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DELIVERING LONG-TERM BUILDING PERFORMANCE: A USER-CENTRED APPROACH

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ABSTRACT

In recent years the drive for the delivery of sustainable built environments has resulted in a focus on energy efficiency (regulated energy) in order to reduce CO_2 emissions and mitigate against climate change.

However, as regulated-energy is decreased the proportional importance of un-regulated energy (small power etc.), which is heavily influenced by occupants, is predicted to increase. In addition there is a body of evidence linking occupant health, wellbeing and productivity to both occupant behaviour and the building environment and it has been suggested that predicted climate change has the potential to impact further on comfort, energy use and the wider building environment.

In this context the short term focus on regulated energy efficiency, although not without merit, risks ignoring the influence of occupants and may impact upon occupant wellbeing, energy performance and ultimately long term building performance. Such a scenario could result in premature building obsolescence.

This paper, building on a body of research by the authors (and others) and supported by a review of the relevant literature, suggests that while consideration near term regulated energy remains important, this alone may not deliver long term performance. The paper presents a theoretical model of long-term building performance, highlighting the need to consider the impact of occupant behaviour on energy use, the impact of the building environment on occupant wellbeing and the potential impacts of climate change. The paper suggests that a user focused approach to design considering long term performance and an active approach to building management is require

INTRODUCTION

The built environment is responsible for a significant proportion of global energy use and CO_2 emissions (U.S. Energy Information Administration, 2015), these emissions have in turn been linked to climate change (Intergovernmental Panel on Climate Change [IPCC], 2014). In this context there has in recent decades been a growing focus on delivering more energy efficient built environments.

To date this has been focused on regulated energy (heating, cooling and lighting), where a number of cost-effective savings can be realised. The implementation of increasingly stringent building regulations will reduce energy use in new buildings, while refurbishment programmes may help to reduce energy use in the existing stock. As regulated energy is further reduced (through regulations and refurbishment) it can be argued that the proportional importance of un-regulated energy (small power, desk level equipment etc.), which is influenced by occupant behaviour, may increase (Mulville et al., 2013). Furthermore, in addition to ambient environmental factors occupant behaviour has been shown to have a significant impact on occupant wellbeing (Haynes, 2007, Mulville et al., 2016).

It has been suggested that the movement towards air conditioned buildings and increasing levels of energy efficiency has resulted in negative impacts on occupants' health, wellbeing and productivity (Smith and Pitt, 2011). Increases in energy efficiency, particularly those focused on heat retention and air tightness may, in some cases, result in unintended consequences such as overheating linked to climate change (Mulville & Stravoravdis, 2016 and Jones et al., 2013), moisture issues and poor air quality (Al-Homoud, 2005).

Linked to these potential unintended consequences, it has been widely recognised that a significant building performance gap and particularly an energy performance gap exists (for a review see van Dronkelaar et al., 2016). Van Dronkelaar et al. (2016) links the performance gap to modelling uncertainty, occupant behaviour and poor operational practices and notes that complexity in design can lead to problems during construction which ultimately may impact upon building performance. These factors may be influenced by design stage assumptions about occupant behaviour, occupant decision making, occupant practices (as noted by Karjalainen, 2015) and the role of unregulated energy (Menezes et al., 2012). Arguably the performance gap may, over time, be further widened by the predicted impacts of climate change (Camilleri et al., 2001, Mulville & Stravoravdis, 2016 and Jones et al., 2013).

Figure 1 suggests how, based on the above issues, a performance gap may manifest itself over time. The 'optimum' line represents the performance that would be expected of a new building at any given point in time if it could be delivered instantaneously. The 'desired' performance line represents the performance owners/developers and occupiers/users would envisage based on returns on investment (developer), comfort (for wellbeing and productivity) and energy use (occupier). This is supported through periodic maintenance and refurbishment, as indicated by the light grey lines attached to the desired performance line. However, a gap emerges where the above issues are not addressed, as this gap grows the building may become increasingly obsolete.

