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Evidence based practice for the built environment: Can systematic reviews close the research - practice gap?

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Abstract

A high performance building is designed and operated to minimise environmental impact whilst providing an indoor environment that maximises occupant health and comfort. The wealth of academic research into technical and non-technical solutions for high performance building continues to grow. However, industry utilisation of academic research is limited and inconsistent due to a number of factors. This situation is compounded by academics using a broad range of methodologies, which prevents a consistent and widely accepted body of knowledge being developed. These factors contribute to a widening research-practice gap. Evidence based (EB) practice is a potential avenue to close this gap. Applied in medicine, EB practice uses a rigorous, more systematic approach on which to base decisions and increase the likelihood of the desired outcome.

This paper will outline an approach being used to introduce evidence based practice to the built environment by a research project of the CRC for Low Carbon Living, an Australian based, industry focussed research collaboration. This paper will detail results from the first stage of the research, which assesses the applicability and suitability of using a systematic review process for built environment research. The paper will discuss the difficulties with such an approach to the built environment field, and proposes a 'realist synthesis' adaptation.

Peer-review under responsibility of the organizing committee iHBE 2016.

Keywords:, evidence based practice, systematic review, built environment, Well building, research practice gap, realist synthesis

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1. BACKGROUND

1.1. Introduction

There has been a strong focus on energy efficiency in commercial buildings over the past 15 years. There is now a re-emergence of wider interest in the health impacts of buildings on occupants. This differs from the ‘Sick Building Syndrome’ which first gained attention in the 1970’s attributed to the introduction of more energy efficient buildings which focused on limiting heat loss through airflow, resulting in air quality issues impacting occupant health [1]. A high performance building is now considered one that minimises environmental impact whilst providing an indoor environment that maximises occupant health and well-being. This renewed interest is resulting in formerly independent fields merging - built environment and public health /epidemiology.

This nexus brings opportunity to further research the next generation of buildings to address both low carbon and human health. It also brings challenges of merging different research styles and methodologies. To achieve this merger, the application of evidence based practice to the built environment sector is being explored. This will require changes to how research is both conducted and applied, and the research-practice gap to be minimised.

Whilst other sectors, such as medicine, public policy and education, have integrated evidence based practices [2] it has limited uptake in built environment. Healthcare design is the most advanced built environment sector merging these fields, adopting more evidence-based practices after Ulrich’s seminal work from the 1980’s that found the rate of patient recovery correlated with access to windows with views in hospitals [3].

This paper will first highlight the need for more evidence based practices in the built environment. It will detail initial findings from a preliminary analysis of built environment studies using a systematic review approach. This approach attempts to understand the current state of evidence around high performance buildings. The paper will draw the theory and findings together with a proposed framework for evidence review assessments to inform built environment activities.

1.2. Addressing the research practice gap in built environment

There is a recognized issue within the design and construction industry of the lack of feedback loops from post-construction and operation of buildings into up-front design, best known as the ‘performance gap’ [4, 5]. Without this feedback, continual improvements in practice and research are difficult. Problems related to the transfer of knowledge is a recognised cause for the existing disconnection between academia and practice [6]. This has resulted in a call to bridge the research practice gap through more collaborative research [7] and through the diffusion of research findings in a format easier for industry to apply [8].

This research is investigating both the ‘knowledge gap’ and ‘practice gap’ in order to develop industry tools to encourage more Evidence Based (EB) practices in the built environment, connecting relevant scientific research and industry practice. The proposed strategy for achieving this is shown in Figure 1.

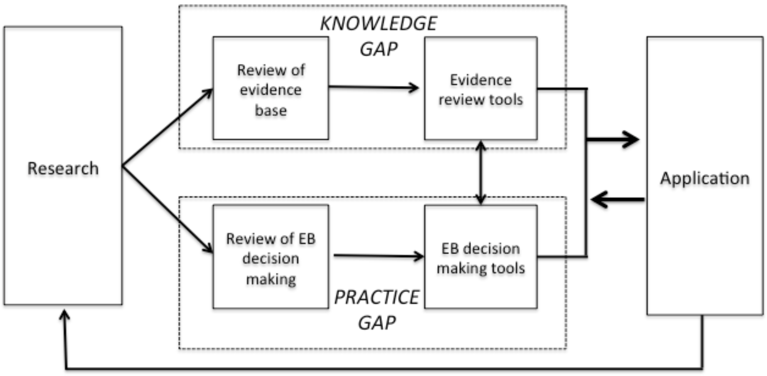

Fig. 1 CRC Closing the Loop - research map

Fig. 2: Quality Hierarchy adapted from Evans (2003)

