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Methodologies for Improvement of Non-residential Buildings' Daily Energy Efficiency Reliability

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ABSTRACT

In the Norwegian building sector, we are currently witnessing the transition from a realization gap - the gap between availability of solutions and their implementation - to a reliability gap: the gap between the building's potential performances as it is commissioned to its users and its actual performance in daily use. When new solutions do not live up to their promises, not only the performance of the individual building is at stake. The reliability gap can easily grow into a credibility gap with consequences for the ongoing efforts to realize buildings with high energy ambitions. To achieve energy efficiency in buildings, concepts, methods and measures which promise to close this gap are crucial for facilities managers and users.

In this conceptual paper we present the theoretical discussion behind the structure and first findings of a newly established interdisciplinary research project: Methodologies for Improvement of Non-residential buildings' Day-to-day Energy-efficiency Reliability (MINDER). The research aims to reduce the reliability gap in non-residential buildings. The paper describes the international state of the art regarding such diverse concepts, methods and measures as energy performance contracting, continuous briefing, continuous commissioning, and soft landings, and suggests how these may be brought further to interlink the design and operation phase of non-residential buildings.

KEYWORDS

Facilities management, continuous commissioning, energy performance contracting

1 INTRODUCTION

Surprisingly little attention has been paid to environmental efficiency of facility management (Jensen et al. 2012) even though facilities related activities produce the majority of the company's environmental impact. The most significant environmental impact of buildings is caused by the energy use (Sarasoja & Aaltonen 2012). The use and characteristics of the built environment accounts for roughly 40% of the total energy consumption and hence a significant share of GHG emissions in most developed nations (Kyrö et al 2012). Over the life cycle of buildings more than 80% of the total energy is consumed during the operation phase (Azar and Menassa 2012). The facilities hence present a major energy conservation opportunity (Junnila 2007).

The replacement rate of existing buildings is low (Ma et al. 2012) demonstrating the crucial need to enhance energy efficiency of existing buildings in order to bring down emissions (Price et al. 2011). Retrofitting and adaptation of existing buildings may reduce energy consumption significantly but even the best designed low-energy buildings will not perform as planned if they are not operated properly (Kyrö et al 2012). A wide range of technologies which could significantly reduce energy consumption and GHG emissions from new and existing buildings are already available, but the adoption level is low, and technologies to save energy do not travel well from laboratories to a building's everyday life (Berker 2006). There is a lack of understanding of reasons for high discrepancies between design and actual building performance (Freeman & Preist 2013).

Thanks to stricter regulation in the Norwegian building sector we are currently witnessing that the realization gap - the gap between availability of solutions and their implementation - is starting to close. However, there exists another gap that is revealed after energy ambitious buildings are realized: the gap between the building's potential performance and its actual performance in daily use. When new solutions do not live up to their promises, not only the performance of the individual building is at stake. This reliability gap can easily transform into a credibility gap (Bordass et al. 2004) with severe consequences for the ongoing efforts to realize buildings with high energy ambitions. Therefore, to achieve energy efficiency in buildings, concepts, methods and measures that promise to close this gap are crucial.

In this paper we describe the theoretical discussions related to a recently started research project that proposes (1) to map the state of the art of the implementation of these methods in Norwegian non-residential buildings, (2) to analyze in depth potentials for improvement and further diffusion, and (3) based on this and approaches from product design and social science to propose new modifications and extensions that go beyond the state of the art. This approach extends Jones et al.'s (2013) conclusion that there is a tendency in the construction industry to design and deliver new buildings based on the requirements of the 'here and now' despite that the building owners' needs will inevitably change, and extends their recommendation that facility managers should be key members of the design team.

2 EXISTING METHODS CLOSING RELIABILITY GAPS

Non-residential buildings encompass building types like office buildings, schools, universities, hospitals, nursing homes, hotels, sports buildings, commercial buildings, cultural buildings, and light industry buildings and workshops (ENOVA 2012). Most of these building types are also used as public buildings, and are thus an important part of public infrastructure and contribute to benefit of society. Public buildings have a high level of usage and high requirements in terms of their accessibility. Typically, public building stocks are the result of a historical development, characterized with different construction types, building ages, and building conditions. The challenges to the operation of such buildings are to adapt them to changing user demands and make them accessible mainly to the public and hence to anonymous users (Junghans, 2012a). Moreover, non-residential buildings have a direct and indirect potential to support and impede value creation of their users. Because of these special characteristics, and despite the heterogeneity within this building type, non-residential buildings are much more likely than residential buildings to being managed and operated by professionals who are able to act according to concepts, methods or employ targeted measures.

