The Building as a Lab: Towards the development of a toolbox

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1 Introduction

The construction sector is undergoing significant changes amidst challenging economic conditions, changes in the pace of technology and increasing global narratives around social, personal and environmental health. These narratives are changing the way the construction sector operates, putting an emphasis on projects that can evidence a measurable impact on these performance indicators. Green Building standards (e.g. WELL and LEED) are addressing these challenges by making occupant health and wellbeing a focus of accreditation within building design. This is ushering in a new understanding of value that counterpoints the concept of value engineering"; which can become more of an exercise of cost-cutting than value improvement [1].

The last decade has seen the rise of the living lab research paradigm, placing individuals at the centre of research and development. Living labs are physical environments that act as a laboratory, gathering data and learning from users. By linking building information and Internet-of-Things (IoT) data with occupant feedback, the construction sector can develop buildings as living labs and take an occupant-centric approach to how they innovate the entire building lifecycle.

One area this would benefit is the overall management of building information, which, has come under scrutiny in the wake of the Grenfell Tower disaster. In response to that, A new framework presented [2] legislative and behavioural changes to the construction industry. Authors proposed the idea of a 'Golden Thread of Information', to act as a digital record of data from design through to decommissioning that would include construction and ongoing building-in-use data. Moreover, the framework addressed the lack of knowledge and transparency in building information, which may have served as a catalyst to the events which took place at Grenfell. However, the amount of building data required creates many complex technological challenges that will likely act as barriers to the framework's success.

One aspect of building management which has notable technical challenges is environmental monitoring. Indoor environment is typically measured as the performance of the physical building rather than the experience of the building occupants [3]. To gain a more holistic understanding of the indoor environment, there is a need to capture occupant experiences. Building operation and occupant practices are not static but change over time and in response to one another. New ways to capture occupant experiences would make it possible to better understand the dynamic relationship between occupants, the building and its operation. Hence, buildings are becoming testbeds for more focused research to ensure robust design for improved occupant health and wellbeing. This paper explores some 'building as a lab' methodologies which could form a suite of tools for researchers and practitioners concerned with IoT-based environment management.

2 Background

A recent scoping review [4]. identified the need for low-cost monitoring solutions to better understand indoor environment quality (IEQ). Whilst state-of-the-art sensors can provide a high degree of accuracy, the capital investment required can make it difficult to promote beyond research [5]. This results in either fewer sensors being used, which makes it difficult to measure individuals or solutions being developed that are not pragmatic in construction projects.

The review [4] also identified a need for user-centric research within environmental monitoring studies, aligning with the living lab paradigm. Outlining the prevalent need for user-centric research within building studies, authors explored sensor technologies and environmental factors which are fundamental measuring IEQ. This highlighted a degree of ambiguity around how IEQ is used. It was also noted that future studies should consider supplementing environmental sensor technologies with wearables. This would enable researchers to measure individual patterns of behaviour [6], taking a user-centric approach to study relationships between building and occupant.

Whilst the identified knowledge gaps in IEQ research align with the outcomes of the living lab paradigm, there is no single way to apply this to turn buildings into living labs. Instead, there are several technologies, methodologies and frameworks that can be combined to suit the specific needs of a building or research question.

3 Exploring toolbox development

There are many workflows, methods and technologies, which could be incorporated into a toolbox. However, it is important to initially choose a suitable research methodology to underpin research approaches.

3.1 Methodology

In epidemiological studies, n-of-1, or single-case research, methods are an effective way of exposing how the manner of an individual's health can change over time, with greater accuracy than is seen in group trials [7]. Specifically, n-of-1 methods involve repetition around the measurement of an individual over a longer period of time compared to traditional observational studies [8]. n-of-1 methods can inform many types of research design, but they can also be particularly useful in exploratory research and early-phase trials [9]. Moreover, the versatility of n-of-1 methods is acknowledged across disciplines, enabling measurement of high-resolution data [7]. This makes them ideal for measuring intra-day telemetry data gathered from buildings and occupants, through IoT sensors and wearable devices.

3.2 Holistic Cloud-Based Systems

It is possible to develop prototype monitoring solutions with little to no software development. Web-based services such as IFTTT *(If-This-Then-That)*, enable the creation of services that connect IoT devices via simple logic rules [10]. These services are an effective and affordable way to test the interconnectivity of monitoring solutions with limited capital investment. However, it is likely that, beyond prototyping, holistic cloud-based systems would be required to collect, store and analyse such a complex data stream from multiple sensor sources. It is important that cloud-based systems act as a single source of information right throughout a building's lifecycle and can be legislated both into new buildings and the existing building stock.

3.3 Wearable Technologies and Mobile Devices

Wearable technologies, such as Fitbit personal fitness trackers, present an accessible way to connect individuals with environments. Not only could wearables deliver individualised health measures, but the augmentation of the data with data from environmental sensors will potentially reduce the subjectivity found in occupant studies that focus on health and wellbeing [11]. These devices could also link to mobile devices to allow users to be involved in the research and capture the views of individual occupants, a foundation to the Living Lab paradigm [12]. Furthermore, by augmenting these devices with low-cost sensors, researchers could incorporate more sensors into their studies to ensure solutions have pragmatic real-world applications.

3.4 Digital Ledger Technology

Digital Ledger Technology (DLT) is a transparent and immutable, digital record of transactions that is synchronised across multiple peers on a network of users. When a transaction is transmitted to the network, all users receive an identical record of the transaction and the validity is verified by cross-referencing with all other users [13]. Given the need for transparency and accountability within the Golden Thread of Information, it is likely that DLTs would be needed to underpin and support these workflows. DLTs could also have a place right throughout the building lifecycle. As the data on a building grows over time it will be imperative that contributions and amendments to that data are extremely transparent. By doing this will the ideas that underpin the Golden Thread be greatly reinforced.

4 Discussion and conclusion

This paper explores a conceptual approach to how principles, workflows and technologies could be incorporated into a toolbox that would underpin living lab research in buildings. The principles presented, above all else, highlight the need and value of multi-disciplinary research in this domain. Research siloes have resulted in ambiguity in terminology and research methods, which is forcing current research to sit at the precipice of what is possible. By unifying multidisciplinary approaches, i.e. technologies, workflows and disciplines, to create a suite of tools, it is felt that researchers could provide a deeper understanding of the relationship between building and occupant that is currently seen across the literature base. This would add value to researchers and practitioners and aim to address an industry need for transparency, verbosity and accountability of building information.

5 References

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