Institution: University of Cambridge

Unit of Assessment: UoA16

Title of case study: Low-energy design strategies for healthcare buildings in a changing climate

1. Summary of the impact (indicative maximum 100 words) (79)

Research conducted by Professor Short in the use of natural ventilation and passive cooling in non-domestic buildings is altering policies and plans in the refurbishment of existing healthcare buildings and in new-build for acute and primary care, both within and outside the UK. Moreover, the massive demolition and replacement of healthcare building stock, presumed to be required to simultaneously adapt to the increased ambient temperatures due to climate change and mitigate carbon emissions through improved energy efficiency, has been shown to be unnecessary.

2. Underpinning research (indicative maximum 500 words)

Professor Alan Short of the Department of Architecture (at Cambridge throughout the REF period) and colleagues, latterly including Dr Alistair Fair (Postdoctoral Research Fellow 2009-2012, Leverhulme Early Career Research Fellow from 2012) have conducted research on low-energy strategies for ventilation and cooling of non-domestic buildings for over 20 years. Most recently they have examined the additional complexities that arise in buildings for healthcare, such as resilience in heatwaves, prodigious internal heat gains, vulnerable occupants and airborne cross-infection concerns.

The initial work undertaken by Short and colleagues in natural stack ventilation and passive cooling included designs for Farsons' Brewery Process Block Malta (completed 1990), which won first prize in *Architecture Today*'s High Architecture, Low Energy Awards 1992, and was a finalist in the Design Museum's Design Sense Award competition 1999; the Queens Building at De Montfort University (1993), awarded Green Building of the Year 1995 by *The Independent*; and the 110,000ft^2 Lanchester Library and Learning Resource Centre for Coventry University (2000), thought to be the first modern naturally conditioned deep plan building in the world, [1]

Short and his team then evolved the approach further to deliver cooling benefit within the London Urban Heat Island by the introduction of Passive Downdraught Cooling (PDC). This low-energy technique distributes pre-cooled air into the building without mechanical fan assistance, extending its range. The underlying principles of the technique were explored using physical models, and the anticipated performance predicted using thermal modelling.[1] These ideas were then applied in the design and construction of the UCL School of Slavonic and East European Studies (2006), believed to be the first large-scale application of PDC, and an international competition winner in 2003. A significant extension of these ideas for use in a continental climate was the incorporation of a breathing double envelope, with modelling undertaken for Chicago [6] and Beijing.

The UK Department of Health (DH) first became interested in Short's work through the publicity surrounding Coventry University Library. The DH Director of Estates and Facilities and DH Chief Architect asked Short if this work could provide a template for a radically different very low-energy acute hospital. In addition, in 2001, Short won the Braunstone Health and Social Care Centre competition for an innovative 40,000 ft^2 integrated centre in Leicester, funded through the New Deal for Communities, to house seven clinical and social services. The building – passively pre-cooled and pre-warmed by a below-ground labyrinth – became a SHINE Learning Network for Sustainable Healthcare Buildings exemplar case study. Interaction with the National Institute for Health Research (NIHR) then led to a series of further projects.

One such project considered existing hospital buildings typical of those operated by four NHS Trusts. The buildings were monitored, and current performance simulated using dynamic thermal models calibrated against the measured data; future performance was also simulated against the appropriate UKCIP 09 predictive climate base for 2030, 2050 and 2080. Most were found to be significantly vulnerable to summer overheating. Short and his colleagues proposed adaptive

cooling and ventilation refurbishment options to increase resilience, and predicted relative performance against existing internal conditions, energy demands and CO_2 emissions. For example, a detailed study of a representative late 1960s tower [2] showed that the building could achieve good resilience to overheating until 2080 with relatively non-invasive and energy-saving modifications and, surprisingly, that there would be significant mitigation co-benefits. Similar conclusions arose from work on mid-rise 1970s ward blocks.[3]

Furthermore, a similar study of a 1920s traditional heavyweight masonry block revealed the unsuspectedly significant resilience of cross-vented open 'Nightingale' wards.[4] This study demonstrated that significant resilience to overheating in the face of changing climate – and also energy savings – could be achieved by light-touch measures. When the communal bed layout of Nightingale wards led to this type being condemned by then Under-Secretary of State Hazel Blears, Short and his team investigated various reconfigurations of the Nightingale interior (in the DeDeRHECC project). They demonstrated that care closer to present care models can be delivered, recovering the innate resilience of type (i.e. zig-zag bedspace layout option dubbed the 'Business Class' option by Cabinet Office 2012).