1.3. What is evidence and how is it assessed?

'Evidence' implies a level of proof of relationship or causality and can take on many different forms and levels of quality. Evidenced based practices take the most reliable and rigorous evidence available and apply it to a situation for improved outcomes. Common definitions of forms of evidence based practice are listed in Table 1. The introduction of evidence based practice in medicine was to complement doctors' individual expertise with the best available clinical and research evidence, helping professionals to mitigate their bias and deliver accurate up to date treatments [9].

Table 1: Forms of Evidence Based Practice

	Definition/ evolution	**Reference**
Evidence Based Management/ Evidence based decision-making	Is about making decisions through the conscientious, explicit and judicious use of the best available evidence from multiple sources to increase the likelihood of a favourable outcome	*Centre for Evidence Based Management*
Evidence Based Design	Is the process of basing decisions about the built environment on credible research to achieve the best possible outcomes	*The Centre for Health Design*
Evidence Based Medicine	The conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients	[9]

There are various methods for collecting and collating evidence. A literature review is the simplest form, where recent research on a particular topic is collated. Whilst such reviews should critically evaluate all aspects of a topic, they can be biased as certain pieces of evidence are selected to support a specific view, or justify the need for further research. To minimise this bias, systematic reviews can be conducted. This is a review of evidence using systematic, explicit and accountable methods [10] to mitigate bias. Reviewers assess multiple studies, such as Randomised Control Trials (RCTs), through a prescriptive review and quality assessment process to synthesize findings. Argued not as rigorous, scoping studies can also be used when assessing large volumes of studies to understand a non-bias breadth and depth of a field [11, 12].

There are levels of quality for evidence that take into consideration how the research is conducted and the levels of bias. Bias can lead to the over-estimation of results and make the evidence unreliable for decision-making [13]. Bias can occur within studies themselves (how the research is conducted), impacting the validity of results

[14], and also in the review and collation of studies.

Different forms of evidence vary in bias and quality. The generally accepted quality hierarchy for evidence is shown in Fig. . For a field such as medicine, RCTs, systematic reviews and meta-analyses of RCTs are considered high quality forms of evidence.

1.4. The challenges of introducing systematic reviews to the built environment

The shift towards evidence based practice for the built environment requires a significant cultural shift in how research is conducted and applied in practice. There is no commonly accepted and understood mechanism for reviewing and assessing the credibility of built environment research [15]. Built Environment studies have neither a central library for practitioner access (as in medicine), nor common practices for applying new evidence to decision making.

In order to build an evidence assessment approach that can inform high performance building design with positive health outcomes, there are some key challenges to be addressed:

- Fragmented research methods and impracticality of RCTs
- Practitioner access to, and comprehensibility of scientific evidence
- Changing the system – application to practice

Fragmented methods and impracticality of RCTs

There are many forms of evidence in built environment research, such as case studies, occupancy evaluations, simulations, dataset modeling and quasi quantitative and qualitative studies. In comparison to medicine, these would sit relatively low on the evidence quality hierarchy [16, 17] shown in Fig. . RCTs examine efficacy of an intervention, such as a drug intervention to treat a particular cancer. Studies are more complex in the built environment. It is not practical to have two identical buildings in which control and test groups are studied. For example, a form of low energy lighting could be tested in a study to see what lighting conditions can be provided for occupants using such a solution. Whilst the study may demonstrate lighting comfort and reduced energy, the room dimensions, building orientation, and external light conditions change study to study, and rarely use a control comparison, much less a “double blind, placebo controlled” comparison as is used in many drug trials.

The practitioners

A challenge not to be over-looked in the built environment transition to EB practice is the change agent, or the design professional, whom has very limited access to academic research housed within university databases and scholarly journals. Rather than accessing this evidence consistently, the design and construction industry develops knowledge on a project-to-project basis [18]. A 2015 industry based survey of Evidence Based Practice architecture and urban planning showed that only 16% of practitioners review research literature as part of their normal practice [19].