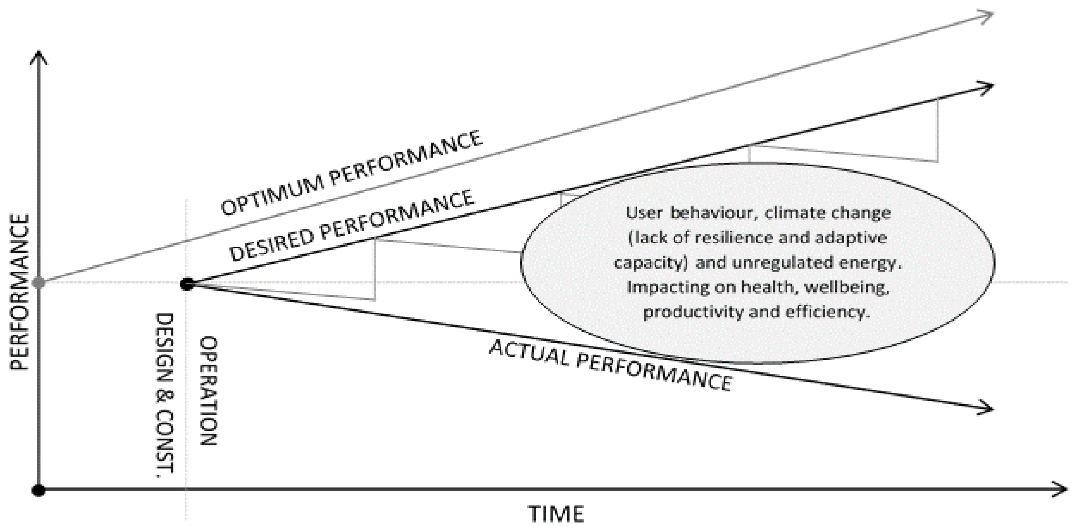

Figure 1. Long Term Building Performance Gap (Adapted from Jones et al., 2015)

The discussion that follows explores the issues noted in **Figure 1** in greater detail. It is argued that, in order to deliver a truly sustainable built environment, a focus on long term building performance beyond the 'point of handover', that considers the influence of occupant behaviour and the potential impacts of climate change is required.

LONG TERM BUILDING PERFORMANCE

The British Council of Offices [BCO] (BCO, 2015 in Sanderson & Edwards, 2016) defines building performance as:

> "the way that a building supports occupiers' differing aims and needs including driving quality and value, meeting sustainability objectives and providing environments that meet the needs of users, resulting in efficient and effective workplaces" (pg.32)

This multifaceted goal presents a number of challenges to both building designers and operators in delivering user centred buildings that are sustainable, efficient and effective. As noted by Cox et al. (2015) sustainability in the built environment largely refers to reducing the environmental impacts of buildings, as such, it may not be holistic sustainability but a relative term focused on particular aspects. Indeed, it has been argued (Voinov & Farley, 2007) that increased sustainability in one system or area may come at the cost of less sustainability in another. This discussion rings true in the built environment where there is often difficulty in finding the economic value of sustainability beyond immediate returns on cost (Keenan, 2015). In this context it can be argued that the sustainability debate in the built environment focuses largely on returns on energy savings. However, in many non-domestic buildings such as commercial offices, employee costs may significantly outweigh energy costs (CABE, 2005). The non-energy benefits or 'co-benefits' of user focused sustainable buildings may be more difficult to measure (such as better Indoor Environmental Quality [IEQ]). However, as noted by Sanderson and Edwards (2016) there is increasingly a move towards a customer centred approach to property management (reflected in the above definition) and as a result the recognition and perceived value of these 'co-benefits' may rise.

