health and Social Care, University of Salford                        |
| Dr. Yisong Zhao                   | --  | --  |

## Table 2 HaCIRIC-related PhD cohort

DTG sponsored (\*)

|                   |   |  |      |
|-------------------|---|--|------|
| Ahmed Ibrahim     | PhD: Development of a Continuous Improvement Framework for the Procurement of Primary Health Care Facilities.<br>Destination: Head of Department, Department of Quantity Surveying, Ahmadu Bello University, Zaria, Nigeria.        | Professor Andrew Price<br>Professor Andrew Dainty            | 2007 |
| Steven Ruddock    | PhD: Assessment of the built environment for healthcare: a case study in the development of an evaluation framework<br>Destination: Research Associate in Construction Management and Economics at University of Central Lancashire | Prof. Ghassan Aouad  | 2009 |
| Niluka Domingo    | PhD: Reducing construction waste in healthcare facilities: a project life cycle strategy.<br>Destination: Lecturer at the University of Massey, New Zealand.  | Prof Andrew Price<br>Mohamed Osmani                          | 2011 |
| Ashik Joarder     | PhD: The impact of natural light on the built healing environment.<br>Destination: Assistant Professor, Bangladesh University of Engineering and Technology (BUET)  | Prof Andrew Price<br>Dr Monjur Mourshed                      | 2011 |
| Ruth Sengonzi     | PhD: Improving whole life value through better briefing and optioneering.<br>Destination:   | Dr Peter Damien<br>Prof Stephen Emmitt                       | 2011 |
| Amey Sheth        | PhD: Design of Sustainable Healthcare Infrastructure:<br>Destination: Project Manager at an industrial firm in Mumbai (India)   | Prof Andrew Price<br>Prof Jacqui Glass                       | 2011 |
| Zulfikar Adamu    | PhD: The feasibility of natural ventilation in healthcare buildings<br>Destination: Lecturer in Architectural Technology, Loughborough University   | Prof Andrew Price and<br>Dr Malcolm Cooke                    | 2012 |
| Bronwyn Platten*  | PhD: Mouths and meaning<br>Destination: Freelance Artist and Researcher   | Prof. Michail Kagioglou<br>Dr. Alexandra Kokoli              | 2012 |
| Clementinah Rooke | PhD: Improving way finding in old and complex hospital environments<br>Destination: Manchester Mental Health and Social Care Trust bank staff nurse   | Dr. Patricia Tzortzopoulos<br>Dr. John A. Rooke              | 2012 |
| Patricia Tillmann | PhD: A conceptual framework for improving value generation in complex construction projects<br>Destination: Post doc at UC Berkeley   | Prof. Carlos Formoso<br>Dr. Patricia Tzortzopoulos           | 2012 |
| Omid Titidez      | PhD: Assessing Transport Implication for Healthcare Facilities GIS<br>Destination:  | Prof Andrew Price<br>Prof Stephen Ison<br>Dr Mohammed Quddus | 2012 |
| Ahmad Ahmad*      | PhD: The application of Building Information Modelling (BIM) to support the design of a change-ready healthcare facility.   | Prof Andrew Price<br>Dr Peter Damien                         | 2013 |
| Ricardo Codinhoto | PhD: Evidence in Design: An investigation about the use of evidence in the design of Healthcare Environments.<br>Destination: Lecturer in Construction Management, School of the Built Environment, University of Salford.          | Prof. Michail Kagioglou<br>Prof. Lauri Koskela               | 2013 |
| Fawaz Fram*       | Patient information provision and involvement of patients by stroke professionals: implications for the patient-provider relationship.<br>Destination: BlueCrest Capital Management (UK) LLP  | Prof. James Barlow<br>Dr. Steffen Bayer                      | 2013 |



|                         |   |  |      |
|-------------------------|---|--|------|
| James Henderson *       | PhD: Enhancing Buildability through Improving Design-Construction Feedback Loops within Complex Projects.<br>Destination: Customer Support, SnagR.  | Dr Kirti Ruikar<br>Prof Andy Dainty                      | 2013 |
| Grant Mills             | PhD: Values and Value in Design<br>Destination: Lecturer in Project Management and Enterprise at UCL.   | Prof Simon Austin  | 2013 |
| Masoumeh Nazarian       | PhD: Hospital nursing staff productivity- the role of layout and people circulation.  | Prof Andrew Price<br>Dr Peter Damien                     | 2014 |
| Linda Pomeroy*          | The evolution of knowledge translation networks in healthcare.<br>Destination: University College London  | Prof. James Barlow<br>Dr. Jane Hendy                     | 2013 |
| Erica Ricks/Bishop      | PhD: The Benefits of Department of Health Estates-Related Standards and Guidance<br>Destination: Integra  | Prof Andrew Price<br>Prof Simon Austin                   | 2013 |
| Stelios Sapountzis      | PhD: An investigation into the development of an effective benefits realisation process for healthcare infrastructure projects<br>Destination: Salford Business School, University of Salford               | Prof Michail Kagioglou                                   | 2013 |
| Yisong Zhao             | PhD: Resource optimisation during refurbishment/<br>space-relocation.   | Prof Andrew Price<br>Dr Grant Mills                      | 2014 |
| Phil Astley             | PhD: Scenario Based and System-Separation Approach for the Pre-Design of Healthcare Infrastructure.<br>Destination: UCL   | Prof Andrew Price<br>Dr Grant Mills                      | 2014 |
| William Collinge        | PhD: Stakeholder engagement in healthcare infrastructure provision  | Dr Chris Harty<br>Prof. Martin Sexton                    | 2014 |
| Tiago Cravo Oliveira    | Changes in healthcare service utilisation following the introduction of complex technological innovations.<br>Destination: Institute for Health Metrics and Evaluation, Seattle, USA                        | Prof. James Barlow<br>Dr. Steffen Bayer                  | 2014 |
| Hatim Fakhri            | PhD: Evaluation of patient involvement approaches and methods in healthcare infrastructure provision  | Dr Chris Harty<br>Dr Shu-Ling                            | 2014 |
| Fahmida Khandokar*      | PhD: Key Determinants for Changing Travel Behaviour of Hospital Staff: An NHS Case Study  | Prof Andrew Price<br>Dr Tim Ryley                        | 2014 |
| Ilias Krystallis        | PhD: FPS Design Methodology: Future-Proofing Scenarios in Conceptual Healthcare Design Using BIM.   | Prof Andrew Price<br>Dr Peter Damien                     | 2014 |
| Sameedha Mahadka        | PhD: Strategic Asset Management for Improved Healthcare Infrastructure Planning<br>Destination: Strategic Delivery Manager, Nottingham University Trust   | Prof Andrew Price<br>Dr Grant Mills<br>Dr Robby Sorrento | 2014 |
| Sharif Shikder          | PhD: Developing adaptation strategies to prevent overheating of buildings for the elderly<br>Destination: Simulation Specialist, Mott MacDonald   | Prof Andrew Price<br>Dr Monjur Mourshed                  | 2014 |
| Nadeeshani Wanigarathna | PhD: Evidence-based design for healthcare built-infrastructure<br>Destination: Lecturer in Quantity Surveying at Anglia Ruskin University   | Prof Andrew Price<br>Prof Simon Austin                   | 2014 |
| Sergio Kemmer           | PhD: Development of guidelines for improving production management of refurbishment projects<br>Destination: PhD and PT Research Associate at The School of the Built Environment, University of Salford    | Prof. Lauri Koskela                                      | 2015 |
| Laura Maftei*           | Exploring CAVES: the Immersive Experience of Designing healthcare   | Dr Chris Harty<br>Prof. Jennifer Whyte                   | 2015 |
| Kathryn Yates*          | PhD: Dementia - An Exploratory study into the impact of an integrated health and social care system<br>Destination: PhD and PT Research Associate, College of Health and Social Care, University of Salford | Dr Ricardo Codinhoto<br>Dr Yates - Bolton                | 2015 |