Furthermore, these professionals need to be able to translate scientific evidence for use in their project decision making processes, which requires a different set of skills and knowledge [20]. In medicine there are dedicated professionals translating scientific findings into systematic reviews, and also the end users are scientifically trained health professionals. The scientific training and expertise between built environment research and practitioners varies. Researchers may have the scientific knowledge, but lack the experience of practical application, and visa versa.

Changing the system – applications to practice

It is important to understand how EB practice will apply on the ground to inform the set-up of the systematic review process. The EB practice model used in medicine is known as the *'research-based practitioner model'* where it is the practitioners' responsibility to be up to date with latest research and developments" [21]. Other models are shown in Table 2, the '*embedded research model'* separates researchers and practitioners, and the *'organisational excellence model'* uses research and industry collaborations.

Table 2: Research-practice models [21]

Model	Explanation
Research based practitioner Model	• Role of practitioners to stay informed on research developments, and apply these in day-to-day practice • Research use is linear (access-appraise-apply) • Professional education & training critical, and access to databases • High degree of professional autonym to adjust practice in light of research
Embedded Research Model	• Practitioners rarely engage directly with the research findings • Translation by intermediaries (i.e. research communicators) • Results enter practice indirectly (embedded in systems and standards) • Uptake depends on widespread adoption of research informed guidance, tools , protocols etc
Organisational Excellence Model	• Practice delivery relies on service model of organisations (leadership, management, culture) • Organisations not only channels for dissemination, but locus for experimentation evaluation and practice development based on research • Facilitated with university and research partnerships

These models are based on behavioural science, and application varies depending on the **state** of the existing research, **accessibility** by practitioners, and review and **dissemination** processes. Understanding these issues is critical for determining the application model.

Building projects have a complex structure of stakeholders. This limits the professional autonomy to implement research to practice. It is restricted by variables beyond a practitioners control such client budgets and timelines. For example, evidence may demonstrate that a particular ventilation strategy has benefits for occupant health as well as energy efficiency, but the final custodian of those benefits is a building owner who may not even be involved in the front-end decision making.

Furthermore a critical influencer for decision-makers is initial, up-front capital cost over long term value. Hence the model for built environment will need to adopt some *Organizational Excellence* criteria for longer term relationships. Research collaborations are an ideal starting point to more rigorously document built environment practices in peer reviewed formats and increase longitudinal validity of an organisation's practices [22].

Diffusions of Innovations theory underpins the application of EB to practice, to take it beyond dissemination of findings into actual changes to practice [23, 24]. If the EB process introduced is too complex, early disengagement is a risk. Potential rejections such as EB practices reducing the ability for architectural creativity [25] will need to be overcome. The adoption by, and attitude of, end users is imperative to success [26] and will require appropriate and wide stakeholder engagement [27].

2. DEVELOPING AN EVIDENCE METHODOLOGY FOR THE BUILT ENVIRONMENT

This section will summarise the process used, and findings from, initial testing of the application of a systematic review approach to selections of built environment studies. The research team is investigating evidence for high performance buildings. For the scope of this investigation, that is defined as research addressing commercial building technologies and or/designs with low carbon and health outcomes for occupants. Health includes findings related to wellbeing and productivity.

2.1. Establishing a framework to collect and collate evidence

Medical systematic reviews follow a conceptual framework investigating a causal link between a population, an intervention being studied, and the outcomes. This is referred to as the PICO (Population, Intervention, Comparison and Outcome) principle. To achieve this a traditional systematic review uses a number of key steps [10]:

1. Form a **team** with relevant expertise to review studies
2. Formulate a clear **review question**
3. Develop the **search strategy** (where evidence will be sourced, and inclusion/ exclusion criteria)
4. Perform the **search**, map, code and collate evidence
5. **Quality assess** the evidence against a evidence hierarchy
6. **Synthesize** findings

The research team tested initial steps (one to three). The challenges discovered with applying a traditional systematic review process for built environment are summarised below, with recommendations for similar projects to consider.

Forming the team for the review

It was necessary to build a multi-disciplinary team for such a project with backgrounds covering architecture, engineering, built environment industry, health, sustainability/ low carbon, and business. The most challenging skills gap to fill was knowledge on systematic reviews with in-depth understanding of the built environment.

Formulate a clear review question

When initially defining the research question for the study '***the impact that buildings have on low carbon and occupant health, wellbeing and productivity*'** was used. This was found to be too broad and with unclear parameters. It was more suited to a literature review approach. Although the guiding literature strongly emphasises a tightly defined framework for a systematic review from commencement, Levac's work on scoping studies recommends taking a broad approach first to understand the literature and using outcomes to define the question for a systematic review [11]. Therefore a broad scoping study approach was used commencing with sub-topic areas: lighting and HVAC.