Short and colleagues also investigated the application of the underpinning ideas about passive cooling and natural ventilation to new build hospitals, and found them equally effective.[5]

Throughout these collaborations, Short as PI researched the DH and NHS Trust context; digitally reconstructed the individual NHS buildings (both as built and as existing); led the interface with the four NHS Trusts and DH; designed all options for new build and refurbishment adaptations. Lomas (De Montfort and Loughborough) led on thermal data collection and modelling. Cath Noakes (Leeds) led on the infection control aspects of adaptation designs. Clarkson (Cambridge, Engineering) examined user health worker/patient/building interaction.

3. References to the research (indicative maximum of six references)

[1] Short, C.A., Lomas K.J., Woods, A. (2004) '*Design strategy for low-energy ventilation and cooling within an urban heat island'*, Building Research and Information, 32 (3), May-June, pp. 187-206. DOI:10.1080/09613210410001679875

[2] Short, C.A., Lomas, K.J., Renganathan, G., Fair, A.J. (2012) '*Building resilience to overheating into 1960's UK hospital buildings within the constraint of the national carbon reduction target: Adaptive strategies'*, Building and Environment, 55, September, pp. 73-95. DOI:10.1016/j.buildenv.2012.02.031

[3] Short, C.A, Cook, M., Cropper, P.C., Al-Maiyah, S. (2010) *'Low-energy refurbishment strategies for health buildings'*, Journal of Building Performance Simulation, 3 (3), February, pp. 197-216. DOI: 10.1080/19401490903318218

[4] Lomas, K.J., Giridharan, R., Short, C.A., Fair, A.J. (2012) '*Resilience of 'Nightingale' hospital wards in a changing climate',* Building Services Engineering Research and Technology, 33 (1), pp. 81-103. DOI**:** 10.1177/0143624411432012

[5] Short C.A., Al-Maiyah S. (2009) '*Design Strategy for low-energy ventilation and cooling of hospitals'*, Building Research and Information, 37 (3), pp.1-29.doi: 10.1080/09613210902885156

[6] Short, C.A., Lomas, K. (2007) *'Exploiting a hybrid environmental design strategy in a US continental climate',* Building Research and Information, 35 (2), pp. 119-143. DOI:10.1080/09613210600852789

Research Grants with Prof Short as Principal Investigator:

- 2007-2009: *Design Strategy for low-energy ventilation and cooling of health buildings*, National Institute for Health Research (NIHR), £265k, with BP Institute Cambridge, IESD Leicester, and Davis Langdon
- 2009 onward: *Design and Delivery of Robust Hospital Environments in a Changing Climate (DeDeRHECC),* EPSRC and Dept of Health, £1.05M, with Loughborough University, Open University, Leeds University, and University of Cambridge Engineering Design Centre
- 2009 onward: *Watford Acute Hospital: Public Sector Comparator,* NIHR, £184k

4. Details of the impact (indicative maximum 750 words)

This research has been widely disseminated in the healthcare and architectural community. *Design strategy for the low-energy ventilation and cooling of health buildings* [1] received the RIBA President's Commendation for 'Outstanding University-based Research' 2009 with the following citation: *"Its originality lies in the adaptation and development of existing knowledge to meet the varied and demanding requirements of large healthcare buildings. The work is highly significant, addressing strategies to meet the very demanding energy and carbon reduction targets set for the healthcare sector."* [7]

The work has demonstrated to the NHS, and to other healthcare providers worldwide (i.e. Kaiser Permanente USA, 3DiFM India, SKANSKA Europe, Mercy Health Australia), that very substantial energy savings are available through design before the application of renewable technologies. Moreover, demonstrating the value in the existing building stock – particularly heavier masonry pre-1945 buildings (such as Nightingale wards), theoretically destined to be decommissioned – has helped to avoid unnecessary demolition and rebuilding costs.