Adaptation and Resilience

As noted by Jones et al. (2013) there is a tendency to design and deliver buildings based around the needs of the 'here and now', however most buildings are developed on the assumption of a 60 year plus design life. In this context buildings must have a degree of resilience to and ability to adapt to economic, social and environmental change. Although efforts to mitigate the impacts of climate change have been increasing, often through increasingly ambitious energy performance targets, it is now widely accepted that a certain amount of climate change is inevitable (IPCC, 2007). In this context, in recent years, several research projects have explored the resilience of existing and recently constructed buildings to the impacts of predicted climate change (for example see Camilleri et al., 2001, Jones et. al., 2013 and Mulville and Stravoravdis, 2016). Cox et al. (2015) notes that a building's resilience is a measure of how well it continues to function after an event (and arguably during the event), while Bosher (2014), reviewing previous research, identifies four categories of resilience: 1) resistance, robustness and aspirations, 2) recovery "bouncing back", 3) planning, preparing and protecting and 4) adaptive capacity. In this context the ability of the building to adapt to change becomes a key aspect of resilience and therefore the overall sustainability of the building. Keenan (2015) argues that the sustainability of a building or system fits within the adaptive cycle of the building and that adaptation may be dependant on wider sustainability issues such as the availability of resources. Adaptation therefore could be viewed as, where resources are available, an opportunity to increase the resilience of the building. Where a building is unable to adapt or has limited resilience it may be at risk of premature obsolescence due to poor performance and such a building could be considered 'high risk' (Cox et al., 2015).

Climate Change and Building Performance

It can be argued that the sustainability aspects of the current regulatory framework in the built environment are largely (although not exclusively) focused on the mitigation of climate change. However, as noted above a certain amount of climate change may now be inevitable (IPCC, 2007) and the buildings we construct and refurbish today, must be capable of performing in or adapting to a changing climate (Mulville and Stravoravdis, 2016). That ability to adapt may be key to the buildings long term performance.

As noted, there is a growing body of research exploring the potential impacts of climate change on domestic and non-domestic buildings, which considers the potential impacts of a warming climate and more frequent extreme weather events. It has been argued that, although not without merit, the current drive to reduce energy use may risk optimising buildings in cool climates for heat retention and several studies have predicted an increasing overheating risk in such buildings (for example see Jones et al., 2013 and Mulville and Stravoravdis, 2016). Jones et al. (2013) in a study of a new educational building, note a number of potential climate change related impacts including a reduction in heating load and increased overheating risk overtime (with some overheating predicted as soon as the 2020s). Overheating has the potential to have significant impacts on occupant health and wellbeing (Mulville and Stravoravdis, 2016) with, in the non-domestic sector, corresponding impacts on productivity (Mulville et al., 2016). The wider impacts of climate change may include increased flood risk, which could impact on critical infrastructure, and more rapid materials degradation (Gething and Puckett, 2013).

As noted by Jones et al. (2013) and supported by Mulville and Stravoravdis (2016) adaptation planning and climate change risk assessments at the design stage, and possibly incorporated into the building regulations, may help to minimise the negative impacts of climate change on long term building performance.

Unregulated Energy

As regulations and other associated mechanisms drive down regulated energy (heating, cooling and lighting) the proportional importance of unregulated energy increases (Mulville et al, 2013). Menezes et al. (2012) suggests that a lack of understanding of unregulated energy is a contributory factor to the energy performance gap. Although small power items and other equipment associated with unregulated energy have increased in efficiency (and will likely continue to do so), the proliferation of devices means that small power is likely to remain an important factor in overall usage (Jenkins et al., 2009). In a study considering desk level energy use Mulville et al. (2013) found that up to 23% of energy used may occur outside normal working hours suggesting significant savings may be possible. Supporting this Kawamoto et al. (2003) found that in use utilisation of desk top equipment may be as low as 43%. Mulville et al (2013) found that savings of up to 20% at a desk level may be possible through monitoring, feedback and education. However, the same study suggests that to ensure the longevity of the savings, more constant monitoring and feedback may be required in order to reinforce the preferred behaviour.

Occupant Behaviour

As previously noted, it has been argued that building performance can be heavily influenced by occupant behaviour. Karjalainen (2015) notes, that there is a body of evidence that suggests occupants often do not understand the principles of how a building may function and as a result may use it in a non-optimal way. For instance, it has been noted that in the office environment artificial lights are often on despite the availability of natural light (Nicol, 2001). Where occupants realise their system understanding is poor they may be passive in their interactions with their environment (Karjalainen, 2015). Arguably as a consequence of this passive approach in commercial offices, much energy consumption may occur outside of working hours (Mulville et al., 2013). Karjalainen (2015) suggests that building designs that are less sensitive to user behaviour may result in significant energy savings. This less sensitive building design may be one where users have less to learn about the building, with more intuitive systems motivating users to save energy (Karjalainen, 2015). However, in such a scenario personal control should not be sacrificed (Karjalainen, 2015). Darby et al. (2016) suggest that a mixture of automatic and manual controls could both minimise energy consumption and maximise occupant wellbeing, by providing a high degree of personal control in an intelligent work environment.