The search criteria focused on lighting or HVAC, commercial buildings, low carbon and occupant health. The volume of articles initially found was extremely large so only studies based on systematic review or meta-analyses were selected. The studies retrieved were still highly varied and a study to study comparison was not possible. An analysis was then conducted on study keywords to understand themes being researched in order to identify more targeted systematic review research questions.

Search strategy

Built Environment studies do not have a clear and identifiable 'PICO – Population, Intervention, Comparison and Outcome'. For example in medicine, when a new drug is tested a population is selected to test, a drug (intervention) is given to a control and trial group (comparison), and the outcomes assessed. Multiple studies are later aggregated for a systematic review. Picking a clear 'intervention' is difficult in built environment and the PICO varies study to study.

The inclusion and exclusion criteria for systematic reviews are much more stringent as compared to scoping studies.

Strict criteria include country where studies are conducted, type of studies, publication level of the journals, dates, data used, study design and sample sizes. The more restricted these criteria the smaller the pool of research to assess. The larger that pool of evidence the more resource intensive the review becomes. Attempts were made to apply study design inclusion criteria (i.e. RCTs only) but this excluded almost all built environment research. However without some exclusion criteria the volume of evidence to assess is too large.

2.2. Establishing keywords for searching

An important step to any systematic review (whether it be built environment or not) is understanding the keywords required to search literature and retrieve relevant articles. There are hundreds and thousands of studies and keywords can often vary, risking studies being missed in the search. In the lighting example there were several ways used to describe daylight control systems, shown in Table 3. There was a high volume of unique keywords not duplicated across studies, an example of some of these from the HVAC search also shown in Table 3.

Table 3: Daylighting system and HVAC unique keywords

Daylight and lighting system keyword examples		**HVAC unique keyword examples**
Daylight-linked system	Lighting system (s)	Thermal protection
Daylight responsive systems	System	Thermal characteristics
Daylight harvesting system	Daylighting systems	Thermally activated building systems (TABS)
Daylighting systems	Daylight control system	Thermally autonomous buildings
Daylight guidance	Daylight control	Thermally homeostatic
Lighting controls	Dynamic control	Thermally manageable
Lighting control system (s)	Energy-efficient lighting	Shape-estabilized phase change
Lighting control strategies	Control optimization	Semi-permeable membrane
Control-system		

The fact that there are many different keywords used to identify studies presents a number of points for consideration:

- Any topic being examined needs a thorough understanding of potential keywords.
- There is high risk that studies can be missed in a review process and bias could be introduced when scanning studies if the research team is unfamiliar with some of the terms.
- The terminologies were highly technical and require specific expertise. If multiple reviews are being run on different technologies, such expertise will be required for each topic.
- When researchers are conducting their own literature reviews, it is important they do a complete search of all keyword terminologies to ensure they are building on the existing knowledge base.
- Even if practitioners were able to access these articles through a shared database, it is highly unlikely the results would be comprehensible without the correct skillset, and different practitioners may use different search terms based on their experience and education.

It was noted when analyzing the keywords that there were more frequent references to occupant comfort (i.e. visual comfort) and satisfaction, as compared to health related keywords (i.e. circadian system). Comfort and health will have a different keywords from built environment to public health studies and will need clear parameters.

2.3. Understanding study designs

Following the initial scoping study, additional searches were undertaken removing the meta-analysis/ review focus. The purpose of these searches was to test inclusion and exclusion criteria when finding and assessing studies. When reviewing large volumes of data the abstracts are used as the first indicator for inclusion or exclusion, therefore this search focused on abstracts only.

The first search used HVAC, health and low carbon. The search criteria used are results are shown in Table 4.