# Appendix 2 - Publications

## JOURNAL ARTICLES

1. Abma, I., Anuradha, J., Bayer, S., Mitra, S., Barlow, J. (2014) Perceptions and experiences of financial incentives: a qualitative study of dialysis care in England. *BMJ Open* 2014;4:e004249. doi:10.1136/bmjopen-2013-004249
2. Achour, N., Miyajima, M., Kitaura, M. and Price, A.D.F. (2011) Earthquake Induced Structural and Non-structural Damage in Hospitals, *Earthquake Spectra*, 27(3), 617-634. DOI: <http://dx.doi.org/10.1193/1.3604815>. Available from: <https://dspace.lboro.ac.uk/2134/8854>.
3. Achour, N., Miyajima, M., Pascale, F. and Price, A.D.F. (2014) Hospital Resilience to Natural Hazards Classification and Performance of Utilities, *Disaster Prevention and Management*, 26(1). (In press).
4. Achour, N. and Price, A.D.F. (2010) Resilience Strategies of Healthcare Facilities: Present and Future, *International Journal of Disaster Resilience in the Built Environment (IJDRBE)*, 1(3), 264-276. DOI: 10.1108/17595901011080869. Available from: <https://dspace.lboro.ac.uk/2134/8852>.
5. Achour, N. and Price, A.D.F. (2011) Healthcare resilience to natural hazards: an achievable target, Editorial: Optimising healthcare facilities performance in natural hazards, in Achour and Price ADF (Eds), *International Journal of Disaster Resilience in the Built Environment (IJDRBE)*, 2(3), 196-199.
6. Adamu, Z.A. Cook, M.J. and Price, A.D.F. (2011) Natural Personalised Ventilation: A Novel Approach, *International Journal of Ventilation*, 10(3), 263-275.
7. Adamu, Z.A., Price, A.D.F. and Cook, M.J. (2012) Performance evaluation of natural ventilation strategies for hospital wards – A case study of GOSH, *Building and Environment*, 56, 211-222, Available from: <http://dx.doi.org/10.1016/j.buildenv.2012.03.011>.
8. Adetunji, I., Price, A.D.F. and Fleming, P.R. (2008) Achieving Sustainability in the Construction Supply Chain, *Engineering Sustainability*, 161(ES3), 161-172.
9. Ahmad, A.M., Demian, P. and Price, A.D.F. (2013) Creativity with Building Information Modelling Tools, *International Journal of 3-D Information Modelling (IJ3DIM)*, 2(1), 1-10.
10. Ahmad, A.M., Price, A.D.F., Demian, P. and Lu, J. (2012) Impact of Space Standardisation and Flexibility on Healthcare Delivery, *Architectural Engineering Design Management (AEDM) Journal*.
11. Al Sehami, A., Koskela, L. and Tzortzopoulos, P. (2012) The Need for Alternative Research Approaches in Construction Management: The Case of Delay Studies, *J. Manage. Eng.*, 9(4), 407-413. [http://dx.doi.org/10.1061/\(ASCE\)ME.1943-5479.0000148](http://dx.doi.org/10.1061/(ASCE)ME.1943-5479.0000148).
12. Al-bizri, S. and Gray, C. (2010) Management framework for technology clusters implementation, *Construction Management and Economics*, 28(7), 771-782.
13. Alfes, K., Truss, K. and Gill, J. (2010) The HR manager as change agent: Evidence from the public sector, *Journal of Change Management*, 10(1), 109-127.
14. Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C. and O'Reilly, K. (2011) Technology adoption in the BIM implementation for lean architectural practice, *Automation in Construction*, 20(2), 189-195.
15. Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C. and O'Reilly, K. (2011) BIM adoption and implementation for architectural practices, *Structural Survey*, 29(1), 7- 25.
16. Arayici, Y., Koskela, L., Coates, P. and Kagioglou, M. (2011) Knowledge and technology transfer from universities to industries: a case study approach from the built environment field, *Journal of Higher Education*, 1(2), 103-110.
17. Austin, S.T., Thomson, D. and Mills, G. (2006) Introducing the VALiD Approach, *Value: The Magazine of the Institute of Value Management*, 15(1), 18-22.
18. Bakis, N., Aouad, G. and Kagioglou, M. (2007) Towards distributed product data sharing environments – progress so far and future challenges, *Automation in Construction*, 16(5), 586-595.
19. Barlow, J. and Bayer, S. (2011) Raising the profile of simulation and modelling in health services planning and implementation, *J Health Services Research & Policy*, 16(3), 129-130.
20. Barlow, J. and Köberle-Gaiser, M. (2008) The private finance initiative, project form and design innovation, *Research Policy*, 37, 1392-1402.
21. Barlow, J. and Köberle-Gaiser, M. (2009) Delivering innovation in hospital construction. Contracts and collaboration in the UK's Private Finance Initiative hospitals program, *California Management Review*, 51, 126-143.
22. Barlow, J., Roehrich, J. and Wright, S. (2013) Europe sees mixed results from public-private partnerships for building and managing health care facilities and services. *Health Affairs*, 32, 146-154. doi: 10.1377/hlthaff.2011.1223.
23. Barlow J. and Hendy, J. (2009) The challenges of adopting integrated mainstream telecare services: lessons from the UK, *Eurohealth*, 15(1), 8-10.
24. Barlow, J., Bayer, S. and Curry, R. (2006) Implementing complex innovations in fluid multi-stakeholder environments: experiences of 'telecare', *Technovation*, 26, 396-406.
25. Barlow, J., Roehrich, J. K. and Wright, S. (2010) De facto privatisation or a renewed role for the EU? Paying for Europe's healthcare infrastructure in a recession, *Journal of the Royal Society of Medicine*, 103, 51-55.
26. Barlow, J., Singh, D., Bayer, S. and Curry, R. (2007) A systematic review of the benefits of home telecare for frail elderly people and those with long-term conditions, *Journal of telemedicine and Telecare*, 13, 172-179.
27. Bassioni, H.A., Hassan, T.M. and Price, A.D. (2008) Evaluation and analysis of criteria and sub-criteria of a Construction Excellence Model, *International Journal of Engineering Construction and Architectural Management*, 15(1), 21-41.
28. Bayer S. and Barlow J. (2011) Raising the profile of simulation and modelling in health services planning and implementation, *J Health Services Research & Policy*, 16(3), 129-130.
29. Bayer, S., Barlow, J. and Curry, R. (2007) Assessing the impact of a care innovation: telecare, *System Dynamics Review* 23(1), 61-80.
30. Bayer, S. and Gann, D. (2006) Balancing work: bidding strategies and workload dynamics in a project-based professional service organisation, *System Dynamics Review*, 22(3), 185-211.
31. Bayer, S. and Gann, D. (2007) Innovation and the dynamics of capability accumulation in project-based organisations, *Innovation: Management, Policy & Practice*, 9(3-4), 207-234.
32. Bayer, S., Petsoulas, C., Cox, B., Honeyman, A. and Barlow, J. (2010) Facilitating stroke care planning through simulation modelling, *Health Informatics*, 16(2), 129-143.
33. Bayer, S. (2014) Simulation modelling and resource allocation in complex services (Editorial), *BMJ Quality and Safety*, doi:10.1136/bmjqs-2013-002742 (online before print).
34. Boshier, L., Carrillo, P.M., Dainty, A.R.J., Glass, J. and Price, A.D.F. (2007) Realising a resilient and sustainable built environment: Towards a strategic agenda for the United Kingdom, *Disasters: The Journal of Disaster Studies, Policy & Management*, 31(3), 236-255.
35. Boshier, L., Dainty, A.R.J., Carrillo, P.M., Glass, J. and Price, A.D.F. (2007) Integrating disaster risk management into construction: A UK perspective, *Building Research and Information*, 35(2), 163-177.

36. Boshier, L., Dainty, A.R.J., Carrillo, P.M., Glass, J. and Price, A.D.F. (2008) Attaining improved resilience to floods: A proactive multi-stakeholder approach, *Disaster Prevention and Management*, 18(1), 9-22.
37. Boudeau, C., Dekker, S. and Wilkin, P. (2013) Ergonomics as authoritarian or libertarian: Reflections on Ward's politics of design, *The Design Journal*.
38. Boudeau, C. (2013) Design meetings and the coordination of expertise, *Construction Management and Economics*, 31(1), 78-89.
39. Boudeau, C. The CAVE: an immersive environment for facilitating client's understanding of design? *CoDesign*.
40. Bower, P., Cartwright, M., Hirani, S., Barlow, J., Hendy J., Knapp, M., Henderson, C., Rogers, A., Sander, A., Bardsley, M., Steventon, A., Fitzpatrick, R., Doll H. and Newman, S. (2011) A comprehensive evaluation of the impact of telemonitoring in patients with long-term conditions and social care needs: protocol for the Whole Systems Demonstrator cluster randomised trial, *BMC Health Services Research*, 11, 184. doi:10.1186/1472-6963-11-184.
41. Bresnen, M. and Harty, C. (2010) Editorial: Objects, knowledge sharing and knowledge transformation in projects *Construction Management and Economics*, 28(6), 549-555.
42. Broadbent, J., Gill, J. and McLaughlin, R. (2008) Identifying and controlling risk: The problem of uncertainty in the Private Finance Initiative in the UK's National Health Service, *Critical Perspectives in Accounting*, 19(1), 40-78.
43. Caldwell, N. D., Roehrich, J. K. and Davies, A. C. (2009) Procuring complex performance in construction: London Heathrow Terminal 5 and a Private Finance Initiative Hospital, *Journal of Purchasing and Supply Management*, 15(3), 178-186.
44. Cartwright M et al. (2013) Effect of telehealth on quality of life and psychological outcomes over 12 months (Whole Systems Demonstrator telehealth questionnaire study): nested study of patient reported outcomes in a pragmatic, cluster randomised controlled trial, *BMJ*, 346, DOI: 10.1136/bmj.f653.
45. Chapman, C. and Kern, A. (2012) What do Academics do? Understanding the Practical Relevance of Research, *Qualitative Research in Accounting & Management*, 9(3).
46. Chapman, C. and Kern, A. (2013), Reflections on the research and practice of costing, *Irish Accounting Review*, 19(1/2), 23-29.
47. Chapman, C., Kern, A. and Laguerre, A. (2014) Costing Practices in Healthcare, *Accounting Horizons*, Special issue on costing in healthcare with Porter and Kaplan. Available from: <http://dx.doi.org/10.2308/acch-50713>.
48. Chen, B., Phiri, M. et al (2011) Design strategies and environmental assessment methods in health care: Lessons from UK's BREEAM, *Architectural Journal*, 2(19), 159-163, ISSN 0529-1399, Available from: [www.aj.org.cn](http://www.aj.org.cn).
49. Cloutman-Green, E., Kalaycioglu, O., Wojani, H., Hartley, J.C., Guillas, S., Malone, D., Gant, V., Gray, C. and Klein, N. (2013) The important role of sink location in hand washing compliance and microbial sink contamination, *Am J Infect Control*, (accepted ahead of Epub). DOI: 10.1016/j.ajic.2013.12.020
50. Codinhoto, R., Aouad, G., Kagioglou, M., Tzortzopoulos, P. and Cooper, R. (2009) Evidence-based design of health care facilities, *Journal of Health Services Research & Policy*, 14(4), 194-196.
51. Codinhoto, R., Tzortzopoulos, P., Kagioglou, M. and Passman, D. (2010) Evidence-based design 'evolving fast', *Health Estate Journal*, 64(3), 29-31. Available from: [www.healthestatejournal.com/Story.aspx?Story=6414](http://www.healthestatejournal.com/Story.aspx?Story=6414)
52. Codinhoto, R., Tzortzopoulos, P., Kagioglou, M., Aouad, G. and Cooper, R. (2009) The impacts of the built environment on health outcomes, *Facilities*, 27(3-4), 138-151.
53. Collinge, W. H. (2013) A conceptual valuation framework (VF) for home telecare system devices, *Journal of Assistive Technologies*, 7(1), 63- 68.
54. Collinge, W. H. (2012) Re-thinking stakeholder management in construction: theory & research, *Project Perspectives*, 34, 16-23.
55. Cravo-Oliveira, T., Barlow, J., Bayer, S. and Gonçalves, L. (2013) Telemedicine in Alentejo, *Telemedicine and e-Health*, 20(1), 90-93.
56. Cravo-Oliveira, T., Barlow, J., Gonçalves, L. and Bayer, S. (2013) Teleconsultations reduce greenhouse gas emissions, *Journal of Health Service Research & Policy*, 18(4), 209-214.
57. Chrysanthaki, T., Hendy, J. and Barlow, J. (2013) Stimulating whole system redesign: lessons from an organisational analysis of the Whole System Demonstrator Programme, *Journal of Health Service Research & Policy*, 18(S1), 47-55.
58. Dainty, A.R.J., Boshier, L., Carrillo, P.M., Glass, J. and Price, A.D.F. (2007) Integrating disaster risk management into construction: A UK perspective, *Building Research & Information*, 35(2), 163-177.
59. Dattée, B. and Barlow, J. (2010) Complexity and whole-system change programmes, *J Health Services Research and Policy*, 15(S2), 19-25.
60. Dattée, B. and Weil, H. (2007) Dynamics of social factors in technological substitutions, *Technological Forecasting and Social Change*, 74(5), 579-607.
61. Davies, R.J. and Gray, C. (2009) Care pathways and designing the healthcare built environment: an explanatory framework, *International Journal of Care Pathways*, 13, 7-16.
62. Davies, R. and Harty, C. (2013) Implementing 'Site BIM': a case study of a large hospital project, *Automation in Construction*, 30, 15-24.
63. Davies, R. and Harty, C. (2014) Measurement and exploration of individual beliefs about the consequences of BIM use, *Construction Management and Economics*. (In press).
64. Eason, K., Dent, M., Waterson, P., Tutt, D. and Thornett, A. (2012) Bottom-up and middle-out approaches to electronic patient information systems: a focus on healthcare pathways, *Informatics in Primary Care*, 20(1), 51-56.
65. Edum-Fotwe, F.T. and Price, A.D. (2009) A Social Ontology for Appraising Sustainability of Construction Projects and Developments, *International Journal of Project Management*, 27(4), 313-322.
66. Ejohwomu, O.A., Proverbs, G.D. and Olomolaiye, P.O. (2008) The impact of multiskilling on UK construction manpower, *ICE Management, Procurement and Law*, 161(1), 25-30.
67. Ewart, I.J. and Luck, R. (2012) Portals to the World: Technological extensions to the boundaries of the home, *Interiors: Design, Architecture, Culture* 3(1-2), 7-22.
68. Ewart, I.J. and Luck, R. (2013) Living from Home: Older people looking beyond the house, *Home Cultures*, 10(1), 25-42.
69. Fu, C., Kaya, S., Kagioglou, M. and Aouad, G. (2007) The development of an IFC-based lifecycle costing prototype tool for building construction and maintenance Integrating lifecycle costing to nD modeling, *Construction Innovation Journal*, 7(1), 85-98.
70. Fu, C., Tah, J., Aouad, G., Kagioglou, M. and Zeisel, J. (2007) Space-centred information management approach to improve Cad-based healthcare building design, *IT Con*, 12(61), 61-71.
71. Gaudart J., Cloutman-Green E., Guillas S., D'Arcy N., Hartley J.C., Gant, V. and Klein N. (2013) Healthcare environments and spatial variability of healthcare associated infection risk: cross-sectional surveys, *PLoS One*, 8(9), DOI:10.1371/journal.pone.0076249.
72. Goulding, J., Sexton, M., Zhang, X., Kagioglou, M., Aouad, G. and Barrett, P. (2007) Technology adoption: breaking down barriers using a virtual reality design support tool for hybrid concrete, *Construction Management and Economics*, 25(12), 1239-1250.