There are several theories related to occupant behaviour both in the domestic and more recently, commercial office environment (for a review see Chatterton, 2011), what is clear from this work is that occupant behaviour is complex. Chatterton (2011) suggests that over time intentions and behaviour form habit and habit is difficult to change. Furthermore, Murtagh et al. (2013) note that self-reported pro-environmental behaviour may not always correlate to energy saving behaviour. Arguably, this could be linked back to the occupants' limitations in terms of understanding the intended function of the building.

Several studies (for example see Mulville et al. 2013 and Murtagh et al. 2013) have noted the potential for behaviour change campaigns supported by feedback, information and education to reduce energy use and potentially to encourage behaviour that is supportive of health, wellbeing and ultimately productivity (Mulville et al. 2016).

Health, Wellbeing and Productivity

Occupant behaviour and work patterns, the ambient environment and building configuration have all been linked to health, wellbeing and productivity in buildings (Mulville et al. 2016, Haynes 2007). Haynes (2007) suggests that the behavioural environment and occupant work patterns, including interaction and distraction, are important in terms of productivity in the workplace. This is supported by Mulville et al. (2016) who found that occupants who took less frequent breaks from their desk, and therefore have less interaction with co-workers, were more likely to experience headaches which may in turn impact upon productivity.

Singh et al. (2010) suggest that better IEQ, which is linked to better health and wellbeing, can lead to lower absenteeism rates. In support of this Bevan (2010) suggests that health and wellbeing improves productivity, while a lack of wellbeing may result in presenteeism (Hamar et al., 2015). Mulville et al. (2016) found that both the ambient environment and workplace behaviour have an impact on health, wellbeing and by extension productivity. That study found that where background noise levels were higher (in comparison to other areas) occupants were less satisfied with environmental conditions, despite air quality and temperature being more amenable than in other areas. This suggests that a hierarchy of environmental conditions may exist in relation to occupant satisfaction with noise being of particular importance. In turn, as previously noted (by Haynes, 2007) this can be linked back to interaction and distraction, thermal comfort and air quality however remain important factors (as noted by Callaghan et al., 2015 and Clements-Croome, 2013). Clements-Croome (2013) notes that improved IEQ can result in productivity gains of 4-10%, which given the importance of employee costs supports the case for a focus on occupant satisfaction.

Building configuration and, in the commercial office space, layout, can have a significant impact on employee satisfaction (Mulville et al. 2016). Open plan offices have been associated with increased levels of stress, a lack of perceived personal control, noise and disturbance (Bodin Danielsson, 2010; Pejtersen et al. 2011; Seddigh et al., 2015). Occupants of open plan offices may be more sensitive to background noise and may suffer from a lack of privacy although some benefits may remain (Van der Voordt, 2004). Levels of perceived personal control (which in some layouts may be minimal) can have an impact on overall satisfaction (Lee and Brand, 2005) and it has been suggested that enhanced, possibly desk level, user controls may be of benefit (O'Neill, 2008) in the workplace.

As suggested by Haynes (2008) and supported by Mulville et al. (2016) an active approach to workplace management may help building managers to understand the impact of the building environment on occupiers and to adjust accordingly. Such an approach could, through the provision of feedback and information, also incorporate behaviour change campaigns to reduce energy use and encourage behaviour in support of health, wellbeing and productivity.