To these professionals, the existence of a reliability gap between theoretical performance of a building and its realization in everyday operation has been known for many years[1]. Today, with increasing ambitions regarding the energy performance of buildings this knowledge has gained new urgency. According to Bordass et al. (2004) disappointing performance of buildings can be related to wrong models, to changes and mistakes made during the construction phase, to bad routines in the commissioning of the building and to deviations from the intended use in the use phase. Improvements restricted to the individual periods in the life cycle of a building are important contributions to the closing of the reliability gap. Examples for these individual efforts are the improvement of modeling methods and software, better routines of fault detection and repair at the building site, and increased flexibility of the resulting building.

While these efforts certainly have the potential to produce better buildings on many levels, they do not tackle directly the disconnection between assumptions about a building's future energy performance and its actual performance in daily operation. A more specific approach to the reliability gap is represented as a broad array of concepts, methods and measures which link actors and technologies from the different sides of the gap together in order to improve a building's performance - but also in order to improve design processes. In the following we present very briefly some of the most prominent examples of such approaches: soft landings (Way 2005), energy performance contracting (EPC), continuous commissioning (CCx, Femp

[1] Jensen 2009, p. 125, quotes an early example from the 1960s

2002), continuous briefing (Jensen 2006), and building performance evaluation (BPE, Preiser & Vischer, 2005).

The primary focus of the **soft landings** methodology is on the post-handover phase in which "[t]oo often clients and users of a building become crash test dummies, abandoned, in effect by the project team after handover, just when they may need some help" (Way 2005,p23). It involves contractual arrangements that extend the project team's responsibility into assisting during the handover phase and beyond the Defects Liability Period (three years). The benefits for the user are clear if changes in usage occur during the first three years of occupancy when project team members are contractually bound to become involved with their knowledge from the construction process. As benefits for the supply side, learning through evaluation and feedback and relatively small costs that are outweighed through the learning effects are expected.

Energy performance contracting (EPC) is similar to the soft landings method in so far as it relies on contracts that (re-)distribute the responsibility for the energy performance of the building. Usually a third party such as an Energy Service Company (but this service has also been offered by construction companies) is entering the contractual arrangement with the building owner and provides energy efficiency during the use phase as a service. This third party analyses the building and proposes, implements, tunes and monitors energy saving measures and receives in turn a certain fraction of the resources saved. In the context of the reliability gap the most interesting aspect of this bundle of different processes and procedures (for an overview see Wargert 2011) is that it creates a link between the implementation of the efficiency measure (most often through a refurbishing activity) and the actual performance of this measure.

Continuous Commissioning (CCx) or **lifetime commissioning** (LTC) extends the tests that make sure that a building functions according to its specifications into the whole lifetime of the building (Holtz 2005; Femp 2002). When building systems show hard (complete) or soft (partial) failures detrimental performance is a likely outcome and the rapid detection of the faults is a concrete measure to prevent a gap between projected and actual performance. The CCx approach is mainly a technical one as documented in the report of an 8-years research project on LTC conducted by the Norwegian research organization SINTEF (Nord et al. 2012). The main element connecting design and operation in CCx are the technical tools that are used within the process: data produced continuously from building energy management systems (BEMS) and other sensors implemented in the design phase and routines and methods that are used to mine this data for errors (related to the measuring equipment) or failures (of the actual technical systems). Additionally, it was proposed that a person responsible for CCx bridges the gap between design and operation by participating both in the design phase making sure that the necessary technical installations are implemented and in the operation phase conducting the actual continuous commissioning (Nord et al. 2012,p15).

Under the label **Continuous Briefing**, Jensen (2006) has described an extension of the classical briefing process from an expert based collection of information to an inclusive and continuous learning process during the whole life of a building. Based on but also deviating from extensive research on efficient and inclusive briefing he proposes to see these processes as learning opportunity with the overarching goal to improve both building operation and design. Compared with Jensen, Preiser and Vischer (2005) start from the opposite end and develop further traditional post occupancy evaluations (POE) to become one of six processes in a comprehensive **Building Performance Evaluation** (BPE) process model. BPE is described as the "process of systematically comparing the actual performance of buildings, places and systems to explicitly documented criteria for their expected performance" (Preiser & Vischer, 2005). BPE encompasses technical and structural performance checks, post-construction evaluation and post-occupancy evaluations during the whole building lifecycle. Like the other methods presented here, BPE aims at improving both individual buildings but also the building industry and provide knowledge on built environments and their impacts in general. Moreover, BPE is aimed to develop a common understanding and the respect of all participants in the building's lifecycle, such as building owners, architects, and facilities managers (Junghans, 2012b).