73. Gray, C. and Al Bizri, S. (2008) Modelling Trade Contractor Information Production, *Architectural Engineering and Design Management*, 3(1), 39-49.
74. Greasley, K., Bryman, A., Dainty, A.R.J., Price, A.D.F., Naismith, N. and Soetanto, R. (2008) Understanding Empowerment from an Employee Perspective: What does it mean and do they want it?, *Team Performance Management*, 14(1-2).
75. Hanson J. et al. (2007) Lifestyle monitoring as a predictive tool in telecare, *Journal of Telemedicine & Telecare*, 13(1), 26-28.
76. Harty, C. (2010) Implementing Innovation: Designers, Users and Actor-Networks, *Technology Analysis and Strategic Management*, 22(3), 297-316.
77. Harty, C. and Whyte, J. (2010) Emerging hybrid practices in construction design work: the role of mixed media, *ASCE Journal of Construction and Engineering Management*, 136(4), 468-476.
78. Harty, C.F., Goodier, C.I., Soetanto, R., Austin, S.A., Dainty, A.R.J. and Price, A.D.F. (2007) The futures of construction: a critical review of construction futures studies, *Construction Management and Economics*, 25(5), 477-493.
79. Hassanain, M.A., Sedky, A., Adamu, Z.A. and Saif, A. (2010) A Framework for Quality Evaluation of University Housing Facilities, *Journal of Building Appraisal*, 5, 213-221.
80. Henderson, J.R., Ruikar, K.D. and Dainty, A.R.J. (2013) The need to improve double-loop learning and design-construction feedback loops: A survey of industry practice, *Engineering, Construction and Architectural Management*, 20(3), 290-306.
81. Hendy, J. and Barlow, J. (2013) Adoption in practice: the relationship between managerial interpretations of evidence and adoption of an innovation, *Health Policy and Technology*, 2(4), 216-221. DOI: 10.1016/j.hlpt.2013.07.004.
82. Hendy, J. and Barlow, J. (2012) The role of the organizational champion in achieving health system change, *Social Science and Medicine*, 74, 348-355.
83. Hendy, J., Fulop, N., Reeves, B.C., Hutchings, A. and Collin, S. (2007) Implementing the NHS programme for information technology: a qualitative study of progress in acute trusts, *British Medical Journal*, 334, 1360-1368.
84. Hendy, J. and Barlow, J. (2012) The role of the organizational champion in achieving health system change, *Social Science & Medicine*, 74(5), 348-355.
85. Hendy, J. et al. (2012) An organizational analysis of the implementation of telecare and telehealth: The Whole Systems Demonstrator, *BMC Health Services Research* 2012, 12-403. DOI:10.1186/1472-6963-12-403.
86. Hendy, J. and Barlow, J. (2012) The role of the organizational champion in achieving health system change, *Social Science & Medicine*, 74(5), 348-355.
87. Hendy, J., Barlow, J. and Chrysanthaki, T. (2011) Implementing remote care in the UK: an update of progress, *Eurohealth*, 17, 21-23.
88. Hignett, S. and Lu, J. (2009) An investigation of the use of Health Building Notes by UK healthcare building designers, *Applied Ergonomics*, 40, 608-616. DOI:10.1016/j.apergo.2008.04.018.
89. Hignett, S. and Lu, J. (2008) Facility design needs clinical approach, *Health Estate Journal*, 62(6) 36-38.
90. Hignett, S. and Lu, J. (2008) Ensuring bed space is right first time, *Health Estate Journal*, 62(2) 29-31.
91. Hignett, S. and Lu, J. (2008) Need for new design guidance identified, *Health Estate Journal*, 62(1) 35-37.
92. Hignett, S., Lu, J. (2010) Space to care and treat safely in acute hospitals: recommendations from 1866 to 2008, *Applied Ergonomics*, 41(5), 666-673.
93. Hignett, S., Lu, J. and Fray, M. (2010) Two Case Studies Using Mock-Ups for Planning Adult and Neonatal Intensive Care Facilities, *Journal of Healthcare Engineering*, 1(3), 399-414.
94. Hirani S., Beyon, M., Cartwright M., Rixon, L., Doll H., Henderson C., Bardsley M., Steventon A., Knapp M., Bower, P., Sanders C., Hendy, J. and Newman S. (2013), The effect of telecare on the quality of life and psychological well-being of elderly recipients of social care over a 12 month period – the Whole Systems Demonstrator (WSD) cluster randomised trial, *Age and Aging*, 2013 Dec 12, (Epub ahead of print).
95. Holton, I., Glass, J. and Price, A.D.F. (2007) Developing a successful sector sustainability strategy: six lessons from the UK construction products industry, *Corporate Social Responsibility and Environmental Management*, 15(1), 29-42. DOI: 10.1002/csr.135.
96. Hourd, P. and Williams, D. (2006) Success in healthcare technology businesses. Co-ordinating the value milestones of new product introduction, financial stakeholders and business growth, *Innovation, Management, Policy and Practice*, 8(3), 229-247.
97. Howitt P et al. (2012) Technologies for Global Health, *The Lancet Commissions*, 380(9840), 507-535. DOI:10.1016/S0140-6736(12)61127-1.
98. Ibrahim, A. D., Price, A. D. F., Khalfan, M. M. A. and Dainty, A. R. J. (2010) Construction Procurement Strategies of the National Health Services in the UK: A Critical Review, *Journal of Public Procurement*, 10(1), 31-67.
99. Ibrahim, A.D., Price, A.D.F. and Dainty, A.R.J. (2006) The analysis and allocation of risks in public private partnerships in infrastructure projects in Nigeria, *Journal of Financial Management in Property and Construction*, 11(3) 91-104.
100. Ibrahim, A.D., Price, A.D.F. and Dainty, A.R.J. (2006) An analysis of success factors for public-private partnerships in infrastructure projects in Nigeria, *Journal of Construction Procurement*, 12(1), 59-69, ISSN: 1358-9180.
101. Ibrahim, A.D., Price, A.D.F. and Dainty, A.R.J. (2007) An Evaluation of the Practices of, and Barriers to, Continuous Improvement through Learning on NHS LIFT Projects, *Journal of Construction Procurement*, 13(2), 88-98.
102. Ibrahim, A.D., Price, A.D.F. and Dainty, A.R.J. (2009) Evaluation of Key Practices under the Local Improvement Finance Trust (LIFT) initiative for UK healthcare facilities, *Engineering, Construction and Architectural Manage* (16)5, 504- 518.
103. Jayanti, A., Weiriden, A.J., Morris, J., Brenchley, P., Abma, I., Bayer, S., Barlow J. and Mitra, S., (2013) Barriers to successful implementation of care in home haemodialysis (BASIC-HHD):1. Study design, methods and rationale. *BMC Nephrology*, 14-197. DOI:10.1186/1471-2369-14-197
104. Jawad, S., Al-Yassin, A., Herridge, D., La,i W. K. L., Rozario, N. and Hendy. J. (2012) Safeguarding patients against stem cell tourism, *British Journal of General Practice*, 62(597), 269-270.
105. Jin, X., Kagioglou, M. and Aouad, G. (2006) Towards a dynamic healthcare process: From requirements capture to simulation, *Journal of Integrated Design & Process Science*, 10(2), 1-19.
106. Joarder, M. A. R. (2009) A Survey on Daylighting Potentiality in the offices of Dhaka Bangladesh, *Global Built Environment Review (GBER)*, 7(1), 5-22.
107. Joarder, M. A. R., Price, A. D. F. and Mourshed M. M. (2010) Access to Daylight and Outdoor Views: A comparative study for therapeutic daylighting design, *World Health Design*, 3(1), 62-69.
108. Joarder, M.A.R. and Price, A.D.F. (2013) Impact of daylight illumination on reducing patient length of stay in hospital after coronary artery bypass graft surgery, *Lighting Research and Technology*, 45(3), 435-449. DOI: 10.1177/1477153512455940.
109. Joarder, M.A.R. and Price, A.D.F. (2012), Impact of Climate Change on the Constructed Luminous Environment: An Evaluation for the Hospital In-patient Rooms Located in London, *The International Journal of the Constructed Environment*, 2(3), 219-232.
110. Kappia, J.G., Dainty, A.R.J. and Price, A.D.F. (2007) Prioritising career development in relation to recruitment and retention: a trade and craft perspective, *Construction Management and Economics*, 25(3), 239-253.
111. Kearney J. R., Percy, D. F. and Kobbacy, K. A. H. (2011) Modelling preventive maintenance as a decay process for a two-state system, *Ingeniería y Gestión de Mantenimiento*, 74, 20-25.
112. Kern, A., Laguecir, A. and Lorino, P. (2010) An instrumental approach for Key Performance Indicators, *Management and Avenir: Special Issue on Vygotsky*.
113. Khandokar, F., Price, A.D.F., Austin, S.A. and Paranagamage, P. (2009) User-perspective: walkable neighbourhoods, *Journal of Urban Design and Planning*, 162(DP4), 155-158.
114. Kobbacy, K. A. H. and S Vadera, S. (2011) A Survey of AI in Operations Management from 2005 to 2009, *The Journal of Manufacturing Technology Management*, 22(6), 706-733.