DELIVERING LONG TERM BUILDING PERFORMANCE

Based on the preceding discussion, if a sustainable built environment that provides long term performance is to be provided, building design and operation must take a user focused approach that delivers health, wellbeing, efficiency, resilience and adaptive capacity. This requires whole of life thinking in terms of building performance. **Figure 2** sets out how such an approach could be delivered with, at the design stage, user centered design to support the preferred/desired behaviours and risk based adaptation planning to consider the potential impacts of climate change. This is then supported at the operational stage by an active approach to building management incorporating feedback, information and education to reinforce the design intention to occupants and provide building managers with guidance on the key issues to address or adapt to as required. The discussion that follows expands upon these suggestions.

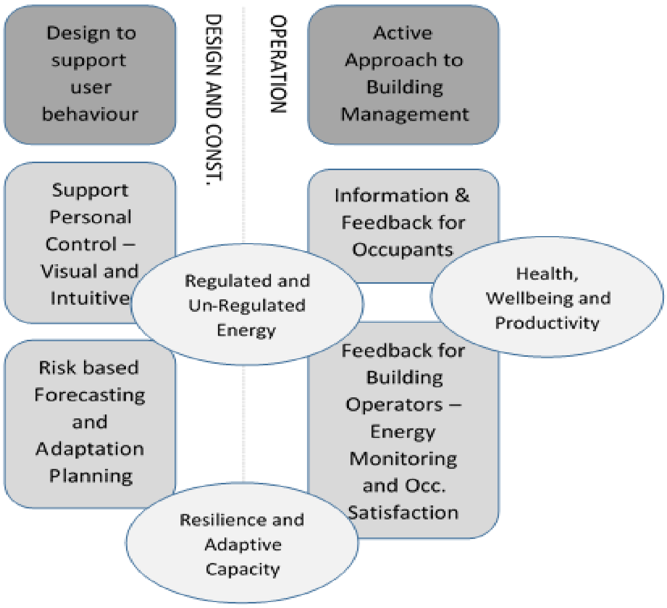

Figure 2. Model of Building Performance

User Centred Design

As suggested by Karjalainen (2015) building designs that are less sensitive to occupant behaviour may offer benefits, especially where more realistic views of occupant behaviour can be taken into account and the building itself is supportive of the preferred behaviour. As noted by Delmas and Lessem (2014) users will not devote much time to learning how the building works. Therefore, less behaviour sensitive designs should include for intuitive controls systems that also take into account the users reactionary as opposed to anticipatory approach to interaction with building systems (Leaman, 1999 in Karjalainen, 2015). This could be in the form of systems that suggest or recommend to users when and how action should be taken, thus providing users with feedback and education and supporting the active approach to workplace management as suggested below. Although fully automated controls may offer benefits in terms of energy consumption they could reduce the perception of personal control which is an important factor in occupant satisfaction, thus highlighting the importance of a user centered approach. As a result, in a building with wider automation the need for personal control would remain, this could be in the form of enhanced local or desk level controls which have been shown to be of benefit (O'Neill, 2008). At the design stage such an approach would require careful consideration of how users are likely to interact with building control systems, this could be informed by input from facilities managers and potential occupants or lessons learnt from the post occupancy evaluations. A requirement for mandatory post occupancy evaluations, implemented through building regulations or environmental assessments to help inform such decisions could be of benefit. Such a user centered approach may help to reduce the performance gap associated with both regulated and un-regulated energy use while improving occupants' satisfaction and productivity.

Risk Based Adaptation Planning

In the context of climate change it has been suggested (Jones et al. 2015) that adaptation planning (incorporating backcasting and forecasting) at the design stage may allow for realistic and cost effective strategies to be developed that take account of the level of risk associated with the predicted impacts. Jones et al. (2013) in a study of a new educational building, in conjunction with the project design team, facilitated the development of a range of potential adaptations, including technical (the use of modular boilers, increased duct sizes for additional cooling capacity etc.), managerial and behavioural adaptions (changes to operational schedules and dress codes) which were then evaluated within a risk framework. This allowed for a number of adaptations to be either implemented during the construction phase or planned in advance and where necessary enabling works conducted to ensure future adaptations could be implemented on a cost effective basis. It has been suggested (Mulville and Stravoravdis, 2016) that a similar approach (all be it that study was discussing domestic buildings) could be incorporated into the regulatory framework through regulations that take a 'forecasting' and risk based approach to climate change, while Camilleri et al. (2001) suggest the use of a climate change sustainability index to identify vulnerable buildings. Such an approach (implemented via the building regulations) could provide users or potential users with a greater understanding of the building's resilience prior to purchase or occupation, much in the same way that Display/ Energy Performance Certificates [DECs/ EPCs] provide comparative information. This approach to adaptation planning could help ensure the building has resilience and adaptive capacity which in turn may improve or maintain energy efficiency and user satisfaction over time.