3 THE MINDER PROJECT'S APPROACH

Despite first signs of change based on a far reaching agreement on the importance of bridging the reliability gap, we can assume that methods which promise to be a remedy are still hardly used both in general and also more specifically when energy efficient buildings are designed and constructed in Norway. Moreover, little is known about the actual extent of this non-diffusion and the barriers and supporting factors. With particularly energy contracting (Kvaale and Jensen 2011[2]) and continuous commissioning (Nord et al. 2012) gaining traction in Norway, the question remains whether these and the other methods are actually implemented in a way that increases knowledge flows between the different phases of a building's lifecycle. Another question is whether individual elements from the methodologies are implemented in a more informal and implicit way, which does not necessarily restrict their effectiveness. In more general terms these questions connected to the actual state of the art of these methods in Norway's buildings direct our attention towards the practices related to user participation and briefing (highlighted in continuous briefing), post-handover (the topic of soft landings), post occupancy evaluations (an element within BPE), contractual and organizational arrangements (used in EPC), and monitoring technologies and automatic fault detection (from CCx).

This conceptual paper is based on a literature study defining the background for the subsequent work within the MINDER project which will collect information about these practices in a structured (web-based) survey sent to a representative sample of owners of non-residential building in Norway. In a second step, based on this survey of the state of the art we aim at developing these existing approaches further. To achieve this, we follow two related strategies: First, we will analyze in depth the context and critical success factors of a limited number of 10-15 cases in which at least certain aspects of the methods have been implemented. These

[2] A current example is Skanska's OPS contract with Oslo municipality to build and operate Veitvet Skole

qualitative case studies will be based on semi-structured interviews with facilities managers, operation personnel and end-users in these buildings. The interviews will be complemented through observation at the building and studies of strategic documents. The case studies will provide insight into the state of the art in current energy efficient building operation and deepen and nuance the image created by the survey. They will also deliver insights into how existing concepts, methods and measures to secure a high level of energy efficiency during the buildings lifetime can be improved and further diffused.

Second, based on the same case studies we will introduce state of the art theory and experiences from the fields of product design and social science to the problem of closing the reliability gap with the goal to go beyond the state of the art.

4 BEYOND THE STATE OF THE ART

Besides arguing that these mapping and analysis activities are long overdue to come to grips with how practitioners “out there” work with closing the reliability gap, we start with an assumption that both **design thinking** and **social practice theory** are able to complement and develop further the concepts, methods and measures described above. Both design thinking and social practice theory focus on what actually happens in daily use and operation of buildings. In both fields it is argued that everyday life has its own logic (or its own tactics and strategies, see de Certeau 1984). This ability to counter or at least heavily modify intentions from the "outside" of peoples' daily life has been demonstrated over and over again in studies of technology appropriation (Berker et al. 2005). Approached like this, the reliability gap is at least partly a result of modifications to the original design of a building that happen during its daily operation and use when the users and operators appropriate the building. The challenge is not to avoid these modifications but to create designs that become part of virtuous circles in which user-building interactions stabilize energy efficiency instead of the more common vicious circles that so often lead to detrimental performance (Bordass et al. 2001).

Design thinking contributes to the creation of these virtuous circles by starting with meticulous observation of the users' everyday life practices:

"Time and again, initiatives falter because they are not based on the client’s or customer’s needs and have never been prototyped to solicit feedback. Even when people do go into the field, they may enter with preconceived notions of what the needs and solutions are. This flawed approach remains the norm in both the business and social sectors." (Brown & Wyatt 2010: 32)

Applied to buildings and the reliability gap, this diagnosis resonates well with observations of architectonical designs that disrespect the human dimension of buildings (Imrie 2003) and consequently meet the users' resourceful resistance (Berker 2011). Design thinking broadens the attention of the design profession beyond the design of single products to addressing more open problems and also providing input at a strategic level. A broad variety of tools and methods are put to use to gain in-depth insight into real-life situations and systems, and designs are developed through iterative cycles of observation, requirements specification, idea and concept generation, testing and evaluation.[3] More recently, design scholars increasingly have started to link theoretical understandings of behavior and consumption to strategies and approaches for design, to assemble or develop tools and methods for design research and generative work. Where much emerging research on sustainability is described as relying on technological persuasion and a rather narrow framing of sustainability, behavior and the relation between them which makes the resulting systems susceptible to breakdown (DiSalvo et al., 2010; Dourish, 2010; Brynjarsdóttir et al., 2012), others explore the value of sociological theories of practice in design research (e.g. Kuijer and de Jong, 2012; Scott et al., 2012).