115. Kobbacy, K. A. H., Wang, W. and Wang, H. (2011) Towards the development of an intelligent supply contract design system, *The Journal of Manufacturing Technology Management*, 22(6), 788-803.
116. Kobbacy, K.A.H. and Vadera, S. Guest Editors (2011), *The Journal of Manufacturing Technology Management*, Special issue on intelligent management systems in operations, 22(6), 704-830.
117. Koskela, L. and Ballard, G. (2012) Is production outside management?, *Building Research & Information*, 40(6), 724-737.
118. Laguecir, A., Kern, A. and Lorino, P. (2011) Une approche instrumentale des indicateurs de performance, *Management & Avenir*, 42, 111-132.
119. Laryea, S. and Hughes, W. (2009) Commercial reviews in the bidding process of contractors, *Engineering, Construction and Architectural Management*, 16(6), 558-572.
120. Lewis, M. A. and Roehrich, J. K. (2009) Contracts, relationships and integration: Towards a model of the procurement of complex performance, *International Journal of Procurement Management*, 2(2), 125-142.
121. Liyanage, C., Elhag, T., Ballal, T. and Li, Q. (2009) Knowledge communication and translation, *Journal of Knowledge Management*, 13 (3), 118 – 131.
122. Lu, J. and Hignett, S. (2008) Using Task Analysis in healthcare design to improve clinical efficiency, *The Health Environments Research and Design Journal (HERD)*, 2(2), 60-69.
123. Lu, J. and Price, A.D.F. (2011) Dealing with complexity through more robust approaches to the evidence-based design of healthcare facilities, in Lu and Price (Eds), *Health Environments Research and Design Journal (HERD)*, 4(4), 5-7.
124. Lui, K., Nakata, K. and Harty, C. (2010) Pervasive informatics: theory practice and future directions, *Intelligent Buildings* 2(1), 5-19.
125. Mahadkar, S., Mills, G. and Price, A.D.F. (2012) Stakeholder Consultation Practices within Healthcare Infrastructure Planning: Developing a Strategic Asset Management Approach, *Journal of Built Environment Project and Asset Management*, 2(2), 127-145.
126. Malik, D.J. and Shama, G. (2012) Estimating bacterial surface contamination by means of ATP: 20 pence short of a pound, *Journal of Hospital Infection*, 80(4), 354.
127. Malik, D.J., Patel, K.V., Clokie, M.R.J. and Shama, G. (2013) On the difficulties of isolating *Clostridium difficile* from hospital environments, *Journal of Hospital Infection*, 84(2), 181.
128. Malik, D.J. (2013) Assessment of infection risk from environmental contamination using rapid ATP surface measurements, *American Journal of Infection Control*, 41(5), 477.
129. Marshall-Ponting, A., Kobbacy, K. A. H., Sapountzis, S. and Kagioglou, M. (2013) A multi-faceted approach to optimising a complex unplanned healthcare system, *International Journal of Logistics Systems and Management*, 15(2/3), 239- 248. ISSN print: 1742-7967, online: 1742-7975.
130. Martin, G.P., Ward, V., Hendy, J., Rowley, E., Nancarrow, S., Heaton, J., Britten, N., Fielden, S. and Ariss, S. (2011) The challenges of evaluating large-scale, multi-partner programmes: the case of NIHR CLAHRCs, *Evidence & Policy*, 7, 489-509.
131. Mathur, V.N., Price, A.D. and Austin, S.A. (2008) Conceptualizing stakeholder engagement in the context of sustainability and its assessment, *Construction Management & Economics*, 26(6), 601-609.
132. McGrath, K., Hendy, J., Klecun, E. and Young, T. (2008) The vision and reality of 'Connecting for Health': Tensions, opportunities and policy implications of the UK National Programme, *Communications of the Association for Information Systems (CAIS)*, 23(1), <http://aiselaisnet.org/cais/vol23/iss1/>
133. Mills, G.R.W. and Austin, S.A. (2013) Understanding Project Emergence and Temporal Systems: Triggering stakeholder values from value, *Engineering Project Organization Journal* [In Press].
134. Mills, G.R.W., Deka, L., Price, A.D.F., Mahadkar, S., Pantartzis, E. and Sellars, P. (2013), *Critical Infrastructure Risk in Healthcare Trusts in England: Predicting the impact of Trust building portfolio age on the national condition of NHS assets*, *International Journal of Strategic Property Management*.
135. Mourshed, M. and Zhao, Y. (2012) Healthcare providers' perception of design factors related to physical environments in hospitals, *Journal of Environmental Psychology*, 32(4), 362-270.
136. Mourshed, M., Shikder, S. and Price, A.D.F. (2011) Phi-array: A novel method for fitness visualization in evolutionary design optimization, *Advanced Engineering Informatics*, 25(4), 676-687. Available from: [www.sciencedirect.com/science/article/pii/S147403461100053X](http://www.sciencedirect.com/science/article/pii/S147403461100053X)
137. Nazarian M., Price A.D.F. and Demian P. (2014) Design lessons from a hospital ward case study in Iran, *HERD*, 2014
138. Osaji, E.E. and Price, A.D.F. (2013) Integrated Modelling, Simulation and Visualisation (MSV) for Sustainable Built Healing Environments (BHEs), *Journal of the Science Teachers Association of Nigeria (JSTAN)*, 48(1), 8-25.
139. Osaji, E.E. and Price, A.D.F. (2008) Innovation Technology for Integration of Healthcare Infrastructure Planning, Design, and Construction, *Innovation and Research Focus*, Issue 73.
140. Osaji, E.E., Price, A.D.F. and Mourshed, M. (2010) Guest editorial, *Journal of Building Performance Simulation*, Special Issue Optimising Healthcare Building Design and Performance through Modelling, Simulation, and Visualisation (MSV), JBPS, 3(3), 169.
141. Osmani, M., Glass, J. and Price, A.D.F. (2008) Architects perspectives on construction waste minimisation by design, *Waste Management*, 28(7), 1147-1158.
142. Paranagamage, P., Austin, S., Price, A.D.F. and Khandokar, F. (2010) Social Capital in Action in Urban environments: An intersection of theory, research and practice literature, *Journal of Urban Design and Placemaking*, 3(2) 231-252. DOI: 10.1080/17549175.2010.526374
143. Paranagamage, P., Price, A.D.F. and Khandokar, F. (2011) Briefing: Holistic assessment of sustainable urban development, *Urban Design and Planning*, 163(3), 101-104. DOI: 10.1680/udap.2010.163.3.101
144. Pascale F., Achour N., Price A.D.F. and Polverino F. (2014) Evaluation of factors and approaches affecting emergency department space planning, *Facilities* 32(11/12). (In press).
145. Phillips, S., Martin, J., Dainty, A.R.J. and Price, A.D.F. (2007) Uncertainty in best value decision making, *Journal of Financial Management in Property and Construction*, 122, 63-72.
146. Phiri, M. (2013) The impact hospital and architectural health care environments have on patients and staff, *Journal of Business Excellence*, Issue 16 Winter 2013. Available from: [www.clinicalbusinessexcellence.co.uk/](http://www.clinicalbusinessexcellence.co.uk/)
147. Phiri, M. and Chen, B. (2010) The role of health care guidance/ standards and tools in design quality and safety improvement or enhancement of the health care estate or physical environment, *Journal of Civil Engineering & Architecture*, David Publishing Company, ISSN 1934-7359 (Print) ISSN 1934-7367 (Online).
148. Pink, S., Tutt, D., Dainty, A. and Gibb, A. (2010) Ethnographic methodologies for construction research: knowing, practice and interventions, *Building Research & Information*, 38(6), 647-659.
149. Pizzo E. (2010) An estimate of costs and benefits of alternative methods of delivery: an empirical analysis in an Italian hospital, *Value in Health*, 13(7), A384.
150. Pizzo, E., Bracci, E., Vagnoni, E., Wilschut, J. and van Ballegooijen, M. (2010) Cost-effectiveness analysis of a FOBT-based colorectal cancer screening program, *Value in Health*, 13(7), A513.
151. Pizzo, E., Pezzoli, A., Stockbrugger, R., Bracci E., Vagnoni, E. and Gullini, S. (2011) Screenee perception and health-related quality of life in colorectal cancer screening: a review, *Value in Health*, 14(1), 152-159.
152. Pizzo, E., Rayment, M., Thornton, A., Hartney, T., Atkins, M., Jones, R., Sullivan, A. (2012) Cost effectiveness of routine HIV testing in non-traditional settings, *HIV Medicine*, 13, 58.
153. Platten, B., Yates, K. and Kagioglou, M. (2008) Pathways – An innovative approach to the use of participatory art practice in Primary Care, *UNESCO e-journal*. Available from: [www.abp.unimelb.edu.au/unesco/ejournal/](http://www.abp.unimelb.edu.au/unesco/ejournal/)
154. Price, A.D.F. and Ibrahim, A.D. (2007) Emerging issues in the procurement of healthcare facilities in the UK, *Journal of Construction Procurement*, 13(2), 88-98, ISSN: 1358-9180.