Active Approach to Building Management

For the operational phase, as suggested by Haynes (2008) and supported by Mulville et al. (2016), an active approach to workplace management may be required to support the organisation and the user. Such an active approach could incorporate measures to encourage energy saving behaviour (such as those noted by Mulville et al., 2013) and behaviours that enhance health, wellbeing and productivity (as noted by Mulville et al. 2016) while providing more detailed building specific performance metrics.

Several studies have demonstrated that behaviour change campaigns can be successful in reducing energy consumption (for example see; Mulville et al., 2013 and Murtagh et al., 2013). While it has also been suggested that similar campaigns could be used to improve occupant health and wellbeing by altering workplace patterns (Mulville et al., 2016). Such campaigns utilise monitoring, feedback and goal setting, education and information, using social norms and competition to encourage the preferred behaviour. An active approach to building management, utilising such measures, should incorporate a continuous feedback loop (Darby et al., 2016) to reinforce the preferred behaviour among occupants and inform building managers of issues arising. As noted by Darby et al. (2016), such continuous reinforcement may be required to ensure that any observed benefit associated with a change in behaviour is not just a short term phenomenon and may, over time, become habitual. This active approach to workplace management could allow, as suggested by Sanderson and Edwards (2016), property managers and occupiers to work together in maximising building performance. The approach suggested could also increase the availability of performance metrics related to the building and help capture user satisfaction which could in turn be made available to potential tenants (as suggested by Sanderson and Edwards, 2016).

These metrics could be incorporated into 'performance leases', which as noted by Janda et al. (2016) have seen increasing use in certain sectors, or, as previously suggested could be incorporated into an alternative versions of a DECs that focus on building performance metrics and risks. In support of this Sanderson and Edwards (2016) suggest that occupiers place greater emphasis on quality over cost when defining building performance and that finding ways to enhance occupiers' business profitability could be of greater importance than cost savings. The approach outlined here, where tied to performance leases or DECs, may help in emphasising the presence of quality (or otherwise) in the workplace while providing greater information for decision making.

DISCUSSION & CONCLUSION

User centred design and an active approach to building management could help to reduce the building performance gap. Considerations of the potential impacts of climate change, through climate impact risk assessments may increase resilience and adaptive capacity and combined, these approaches may help to deliver long term building performance. This could be supported by the use of a climate change index and user satisfaction surveys with performance leasing and an alternative approach to DECs to increase the availability of comparative building performance information.

For building designers, while regulated energy use will remain important, the approach proposed would require a refocusing on the building user. This may present a number of challenges as user behaviour is not commonly considered in depth during the design process beyond a number of predetermined assumptions. It may be that the incorporation of facilities managers into the design stage or mandatory requirements for post occupant evaluations (to provide feedback) may enable designers to deliver such user focused buildings. Where adaptation planning (for climate change) is to be incorporated, the presence of potential users and facilities managers will help to ensure that realistic adaptation proposals can be developed. During the operational stage building owners and property managers may need to take a more active and less reactive approach to delivering building performance. This would require ongoing monitoring, feedback, information and evaluation linked to user satisfaction. More widely ensuring preferred behaviours (to reduce energy use and improve productivity) may require a change of workplace culture so it is seen throughout all levels of the organisation.

At a regulatory level, climate change risk assessment and adaption planning may need to be considered in order to ensure resilience over time, especially where (in the case of commercial offices) most development may be speculative and focus on short term returns. Greater availability of occupant satisfaction and performance in use data may help to increase the use of performance leasing. Such data, in conjunction with climate change risk data, could be made available as part of an alternative or revised approach to DECs.

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