A recent inspiration to this kind of human centered design is derived from the so-called **practice** turn in social science and the humanities (Schatzki et al. 2001). In this turn the inconspicuous routines of everyday life have moved from the background to the center stage of inquiry. Especially in relation to undesired behavior - such as energy waste or unhealthy nutrition - the creation, support, weakening and breaking of habits has now become a central topic within social theory, policy and public discourse. The limited success of decades with interventions that one-sidedly have addressed rational and cognitive aspects have shown that any behavior may as much be the result of blind habit as it may be directed by conscious decisions and cost-benefit estimates. This insight has been popularized in the suggestion that "nudges" - inconspicuous clues that prompt the desired behavior - are more promising than measures which target values and knowledge (Thaler & Sunstein 2008). Where the isolated use of behavioral psychology for the design of "nudges" has been criticized for its ethics (Huang & Baum 2012) and has so far not been able to document lasting changes in behavior, there is a host of recent research which approaches social practices in a more systematic way analyzing their material, symbolic and skill-related aspects such as "stuff, images and skills" (Shove and Pantzar 2005) and "procedures, understandings and engagements" (Warde 2005). Recently, Shove et al. (2012) have proposed a comprehensive framework that promises to inform new ways of understanding, stabilizing and changing practices.

With both design thinking and social practice theory as theoretical background, the case studies conducted in the second step of the project will be analyzed for opportunities for design and operation routines that create virtuous circles between the users' and operators' daily routines and the energy efficiency of the buildings they inhabit.

5 CONCLUDING REMARKS

Professionals operating and maintaining non-residential buildings have for decades been aware of the reliability gap between expected (energy) performance and a building’s actual performance in daily life. In their work they have seen how designs and their implementation

[3] ISO 9241-210 (2010): Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems, International Organization for Standardizations, Geneva.

have failed to cater for energy efficient facilities management. Starting with their experiences and combining design thinking and social practice theory we aim to improve both design, construction and above all the management of buildings - because a building is not energy efficient until its daily operation delivers.

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REFERENCES

Azar, E, Menassa, C (2012), “A comprehensive analysis of the impact of occupancy parameters in energy simulation of office buildings”, *Energy and Buildings*, 55, 841–853.

Berker, T (2006), “The politics of ‘Actor-Network Theory’. What can ‘Actor Network Theory’ do to make buildings more energy efficient?”, *Science, Technology & Innovation studies,* 1, 61-79.
Berker, T (2011), “Domesticating Spaces. Socio-Technical Studies and the Built Environment”. *Space and Culture* 14 (3), 259-268.

Berker, T, Hartmann, M, Punie,Y, Ward, K (2005), *Domestication of Media and Technology.* Open University Press, London.

Bordass, B, Leaman, A (2001) “Assessing Building Performance in Use 5: Conclusions and Implications”. *Building Research & Information* 29 (2): 144-157.

Bordass, B, Robert, C, Field, J (2004), “Energy Performance of Non-Domestic Buildings: Closing the Credibility Gap”. *Building performance congress*, Frankfurt.

Brown, T. Wyatt, J. (2010): “Design Thinking for Social Innovation”, *Stanford Social Innovation Review*, 31-35.

De Certeau, M (1984), *The Practice of Everyday Life*. University of California Press, London.

DiSalvo, C.; Sengers, P.; Brynjarsdóttir, H. (2010): “Mapping the Landscape of Sustainable HCI”, *CHI 2010, Proceedings of the SIGCHI Conference on Human Factors in Computing Systems,* April 10-15, Atlanta, Georgia, USA, ACM, New York, 1975-1984.

Dourish, P. (2010), “HCI and Environmental Sustainability: The Politics of Design and the Design of Politics”, *DIS 2010, Proceedings of the 8th ACM Conference on Designing Interactive Systems,* August 16-20, Aarhus, Denmark, ACM, New York, 1-10.

ENOVA (2012), *Potensial og barrierestudie: Energieffektivisering i norske bygg.* http://www.enova.no/minas27/publicationdetails.aspx?publicationID=595 [25 February 2012].

Freeman, R & Preist, C (2013), “The potential for Energy Savings in a School with Outsourced FM”, *International Journal of Facilities Management* 2013, 227-237.

Holtz, M. (2005), “Phase 4: Construction-commissioning”, in Preiser & Vischer (eds.) *Assessing Building Performance*, Elsevier, Oxford, 63-64.