155. Raj, S., Hillig, J.B. and Hughes, W. (2009) Responsiveness to change by standard-form contract drafters: A case study of the FIDIC White Book, *International Journal of Law in the Built Environment*, 1(3): 205-220.
156. Rechel, B., Barlow, J., Wright, S. and McKee, M. (2010) Hospital capacity planning: from measuring stocks to modeling flows?, *Bulletin of the WHO*, 88: 632– 636.
157. Rechel, B., Wright, S., Barlow, J. and McKee, M. (In press) Capital in the city: Investing in the hospital of the future, *IT Management*.
158. Roehrich, J.K. and Lewis, M.A. (2010) Towards a model of governance in complex (product-service) inter-organisational systems, *Construction Management and Economics*, 28(11), 1155-1164.
159. Roehrich, J.K. and Lewis, M.A. (2014) Procuring complex performance: Implications for exchange governance complexity, *International Journal of Operations & Production Management*, [In Press].
160. Rooke, J.A., Koskela, L.J. and Kagioglou, M. (2009) Some suggestions for researching emergence and informality, *Construction Management & Economics: Special Issue on Informality and Emergence in Construction*, 27(10), 913-22.
161. Rooke, J.A., Rooke, C.N., Koskela, L.J. and Tzortzopoulos, P. (2010) Using the physical properties of artefacts to manage through-life knowledge flows in the built environment, an initial exploration, *Construction Management and Economics: Special Issue on Objects, Knowledge Sharing and Knowledge Transformation in Projects*, 28(6), 601-613.
162. Rooke, J. and Kagioglou M. (2007) Criteria for evaluating research: the unique adequacy requirement of methods, *Construction Management and Economics*, 25(9), 979-987.
163. Rooke, J., Molloy, E.M., Sinclair, M., Koskela, L., Siriwardena, M., Kagioglou, M. and Siemieniuch, C. (2008) Models and Metaphors: Complexity Theory and Through-Life Management in the Built Environment, *Architectural, Engineering and Design Management*, 4(1), 47-57.
164. Rooke, J.A., Koskela, L.J. and Kagioglou, M. (2012) Lean Healthcare: the success of a toolkit depends also on the people who use the tools, *Annals of Emergency Medicine*, 60(3), 395-396.
165. Sanders C et. AL (2012) Exploring barriers to participation and adoption of telehealth and telecare within the Whole System Demonstrator trial: a qualitative study, *BMC Health Services Research*, 12, 220 doi:10.1186/1472-6963-12-220.
166. Sapountzis, S., Yates, K. and Kagioglou, M. (2008) Realising Benefits for Primary Healthcare Infrastructures, *Facilities Journal, Facilities*, 27(3/4), ISSN:0263- 2772. DOI: <http://dx.doi.org/10.1108/02632770910933116>
167. Saurin, T.A., Rooke, J. and Koskela, L. (2013) A complex systems theory perspective of lean production, *International Journal of Production Research*, 51(19), 5824-5838. DOI:10.1080/00207543.2013.796420.
168. Schweber, L. and Harty, C. (2010) Actors and Objects: A Socio-Technical Networks Approach for Construction Management Research, *Construction Management and Economics* 28(6), 657-674.
169. Shama, G. and Malik, D. J. (2013) The uses and abuses of rapid bioluminescence-based ATP assays, *International Journal of Hygiene and Environmental Health*, 216(2), 115.
170. Shikder, S., Mourshed, M. and Price, A.D.F. (2012) Summertime performance of climate change on multi-occupancy British dwellings, *Open House International*, Special issue on Adapting Buildings to Climate Change, 37(4), 50-60.
171. Shikder, S., Mourshed, M. and Price, A.D.F. (2014) Therapeutic lighting design for the elderly: A review, *Perspectives in Public Health*, 132(6), 282-291. DOI: 10.1177/1757913911422288. Available from: <http://rsh.sagepub.com/content/132/6/282>.
172. Soetanto, R., Glass, J., Dainty, A.R.J. and Price, A.D.F. (2007) Structural frame selection: case studies of hybrid concrete frames, *Building Research and Information*, 35(2), 206-219.
173. Soetanto, R., Price, A.D.F. and Dainty, A.R.J. (2007) Improving management of people in construction, *ICE Journal of Management, Procurement and Law*, 160(1), 7-9.
174. Soetanto, R., Price, A.D.F. and Dainty, A.R.J. (2007) Improving management of people in construction, *Proceedings of the Institution of Civil Engineers: Management, Procurement and Law*, 160(MP1), 7-9.
175. Spyridonidis D. and Calnan, M. (2011) Opening the black box: A study of the implementation of NICE guidelines, *Health Policy*, 102(2-3), 117-25.
176. Spyridonidis, D. and Calnan, M. (2011) Are new forms of professionalism emerging in medicine? The case of the implementation of NICE guidelines, *Health Sociology Review*, 20, 394-409.
177. Spyridonidis, D. and Calnan, M., (2010) Implementing clinical governance policy: NICE, *British Journal of Healthcare Management*, 16, 394-401.
178. Steventon A et al. (2012) Effect of telehealth on use of secondary care and mortality: findings from the Whole System Demonstrator cluster randomised trial, *BMJ* 344. DOI:10.1136/bmj.e3874.
179. Thomson, D. S., Austin, P.S., Mills, G.R.W. and Devine-Wright, H. (2013) Practitioner Understanding of Value in the UK Building Sector, *Engineering, Construction and Architectural Management*, 20, 214-231.
180. Tillmann, P., Tzortzopoulos, P., and Formoso, C.T. (2010) Redefining Healthcare Infrastructure: Moving Toward Integrated Solutions, *Health Environments Research and Design Journal*, 3(2) 84-96.
181. Tillmann, P., Tzortzopoulos, P., Sapountzis, S. and Formoso, C. T. (2010) Gestão de benefícios na etapa de projeto em empreendimentos hospitalares do reino unido (Managing Benefits in the Design of Healthcare Facilities in the UK), *Revista Gestao & Tecnologia de Projetos (Journal of Design management and Technology)*, 5(1),109-132. Available from [www.arquitetura.eesc.usp.br/gestaodeprojetos/](http://www.arquitetura.eesc.usp.br/gestaodeprojetos/)
182. Tucker, D. A., Yeow, P.M. and Viki, G.T. (2013) Communicating during organizational change using social accounts: The importance of trust in management, *Management Communication Quarterly*, 27(2), 184-209.
183. Tutt, D. and Hindmarsh, J. (2011) Reenactments at work: Demonstrating conduct in data sessions, *Research on Language & Social Interaction*, 44(3), 211-236.
184. Tutt, D., Pink, S., Dainty, A. R. J. and Gibb, A. (2013) 'In the air' and below the horizon: migrant workers in UK construction and the practice-based nature of learning and communicating OHS, *Construction Management and Economics*, 31(6) 515-527.
185. Tutt, D., Pink, S., Dainty, A. and Gibb, A. (2013) Building networks to work: an ethnographic study of informal routes into the UK construction industry and pathways for migrant up-skilling. *Construction Management and Economics*, 31(10), 1025-1037. DOI:10.1080/01446193.2013.834066
186. Tzortzopoulos, P., Codinhoto, R., Kagioglou, M., Rooke, J. and Koskela, L. (2009) The gaps between healthcare service and building design: a state of the art review, *Ambiente Construido (Built Environment, Journal from Brazil)*, 9(2), 47-55.
187. Tzortzopoulos, P. and Cooper, R. (2007) Design management from a contractor's perspective: the need for clarity, *Architectural Engineering and Design Management*, 3, 17-28.
188. Tzortzopoulos, P., Cooper, R., Chan, P. and Kagioglou, M. (2006) Clients' activities at the design front-end, *Design Studies*, 27(6), 657-683.
189. Tzortzopoulos, P. and Sexton, M. (2007) Implementation of product development process model in construction companies, *Construction Management and Economics*, 25(11) 1151-1162. Available from: [www.tandfonline.com/doi/full/10.1080/01446190701468851#Uu9euPL\\_s1I](http://www.tandfonline.com/doi/full/10.1080/01446190701468851#Uu9euPL_s1I)
190. Uzun-Jacobson, E. et al. (2012) Addressing the barriers, HSI, 4 October. Available from: [www.hsj.co.uk/resource-centre/best-practice/qipp-resources/addressing-the-barriers/5049413.article](http://www.hsj.co.uk/resource-centre/best-practice/qipp-resources/addressing-the-barriers/5049413.article)
191. Waterson, P., Eason, K., Tutt, D. and Dent, M. (2012) Using HIT to deliver integrated care for the frail elderly in the UK: current barriers and future challenges, *Work: A Journal of Prevention, Assessment & Rehabilitation*, 41(1), 4490-4493.
192. White, P. (2009) Knowing body, knowing other: cultural materials and intensive care, *SOCIOL REV*, 56, 117-137, ISSN:0038-0261.
193. Wojgani, H., Kehsa, C., Cloutman-Green, E., Gray, C., Gant, V., Klein, N. (2012), Hospital door handle design and their contamination with bacteria: a real life observational study. Are we pulling against closed doors?, *PLoS One*, 7(10). DOI:10.1371/journal.pone.0040171.
194. Wright, S., Rechel, B., McKee, M. and Barlow, J (2010) Capital in the city. Investing in the hospital of the future, *Healthcare IT Management*, 5(2), 22-25. .
195. Zhao, Y. and Mourshed, M. (2012) Outpatients' perception on the design of waiting areas in healthcare facilities, *Intelligent Buildings International*, 4(4), 199– 215..