The NHS's Acting Director of the Estates & Facilities Policy Division comments: *"This valuable research project ... demonstrated that the existing estate is capable of being sustainably improved to achieve levels of ventilation and cooling which will extend the estates functional suitability for the foreseeable future… Cambridge University's research [is] at the heart of government policy on making the country resilient to climate change."* [8]

The former Director of Estates for Bradford Teaching Hospitals – where the Royal Infirmary revised its position on Nightingales – comments: "*As a result of the DeDeRHECC findings, it is very reassuring to know that Nightingale wards for instance, will be thermally resilient to 2080. … Of particular interest is how these wards might be used for geriatric care, the patient group most at risk from overheating. …I truly believe this work is of international significance."* [12]

The CEO of Great Ormond Street Hospital for Children – and former CEO of the West Herts NHS Trust – comments on the redevelopment of Watford General Hospital: *"This became the first NHS project to deliberately factor in climate change implications… Short's team are now included in the client team as advisors with whom successful tenderers would be expect to consult... In fact the Pro-Cure 21+ High Level Information Pack – WHHT Transforms states, p 17, 'The Trust is committed to developing a sustainable hospital and is working with Professor Alan Short … to bring forward a hospital with very high levels of natural ventilation.'"* [10]

(NHS ProCure 21+ is a six-year framework programme, 2010-16, being run by the UK Department of Health to procure publicly funded capital schemes for England's National Health Service.)

The work is also referred to in DEFRA's "Adapting to climate change: national adaptation programme", [13].

Outside the UK, healthcare consortium Kaiser Permanente has used Short's work to change regulation in the United States. Its Chief Design Engineer comments: *"Regulation in the US currently prohibits natural ventilation. Several advocates have challenged that precedent in 2013. The DeDeRHECC papers were influential references in this effort… The result: design engineers in the US may now choose natural ventilation in non-patient and common areas of a hospital."* [11]

Short's work has also been taken up by Skanska, a major infrastructure developer, whose Head of Sustainability comments: *"Thanks to you Skanska has been very well informed of leading edge thinking and practice. We have used this to help formulate our approach to hospital developments, particularly in the UK, and also in Sweden and the US. This work included the New Karolinska Hospital in Solna which has you know has some impressive green credentials …"* [9] Most recently, Short's research team has joined Skanka's design team for their bid for the new Papworth Hospital project, advising on passive and assisted ventilation, solar control, natural daylighting and

building orientation [9]. The winning bid has not yet been announced.
Dissemination of Short's research was also supported via a 30-minute broadcast-quality project film *Robust Hospitals in a Changing Climate* [14], released in April 2013, which was nominated for (in the assessment period) and won (out of period) the 2013 tve Global Sustainability Film Award held at BAFTA. The film has been widely viewed, but its most tangible impact is perhaps the new collaboration between Short and the Indian Ministry of Health and Family Welfare. The Managing Director of 3DiFM comments: *"3DiFM is working very closely with Prof Chandrashekhar, the Chief Architect to the Govt. of India's Department of Health and Family Welfare. We have introduced Prof Chandrashekhar to Prof Short and having reviewed the DeDeRHECC film, he is very keen to collaborate with Prof Short and Cambridge, in developing and applying the principle findings of DeDeRHECC, to Indian hospitals."* [12]

Professor Chandrashekhar is now collaborating with Short in developing a resilient prototype 200-300 bed hospital, to be the basis of over 600 hospitals planned by MoHFW across India, under the 19 May 2013 Memorandum of Understanding between the UK DH and MoHFW.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[7] http://www.architecture.com/NewsAndPress/News/AwardsNews/Press/2009/PresidentsResearchAwards2009Wionners.aspx
[8] Letter from Acting Director of the NHS Estates & Facilities Policy Division
[9] Letter from Head of Sustainability, Skanska Infrastructure Development
[19] Letter from Chief Executive, Great Ormond Street Hospital
[11] Letter from Chief Design Engineer, Kaiser Permanente
[12] Letter from Managing Director 3DiFM, formerly Dir of Estates, Bradford Teaching Hospitals
[13] DEFRA National Adaptation Programme (p. 146)
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209866/pb13942-nap-20130701.pdf
[14] www.sms.cam.ac.uk/media/1446036