Huang, CJ, Baum, ML (2012), “Nudge Ethics: Just a Game of Billiards?” *The American Journal of Bioethics,* 12:2, 22-24.

Imrie, R (2003). “Architects' conceptions of the Human Body”. *Environment and Planning D:* 21 (1): 47-65.

Jensen, PA (2006). "Continuous Briefing and User Participation in the Building Process." In *Proceedings of Adaptables* 2006: International Conference on Adaptability in Design and Construction,p. 119-123. Eindhoven University of Technology.

Jensen, PA (2009). “Design Integration of Facilities Management: A Challenge of Knowledge Transfer”. *Architectural Engineering and Design Management* 5 (3): 124-135.

Jensen, PA, Voordt, T vd, Coenen, C, Felten, D v, Lindholm, A-L, Nielsen, SB, Riratanaphong C, Pfenninger, M (2012), “In search for the added value of FM: what we know and what we need to learn”, *Facilities,* 30, 5/6, 199-217.

Jones, K, Mulville, M & Brooks, A (2013), “FM, Risk and Climate Change Adaptation”, *International Journal of Facilities Management* 2013, 120-128.

Junghans, A. (2012a). “Building use as source of innovation for energy-efficiency improvement of non-residential buildings”. Gudnadson, G. & Scherer, R. (eds.) *ECPPM 2012 – eWork and eBusiness in Architecture, Engineering and Construction,* Taylor & Francis, London, 89–95.

Junghans, A. (2012b). “Integration of principles for energy-efficient architecture and sustainable facilities management”. *28th International PLEA Conference Opportunities, Limits & Needs Towards an environmentally responsible architecture.* LIMA, 7–9 November 2012.

Junnila, S (2007), “The potential effect of end-users on energy conservation in office buildings”, *Facilities,* 25, 7/8, 329-339.

Kuijer, L.; de Jong, A. (2012): “Identifying design opportunities for reduced household resource consumption: exploring practices of thermal comfort”, *Journal of Design Research,* 10(1-2), 67-85.

Kvaale, E.; Jensen, B. (2011), *Energy Performance Contracting. Om bruk av energisparekontrakter på boligsektoren i Europa,* Husbanken.

Kyrö, R, Heinonen, J, Junnila, S (2012), “Housing managers key to reducing the greenhouse gas emissions of multi-family housing companies? A mixed method approach“, *Building and Environment,* 56, 203-210.

Ma, Z, Cooper, P, Daly, D, Ledo, L (2012), “Existing building retrofits: Methodology and state-of-the-art”, *Energy and Buildings*, 55, 889–902.

Nord, N.; Novakovic, V.; Frydenlund, F. 2012. *Lifetime commissioning for efficient operation of buildings.* Sintef energy research. Trondheim.

Preiser, W. & Vischer, J. (2005). The evolution of building performance evaluation: an introduction". Preiser, W. & Visher, J. (eds.) *Assessing Building Performance*. Elsevier Butterworth-Heinemann, Oxford.

Price, S, Pitt, M, Tucker, M (2011), "Implications of a sustainability policy for facilities management organisations", *Facilities*, 29, 9/10, 391-410.

Sarasoja, A-L and Aaltonen, A (2012), "Green FM as way to create added value", Jensen, PA, Voordt, T vd, Coenen, C (eds.), *The added value of facilities management. Concepts, findings and perspe*ctives, Polyteknisk Forlag, Lyngby, 195-204.

Schatzki, T. R.; Knorr-Cetina, K.; Savigny E. (2001). *The Practice Turn in Contemporary Theory*. New York: Routledge.

Scott, K, Bakker, C, Quist, J (2012): "Designing change by living change", *Design Studies*, 33(3), 279-297.

Shove, E.; Pantzar, M. (2005). "Consumers, Producers and Practices". *Journal of Consumer Culture* 5 (1): 43-64.

Shove, E, Pantzar,M Watson, M (2012). *The Dynamics of Social Practice: Everyday Life and How It Changes*. SAGE Publications.

Thaler, RH, Sunstein, CR. (2008). *Nudge: Improving Decisions About Health, Wealth, and Happiness.* Yale Univ Press

Warde, A (2005). "Consumption and Theories of Practice". *Journal of Consumer Culture* 5 (2) (July 1): 131-153.

Wargert, D (2011), *Energy Contracting models in Germany and Sweden*, Master Thesis, Miljö- och energisystem, Teknik och samhälle, LTH.

Way, M. 2005. "Soft Landings". *Journal of Facilities Management* 4 (1): 23.