## BOOK CHAPTERS

1. Al-Bizri, S. and Gray, C. (2013) Design Management. In 2nd Edition, Clements-Croome, D. Intelligent Buildings. London: Thomas Telford, 167-196.
2. Barlow, J., Hendy, J. and Chrysanthaki, T. (2012) Scaling-up remote care in the United Kingdom: Lessons from a decade of policy intervention. In Glascock, A. and Kutzik, D. (eds.) Essential Lessons for the Success of Telehomecare - Why It's not Plug and Play. IOS Press.
3. Barlow, J. (2010) Delivering innovation in hospital design: finance, contracts and the institutional context. In Caldwell, N. and Howard, M. (eds.) Procuring Complex Performance: Studies of Innovation in Product-Service Management. London, Routledge, 159-173.
4. Barlow, J., Bayer, S., Curry, R., Hendy, J. and McMahon, L. (2010) From care closer to home to care in the home: the potential impact of telecare on the built environment. In Kagioglou, M. and Tzortzopoulos P (eds.) Improving Healthcare Through The Built Environment. Oxford: Wiley-Blackwell, 131-138.
5. Barlow, J. (2013) Strengthening the spread of innovation in the UK's National Health Service. In Osborne, S. and Brown, L. (eds.) Handbook of Innovation and Change in Public Sector Services. Elgar.
6. Barlow, J., Bayer, S. and Cravo Oliveira, T. (2011) Remote care: Health at home. In Harper, R. (ed) The Connected Home: The Future of Domestic Life. Springer.
7. Barlow, J., Bayer, S., Curry, R. and Hendy, J. (2007) The costs of telecare: from pilots to mainstream implementation. In Curtis, L., and Netten, A. (eds.) Unit Costs of Health and Social Care. Dept. of Health / PSSRU, 9-13.
8. Bayer, S., Bolt, T., Brailsford, S. and Kapsali, M. (in press) The social role of models. In Brailsford S, Churilov L, Dangerfield B (eds.) Discrete Event Simulation and System Dynamics for Management Decision Making. Wiley.
9. Codinhoto, R., Platten, B., Tzortzopoulos, P. and Kagioglou, M. (2010) Supporting Evidence-Based Design. In Kagioglou, M. and Tzortzopoulos, P. (eds.) Improving healthcare through Built Environment Infrastructure, Oxford: Wiley-Blackwell, 151-165.
10. Cooper, R., Boyko, C. and Codinhoto, R. (2009) The Effect of the physical environment on mental wellbeing. In Cooper, C., Goswami, U. and Sahakian, B. J. (eds.) Mental Capital and Wellbeing. Wiley-Blackwell.
11. Erskine, J., Cheng, M., Mills, G., Komma, O. and Kiss, Z.I. (2012) A Quality Framework for Healthcare Infrastructure. In Busse, R. et al., (eds.) Improving quality in European health systems – a comprehensive framework. Berlin : WHO, European Observatory for Health Systems and Policies.
12. Hillman, A., Latimer, J. and White, P. (2009) Accessing Care: Technology and the Management of the Clinic. In Schillmeier, M. and Domènech, M. (Eds.) New Technologies and Emerging Spaces of Care. Surrey: Ashgate.
13. Hughes, W., Kwawu, W. and Hillig, J.B. (2010) Contracts and incentives in the construction sector. In Caldwell, N. and Howard, M. (eds.) Procuring complex performance. Studies of Innovation in Product-Service Management. Oxford: Routledge, 59-77. ISBN 9780415800051.
14. Ibrahim, A.D., Price, A.D.F. and Dainty, A.R.J. (2010) Achieving Continuous Improvement in the UK Local Improvement Finance Trust (LIFT) Initiative. In Kagioglou, M. and Tzortzopoulos, P. (eds.) Improving Healthcare through Built Environment Infrastructure. Oxford: Wiley-Blackwell, 196-212.
15. Kagioglou, M. and Tzortzopoulos, P. (eds.) (2010) Improving healthcare through built environment infrastructure. Blackwell Publishers. ISBN: 9781405158657.
16. Koskela, L., Codinhoto, R., Tzortzopoulos, P. and Kagioglou, M. (2013) The Aristotelian proto-theory of design. In Chakrabarti, A. and Blessing, L. (eds.) An Anthology of Theories and Models of Design. London: Springer.
17. Langford, D. and Hughes, W. (eds.) (2009) Building a Discipline: The Story of Construction Management. Reading: ARCOM.
18. Lewis, M.A. and Roehrich, J.K. (2010) Contracts, relationships and integration: Towards a model of the procurement of complex performance. In Caldwell, N.D. and Howard, M. (eds.) Procuring Complex Performance: Studies of Innovation in Product- Service Management. Oxford: Routledge.
19. Roehrich, J.K., Barlow, J. and Wright, S. (2013) Delivering European healthcare infrastructure through public-private partnerships: The theory and practice of contracting and bundling. In Das, T.K. (ed.) Managing Public-Private Strategic Alliances. Information Age Publishing.
20. Sapountzis, S., Yates, K., Lima, J. and Kagioglou, M. (2010) Benefits realisation: Planning and evaluating healthcare infrastructures and services. In Kagioglou, M. and Tzortzopoulos, P. (eds.) Improving healthcare through Built Environment Infrastructure. Oxford: Wiley-Blackwell, 166-195.
21. Ochieng, E., Moore, D. and Price, A.D.F. (2013) Management of Global Construction Projects. Hampshire, UK: Palgrave Macmillan's Global Academic.
22. Phiri, M. and Chen, B. (2013) Sustainability and Evidence-Based Design in the Healthcare Estate. Springer. Electronic ISBN 978-3-642-39203-0 Print ISBN 978-3-642-39202-3.
23. Phiri, M. (2013) Design indicator tools for evidence-based architectural healthcare design. Routledge, Taylor & Francis Books (Architecture & Engineering).
24. Uzun, E. (2010) Definition and Examples of Continuous-Time Markov Chains. Encyclopedia of Operations Research and Management Science.
25. White, P. (2009) Knowing Body, Knowing Other: cultural materials and intensive care. In Latimer, J. and Schillmeier, M. (eds.) Un/known Bodies. Oxford: The Sociological Review/Blackwell.

## REPORTS

1. Achour, N. (2009) *Resilience of Built Healing Environment*, HaCIRIC BHE Final Study Report, Health and Care Infrastructure Research and Innovation Centre (HaCIRIC), Loughborough University, Loughborough, UK, 119-133.
2. Achour, N., Buxton, D. and Price, A.D.F. (2009) *Resilience of Healthcare Facilities*, Health and Care Infrastructure Research and Innovation Centre (HaCIRIC), Interim Report, September 2009, Loughborough University, Loughborough, UK.
3. Achour, N. and Price, A.D.F. (2011) *Planning for more resilient healthcare in emergencies under increasing risks and decreasing budgets: Preliminary report on the workshop findings and way forward*, Loughborough University, Loughborough, UK.
4. Achour, N. (2011) *Healthcare Resilience Tool, Design and Decision Making to Improve Healthcare Infrastructure*, Loughborough University, Loughborough, UK, 35.
5. Adamu, Z.A. and Cook, M. (2009) *Ventilation, Infection Control and Occupant Wellbeing in Healthcare Buildings, Evidence Based Design of Built Healing Environment*, HaCIRIC BHE Final Study Report, Health and Care Infrastructure Research and Innovation Centre (HaCIRIC), Loughborough University, Loughborough, UK, 53-70.
6. Angele-Halgand, N., Angert A., Campenale, C., Chapman, C.S., Cinquini, L., Doyle, G., Garrot, T., Hansen, A., Hartmann, F., Hinz, V., Kern, A., Laguerre, A., Mateus, C., Perego, P., Quentin, W., Sikkut, R., Tenucci, A. (2013) *International approaches to Clinical Costing*, Commissioned by HFMA and Monitor.
7. Astley, P., Bolgar, B., Mahadkar, S., Mills, G., Price, A.D.F., Raford, N., Soriano, B. and Titidez, O. (2009) *PHI0: Planning Healthcare Infrastructure; Implementing the Next Stage Review Healthcare Infrastructure*, Prince's Foundation for the Built Environment.
8. Astley, P. and Hind, R. (2013) *Strategic Project Prospectus, Medical Respite Centre for Single Homeless accessing Emergency and Urgent Care*, London Pathway, University College London.
9. Astley, P., Hind, R. and Robinson, S. (2013) *Cambridge University NHS Hospitals, Health Building Note Health Building Note (HBN) 15-01: Accident & Emergency, non-prescriptive design guidance utilising systems separation approaches to planning*, Department of Health.
10. Barlow, J. (2006) *Building an evidence base for successful telecare implementation*, Updated report of the Evidence Working Group of the Telecare Policy Collaborative chaired by James Barlow, Care Services Improvement Partnership, London. Available from: [www.scie-socialcareonline.org.uk/profile.asp?guid=60f39639-99c3-4ed6-8e9f-57354b37e3e5](http://www.scie-socialcareonline.org.uk/profile.asp?guid=60f39639-99c3-4ed6-8e9f-57354b37e3e5)
11. Barlow, J. and Burn, J. (2008) *All change please. Putting the best new healthcare ideas into practice*, Policy Exchange, London. [www.policyexchange.org.uk/publications/category/item/all-change-please](http://www.policyexchange.org.uk/publications/category/item/all-change-please)
12. Barlow, J., Köberle-Gaiser, M., Moss, R., Noble, A., Scher, P. and Stow, D. (2009) *Adaptability and innovation in healthcare facilities. Lessons from the past for future developments*, Howard Goodman Fellowship / HaCIRIC. Available from: [www.haciric.org](http://www.haciric.org).
13. Barlow, J. et al. (2012) *Remote Care plc. Developing the capacity of the remote care industry to supply Britain's future needs*, Report for WSD evaluation. Available from: [www.haciric.org](http://www.haciric.org).
14. Barlow, J., Hendy, J., and Tucker, D. (2013) *Managing major service and infrastructure transitions: A comparative study of UK, US and Canadian hospitals*. Available from [www.haciric.org](http://www.haciric.org).
15. Chapman, C. and Kern, A. (2010) *ABC in the NHS*, Chartered Institute of Management Accountants (CIMA) Discussion Paper.
16. Chapman, C. and Kern, A. (2010) *Costing in the NHS: From Reporting to Managing*, Commissioned by CIMA.
17. Codinhoto, R., Kiviniemi, A., Kemmer, S. and Rocha, C. (2011) *BIM Implementation: Manchester Town Hall Complex*, Research Report, The University of Salford, Salford, UK.
18. Domingo, N. (2009) *Reducing Construction Waste in Healthcare Facilities: A Project Lifecycle Approach*, Literature Review Report, Loughborough University, Loughborough, UK.
19. Eason, K., Dent, M., Waterson, P., Tutt, D., Hurd, P. and Thornett, A. (2012) *Getting the benefit from electronic patient information that crosses organisational boundaries*, Final report, NIHR Service Delivery and Organisation programme.
20. *Built Healing Environment Final Report*, Health and Care Infrastructure Research and Innovation Centre (HaCIRIC), Loughborough University, Loughborough, UK.
21. Hignett, S., Lu, J. and Morgan, K. (2008) *Empirical review of NHS Estates Ergonomic Drawings*, Department of Health Estates and Facilities Management Research Report B(02)13, The Stationery Office, London.
22. Hobson H et al. (2008) *Health Technology Scenarios and Implications for Spectrum* (Report 1, Health Socio-Economic Study, Report 2 Technology Scenarios Development), Ofcom, London. Available from: <http://stakeholders.ofcom.org.uk/market-data-research/technology-research/research/sector-studies/>
23. Ison, S., Mills, G., Price, A. D. F., Quddus, M. A., Titidez O. and Adamu Z. (2009) *Loughborough and Hinckley Hospitals: Travel and Access Report*, Loughborough University, Loughborough, UK.
24. Joarder, M. A. R. (2010) *Implementation of Therapeutic Daylight on Architectural Design of Hospital Buildings to Accelerate Clinical Recovery*, PhD Second Year Report, Loughborough University, Loughborough, UK.
25. Joarder, M. A. R., Mourshed, M. M. and Price, A. D. F. (2009) *Impact of Daylight on Patient's Health, Evidence Based Design of Built Healing Environment*, HaCIRIC BHE Final Study Report, Health and Care Infrastructure Research and Innovation Centre (HaCIRIC), Loughborough University, Loughborough, UK, 71-86.
26. Joarder, M.A.R., Price, A. D. F. and Mourshed M.M. (2009) *Direct and Indirect Impact of Daylight on Human and Evidences of Health Outcomes*, HaCIRIC Literature Review, UK, September, 1-15.
27. Kemmer, S. and Koskela, L. (2012) *Developing a lean model for production management of refurbishment projects*, Research Report, The University of Salford, Salford, UK.
28. Kemmer, S.L., Koskela, L., and Sapountzis, S. (2011) *Best Practices in Design Management*, HaCIRIC, April, The University of Salford, Salford, UK.
29. Khandokar, F., Ryley, T.J. Ison, S. and Price, A.D.F. (2013) *The NHS Acute Trusts' perspectives on hospital travel plans in England: A survey summary report for the practitioners*, Loughborough University, Loughborough, UK.
30. Lu, J. and Zhao, Y. (2009) *Health Space Design, Evidence Based Design of Built Healing Environment*, HaCIRIC BHE Final Study Report, Health and Care Infrastructure Research and Innovation Centre (HaCIRIC), Loughborough University, Loughborough, UK, 32-52.
31. Mahadkar, S., Mills, G. R. and Price, A. D. F. (2009) *Master Planning and Integrated Service Provision within the Healthcare Sector: Literature Review*, HaCIRIC Informing Study Report, Loughborough University, Loughborough, UK.
32. Mahadkar, S., Mills, G.R. and Price, A.D.F. (2012) *Service Led Infrastructure Management (SLIM) Road Map Development Workshop: (Estates Focus)*, Collaborative Report with Community Health Partnerships and Loughborough University, 25 January 2012, Nottingham.
33. Mahadkar, S., Mills, G.R., Erskine, J. and Price, A.D.F. (2010) *EUHPN Workshop, One Problem Many Solutions: how to make healthcare infrastructure deliver for society*, Loughborough University, UK. Available from: [www.haciric.com/static/pdf/publications/EuHPN%20WorkshopReport\\_Final\\_%20nov%202010pdf.pdf](http://www.haciric.com/static/pdf/publications/EuHPN%20WorkshopReport_Final_%20nov%202010pdf.pdf)
34. Mills, G. R. W., Mahadkar, S., Ricks, E. and Price, A. D. F. (2011) *Patient experience in adult NHS services: improving the experience of care for people using adult NHS services- FULL VERSION*, Report on Guidance and Quality Standard NICE xConsultation, Loughborough University, Loughborough, UK.
35. Mills, G. R., Astley, B., Raford, N. and Oklak, A. (2010) *Planning Healthcare Infrastructure: Final Report*, The Prince's Foundation and Department of Health, London.

36. Mills, G. R., Mahadkar, S. and Price, A. D. F. (2009) *Stakeholder Consultation Review*, Research Progress Report, HaCIRIC Third Year Review, Loughborough University, Loughborough, UK.
37. Mills, G., Mahadkar, S., Price, A.D.F. (2011) *Review of the Evidence for the Contribution of Healthcare Infrastructure Investment to Health Gain, with Particular Reference to Hospitals (HIIHG)*, Discussion and final edits, European Investment Bank with Steve Wright and Barrie Dowsdell, European Centre for Health Assets and Architecture.
38. Mills, G.R. and Mahadkar, S. (2011) *Healthcare Infrastructure Planning: Strategic Asset Management and Integrated Service Provision within the healthcare sector*, Design and Decision Making to Improve Healthcare Infrastructure, September 2011, Loughborough University, Loughborough, UK, 27-33. Available from: [www.haciric.org/static/pdf/publications/HaCIRICLoughboroughRpt-Design\\_and\\_Decision\\_Making22.9.11.pdf](http://www.haciric.org/static/pdf/publications/HaCIRICLoughboroughRpt-Design_and_Decision_Making22.9.11.pdf)
39. Osaji, E.E. and Price, A.D.F. (eds.), Norwood, A., Lu, J., Ding, C., Guerrero, A. and Wahid, B. (2009) *Integrating Digital Tools in Built Environment and Healthcare Sectors for Improved Hospital Room Performance*, CECA-HaCIRIC PoC Final Study Report, Loughborough University, Loughborough, UK.
40. Osaji, E.E. and Price, A.D.F. (2010) *Improving Healthcare Building Thermal Performance through Parametric Modelling, and Environmental Simulation and Design*, Loughborough University, Loughborough, UK.
41. Paranagamage, P., Khandokar, F., Price, A. D. F. and Austin, S. A. (2010) *The impacts of urban design in social capital: A case study on the Braunstone New Deal for Communities Area*, Loughborough University, Loughborough, UK.
42. Patel, K. V. (2009) *Investigation into the Presence of Clostridium difficile in Healthcare Environments*, PhD 1st Year Report, University of Leicester, Leicester, UK.
43. Phiri, M. (2013) *Tameside General Hospital POE for Balfour Beatty Capital Projects*, School of Architecture, The University of Sheffield, Sheffield, UK.
44. Phiri, M. and Lawson, B.R. (2009) *Disseminating good practice (DGP): developing an exemplar layer for AEDET Evolution and ASPECT design evaluation tools*, Department of Health R&D Report B(04)03, School of Architecture, The University of Sheffield, Sheffield, UK. Available from: <https://publications.spaceforhealth.nhs.uk/>.
45. Pikas, E., Koskela, L., Dave, B., Sapountzis, S. and Owen, R. (2011) *Overview of Building Information Modelling in healthcare projects*, HaCIRIC, The University of Salford, Salford, UK.
46. Priya, K.P.L. (2009) *Sensitive Design, Evidence Based Design of Built Healing Environment*, HaCIRIC BHE Final Study Report, Health and Care Infrastructure Research and Innovation Centre (HaCIRIC), Loughborough University, Loughborough, UK, 22-31.
47. Ricks, R. (2010) Internal review for Department of Health on standardisation of taxonomy.
48. Sapountzis, S., Lima, J., Yates, K. and Kagioglou, M. (2009) *BeReal, Benefits Realisation for Healthcare*, 2009 progress report, HaCIRIC, The University of Salford, Salford, UK.
49. Shikder, S., Mourshed, M. and Price, A. D. F. (2009) *Evidence Based Design of Elderly Lighting, Evidence Based Design of Built Healing Environment*, HaCIRIC BHE Final Study Report, Health and Care Infrastructure Research and Innovation Centre (HaCIRIC), Loughborough University, Loughborough, UK, 87-100.
50. Shikder, S. (2010) *Optimisation of luminous environments of healthcare spaces, PhD first year progress report*, Department of Civil and Building Engineering, Loughborough University, Loughborough, UK.
51. Shikder, S. and Price, A.D.F. (2011) *Design and decision making to improve healthcare infrastructure*, School of Civil and Building Engineering, Loughborough University, Loughborough, UK, ISBN 978-1-897911-40-2.
52. Shikder, S., Price, A.D.F., Mourshed, M. (2009) *Evidence based design of elderly lighting: A systematic review*, Built Healing Environment (BHE) Report, Submitted to Engineering and Physical Sciences Research Council (EPSRC) Panel Review, University of Reading, September, Reading, UK.
53. Spyridonidis, D. and Calnan, M. (2009) *Understanding the implementation process: the case of NICE guidelines*, NICE, November 2009.
54. Tezel, A., Koskela, L. and Tzortzopoulos, P. (2009) *Visual Management in Construction – Case study report*, SCRI, The University of Salford, Salford, UK.
55. Tutt, D., Dainty, A., Gibb, A. and Pink, S. (2011) *Migrant Construction Workers and Health and Safety Communication*, Construction Skills Report. King's Lynn, Norfolk. Available from: [www.cskills.org/uploads/migrant-construction-workers-health-safety-communication\\_tcm17-25018.pdf](http://www.cskills.org/uploads/migrant-construction-workers-health-safety-communication_tcm17-25018.pdf).
56. Yates-Bolton, N., Yates, K., Williamson, T., Newton, R. and Codinhoto, R. (2012) *Improving Hospital Environments for People with Dementia*, University of Salford, Salford, UK.
57. Zhang, C. (2009) *Mitigation of Acoustic Impact within healthcare Facilities, Evidence Based Design of Built Healing Environment*, HaCIRIC BHE Final Study Report, Health and Care Infrastructure Research and Innovation Centre (HaCIRIC), Loughborough University, Loughborough, UK, 87-100.

# Appendix 3 - Collaborators and Partners

Excluding over 30 project collaborators who wished to remain anonymous.

1. 3M Microbiology
2. Activeplan Solutions Ltd
3. Adept Management Limited
4. Alder Hey Children's NHS Foundation Trust
5. Alexandra House
6. Alfred McAlpine
7. ArcHealth
8. Architects for Health (AfH)
9. Army
10. Asta Development Plc
11. Aston Business School
12. Balfour Beatty
13. Balfour Beatty plc, Manchester Hospitals
14. Barts and The Royal London NHS Trust
15. BBCAP
16. Bedford Hospital NHS Trust
17. Bentley Systems
18. Berkshire Healthcare NHS Foundation Trust
19. Berkshire Shared Services
20. Betsi Cadwaladr University Health Board
21. BRAHMS LIFT
22. Brighton and East Sussex University Hospital NHS Trust
23. British Council PMI2 Connect Partnership Development Grant
24. British Red Cross
25. BT
26. Buckinghamshire Hospitals NHS Trust
27. Building Design Partnership (BDP)
28. Building Information Warehouse
29. BWB (Integrated Engineering and Environmental Consultants)
30. BWB Consulting
31. CABE
32. Cambridge NHS Foundation Trust Hospitals
33. Capita Architects
34. Cardionetics
35. Care Services Improvement Partnership
36. Careline UK Ltd & Appello Telehealth
37. Catalyst
38. Centre for Health Assets Australia
39. Centre of Excellence in Customised Assembly (CECA) Proof of Concept (PoC)
40. CEP International Ltd
41. Chalmers University of Technology
42. Charnwood Neighbourhood Housing
- Comment [JB1]: ??? check what this was
43. Chesterfield Royal Hospital NHS Foundation Trust
44. University College London NHS Foundation Trust Hospital
45. CHKS (Health Quality Service) UK
46. Christies Hospital Development
47. COI
48. Community Health Partnerships
49. Complexity Solutions
50. Construction Industry Solutions
51. Cornwall County Council
52. Coxa Hospital, Tampere, Finland
53. CPMG Architects
54. Croydon County Council
55. Croydon PCT
56. Davis Langdon
57. Defra
58. Department of Creative Arts, University of Lagos, Nigeria
59. Department of Health
60. Derby City NHS
61. Derby Hospitals NHS Foundation Trust
62. Design and Health
63. DHSSPS Health Estates
64. Division of Construction Engineering and Management, Purdue University, USA
65. Docobo Ltd
66. Durham County Council
67. Durham PCT
68. East & Coastal Kent PCT
69. ECHAA (European Centre for Health Assets and Architecture)
70. Editor Partnerships Bulletin
71. Envision Centre, Purdue University
72. Fukui Institute of Technology, Japan
73. Garanti Bank HQ Occupational Health Department
74. Green Prison
75. Greenwich PCT
76. GVA Grimley Ltd
77. Halcrow
78. Halcrow Yolles
79. Hamad Medical Corporation
80. Harvard Medical School, Division of Clinical Informatics
81. Health Facilities Scotland
82. Healthcare Partnering
83. Heatherwood & Wrexham Park Hospitals NHS Foundation Trust
84. Henley Business School
85. HEPSU
86. HM Treasury
87. HOK Architects
88. HOK Design
89. HOK, USA
90. Home Office
91. HUDU (London Healthy Urban Development Unit)
92. Hull and East Yorkshire Hospitals NHS Trust
93. IBM Maximo
94. Institute of Child Health UCL
95. Integra
96. Intelligent Space Atkins
97. Israel Strategic Initiatives
98. Istanbul Government
99. Jane Wernick Associates
100. Kanazawa University, Japan
101. Kent County Council- Adult Social Services
102. KPMG
103. Leicester City Council
104. Leicester City Primary Care Trust
105. Leicester, Leicestershire and Rutland Healthcare Trust
106. Leicestershire County and Rutland PCT
107. Leicestershire County Council
108. Leicestershire County Council Adults and Communities Dept
109. Leicestershire Partnership NHS Trust
110. LIFT Council
111. Lincoln County Council
112. Lincoln PCT

113. Liverpool PCT
114. LLR East Leicester PCT Cluster
115. London Borough of Greenwich
116. London Borough of Newham
117. MAAP Architects
118. Mace Limited
119. Maidstone and Tunbridge Wells NHS Trust
120. Manchester City Council
121. Manchester Joint Health Unit
122. Manchester Royal Infirmary
123. Massachusetts Institute of Technology, Engineering Systems Division
124. MaST Lift Co
125. MedStar Institute for Innovation
126. Mersey Care
127. Mid-America Earthquake Center, Illinois University
128. Milton Keynes.South Midlands (MKSM)
129. MJ Medical, UK
130. MoH Bakirkoy Dr. Sadi Konuk Research and Training Hospital
131. MR1 Consulting
132. National Audit Office
133. National Cheng Kung University, Taiwan
134. NEP
135. Newham PCT
136. NHS Cornwall and Isles of Scilly
137. NHS Cumbria
138. NHS East Midlands
139. NHS Estates
140. NHS Leicestershire County & Rutland PCT
141. NHS London
142. NHS MaST Lift Partnership
143. NHS Salford
144. NHS Scotland
145. NHS South East Coast
146. Nightingale Associates
147. NIHR CLAHRC for North West London
148. Norfolk County Council
149. Norfolk PCT
150. North Bristol NHS Trust
151. North East Cluster PCT, Colchester
152. North Middlesex University Hospital NHS Trust
153. North-East and Southern Region Maternity Care Group
154. Northumbria University
155. Nottingham City Council
156. Nottingham University Hospitals NHS Trust
157. Nuffield Trust
158. P21
159. P+HS Architects
160. Paragon Simulation
161. Parallel Interactive Media
162. Philips Healthcare
163. Pozzoni LLP
164. Production Modelling Limited
165. Project Co
166. Queen Elizabeth Hospital NHS Trust
167. Queen Mary's Hospital NHS Trust
168. Ribera Salud, Valencia, Spain
169. Royal Berkshire Hospital NHS Trust
170. Rutland and University Hospital Leicester
171. Salford Primary Care Trust
172. Sandwell and West Birmingham Hospitals NHS Trust
173. Sandwell County Council
174. Sandwell PCT
175. School of Health Sciences, Purdue University, USA
176. Scottish Government
177. Scottish National Stroke Audit
178. SHA North West
179. Simulation and Visual Analytics
180. SINTEF Health Research
181. Skanska Construction
182. Skanska Infrastructure Development
183. Skanska Technology
184. Skanska UK
185. Solcom Limited
186. Solent Healthcare Southampton PCT
187. South East London SHA
188. Square Hospitals Ltd
189. St. Bartholomew's and the Royal London Charitable Foundation
190. Stockport PCT
191. Surrey County Council
192. Surrey PCT
193. Technology Strategy Board
194. Telehealth Solutions
195. The Architecta Practice
196. The Big Life Company
197. The Eric Wright Group of Companies
198. The Intelligent Building Institute, Huazhong University of Science and Technology, China
199. The Prince's Foundation
200. The Rogosin Institute
201. The Royal Wolverhampton Hospitals NHS Trust
202. The Salvation Army
203. Thinking different about dementia
204. Tribal Group
205. Tunstall Healthcare (UK) Ltd
206. Turkish National Medical Rescue Team
207. TWI Ltd
208. UHL
209. University Hospitals of Leicester NHS Trust
210. University of Aberdeen
211. University of Dundee
212. University of Edinburgh
213. University of Leeds
214. University of Liverpool
215. University of Naples "Federico II"
216. Unlimited Potential
217. Vancouver Island Health Authority (VIHA)
218. Virtua Health
219. Viterion TeleHealthcare, A Business of Bayer HealthCare
220. VTT, Finland
221. Wates Group
222. Welsh Health Estates
223. West Herts Hospital NHS Trust
224. West Kent PCT
225. West Sussex PCT
226. Willmott Dixon Construction
227. World Agency of Planetary Monitoring & Earthquake Risk Reduction (WAPMERR)
228. WS Atkins plc
229. York Teaching Hospital NHS Foundation Trust
230. YRM Architects

## PRINCIPAL RESEARCH PROJECTS

### *Better decision making*

- A refurbishment framework with an emphasis on energy consumption of existing healthcare facilities
- An approach to stakeholder consultation and engagement for use within estates planning strategies
- An evidence based investment appraisal process to be used within business case development
- An integrated approach to the design of high quality healthcare space and flexible layouts using Modelling, Simulation and Visualisation (MSV)
- Benefits Realisation
- An evidence and model-supported approach to Strategic Asset Management
- FPS Design Methodology: Future-Proofing Scenarios in Healthcare Conceptual Design Using BIM
- Guidelines for the use of analytical tools more effective in healthcare planning processes
- Modelling Complex Sustainable Urban Environments for 2050
- Modelling the Effects of Ubiquitous Monitoring on Staff and Patient Behaviour in Healthcare
- MSV: Integrated programme on the application of modelling, simulation and visualisation to the delivery of enhanced performance and value in healthcare facilities
- MSV1: Theoretical perspectives on performance indicators, parameters and modelling approaches to be considered during the design of healthcare facilities
- Open Planning for Healthcare Infrastructure (OPHI), with Emergency and Urgent Care case studies
- Optimising future unplanned urgent healthcare through the use of simulation and modelling
- Quantifying the Benefits of Healthcare Infrastructure Development
- Reducing Construction Waste in Healthcare facilities: A Project Lifecycle Approach
- Resilience of healthcare delivery systems
- Strategic Asset Management and Integrated Service Provision within the Healthcare Sector
- The Design of Sustainable Healthcare Infrastructure: Improving Resilience, Energy and Waste Management
- The Value of Department of Health Estates-Related Standards and Guidance
- Use of Modelling Tools

### *Home not hospital*

- Assessing Transport Implications of Healthcare Facility Reconfiguration using GIS
- Implementation and impact of telecare and telehealth – the Whole System Demonstrator evaluation
- Innovation in stroke care delivery
- Innovations in renal care: BASIC-HHD: BARRiers to Successful Implementation of Care in Home HaemoDialysis

### *Safer patients*

- Effects of the built environment on health
- Impact of Daylight on Occupants' Wellbeing in Care Home Environments
- Incorporation of Therapeutic Effect of Daylight in the Architectural Design of In-patient Rooms to Reduce Patient Length of Stay (LoS) in Hospitals
- MSV2: Decision support system through modelling and simulation to optimise lighting design of healthcare spaces
- MSV3: Monitoring indoor environmental parameters to investigate from health impacts
- MSV4: CFD based evaluation method to improve natural ventilation, environmental performance and maintain health without harm in healthcare spaces
- Healthcare facilities: The environment and users' behaviour, and how these relate to the acquisition of hospital acquired infection
- Objective assessment of hospital ward cleaning using hygiene surveillance and continuous improvement process tools
- The feasibility of natural ventilation in healthcare buildings
- The Innovative Design of Well-Performing Built Healing Environments

### *Smarter purchasing*

- Adaptability and Innovation in Healthcare Facilities
- Demand driven innovation: European Structural Fund supported healthcare projects
- Embedding Patient-level Information and costing Systems in the Health System: Implementing and Using PLICS
- European Healthcare PPPs

### *Managing change and innovation*

- An investigation into the socio-economic, psychological and situational determinants for changing travel behaviour of the NHS hospital staff in the context of travel plans
- An organisational analysis of North West London Collaboration for Leadership in Applied Health Research and Care (CLAHRC)
- Design for Flexibility and Change within health service providers
- The role of evidence in remote care adoption decisions care
- Managing major service and infrastructure transitions: A comparative study of UK, US and Canadian hospitals
- MSV5: The implementation and use of BIM tools and processes in the design and construction of two major UK hospitals
- Optimisation of healthcare facility spatial layout
- Unscheduled care as a complex system





## HaCIRIC Partners



**Imperial College  
London**



**Loughborough  
University**

**University of  
Salford**  
MANCHESTER

For further information please contact:

**Professor James Barlow**

Imperial College Business School  
South Kensington Campus  
London SW7 2AZ

**E:** [j.barlow@imperial.ac.uk](mailto:j.barlow@imperial.ac.uk)