Table 4: Search criteria HVAC, low carbon and health

Area	Key words	Inclusion and Exclusion	Results Web of Science	Results Proquest
Initial search	(office OR "commercial building" OR "non-residential building" OR building OR "commercial office" OR workplace OR workstation) AND (energy or "energy efficien*" OR "low carbon" OR green OR sustainab*) AND (HVAC OR heating OR cooling OR ventilat* OR "air-condition*")	Journal articles, 1995-2016	14,057	132,641
Revised search	(office OR "commercial building" OR "non-residential building" OR building OR "commercial office" OR workplace OR workstation) AND (energy OR "energy efficien*" OR "low carbon" OR green OR sustainab*) AND (comfort* OR satisfaction OR health OR wellbeing OR productivity OR wellness) AND (HVAC OR heating OR cooling OR ventilat* OR "air-condition*") OR "natural ventilat*") NOT school NOT hospital NOT residential NOT house	Journal articles, 1995-2016	1,924	42,095

The initial search was conducted in Web of Science using Boolean operators between words that focused on office buildings, HVAC and low carbon. This search revealed 14,057 results. To reduce this volume, additional criteria for health and comfort were added. By adding these criteria the search required articles to be found which addressed both low carbon and health as well as HVAC, and excluded non-office buildings. This reduced results to 1924 (shown as 'first search' and 'revised search' in Table 4). If a systematic review were being conducted, it would require a layer of inclusion and exclusion criteria at this point, such as minimum sample sizes, particular study designs (i.e. RCT) and other research criteria to reduce this volume of studies selected for review.

However, at this point the research team wanted to understand what impact various inclusion, exclusion and assessment criteria would have on the search. Therefore studies were extracted from 2015 only and an analysis was conducted on a random sample of twenty abstracts.

Abstracts were extracted to excel and a number of categorisation criteria applied to understand the design of the studies. The criteria were selected based on typical factors considered for inclusion or exclusion in systematic review and an attempt to assess the validity of applying the 'PICO – Population, Intervention, Comparison, Outcome' principle to the group of studies. The categorisation criteria used were:

- Setting – where the research was conducted (i.e. office, room, lab) and if it was regionally specific
- Data – if the study used real or simulated data
- Sample sizes
  - The setting (i.e. number of buildings)
  - Any physical element tested (i.e. type of HVAC)
  - Any occupants studied
- Experiment designs
  - Set up
  - What and how data was collected
- Bias

The ‘interventions’ varied between a physical element (i.e. a cooling unit filled with Phase Change Materials), a design process (i.e. new algorithms for real-time thermal loads), an actual intervention (i.e. increased ventilation rates) and reviews of existing data.

Findings and implications for the frameworks inclusion and exclusion criteria are summarized in Table 5. The column on the left summarises the findings from the analysis and the right column explains the implication for inclusion and exclusion criteria.

Table 5: Findings from abstract analysis and implications for inclusion and exclusion criteria

FINDINGS – ABSTRACT ANALYSIS	**IMPLICATIONS FOR INCLUSION/EXCLUSION CRITERIA**
Context setting and regional variations	
• Studies were run in rooms, labs, whole buildings and simulations. • Multiple areas were sometimes tested within one building (i.e. occupant comfort, air quality, energy use), whereas lab studies were more controlled. • The context was vague for some studies, it was unclear what type of building was used • Some studies were regionally specific with findings, others could be applied across regions	• Initial consideration was to only include studies from ‘real’ buildings but this is too limiting – labs, rooms and other settings are also viable • Regional criteria should be introduced depending on the study intension, some findings from regionally specific studies are still valid in other regions
Data	
• The data used was a mix of real and simulated data (50% real, 25% simulated, 25% mixed) • Thermal comfort data was mostly simulated, three studies used actual questionnaires with occupants. • Unclear distinction of study description between simulated and actual data, and relation to overall findings. • Very limited data on financial cost implications of findings	• Initially the thought was to exclude studies using simulated data, this could exclude some valid studies with mixed data • Quality assessment focus needs to be on relation between data and findings, and claims made by author(s) • It is unlikely that financial costs and benefits will be directly extracted from studies and should not be an inclusion/exclusion criteria. Financial implications will need to be modeled separately
Samples and sample sizes	

• Studies showed three potential samples:
  • the setting (i.e. the number of office buildings or rooms)
  • the physical element being tested (i.e. 12 types of PCM) and;
  • the people (i.e. 11 office workers).
• Sample sizes for setting and physical elements were sometimes unclear or unstated
• Occupant sample sizes were clear but in some cases modeled occupant data was used and reported as health or comfort outcomes (i.e. thermal comfort)
	• Minimum sample size is not recommended for setting and physical element
	• Sample size criteria could be used for occupants, minimum sample needs further investigation
	• Bias is apparent in some occupant samples s (i.e. male only occupants)
	• Quality assessment needs to apply in authors claims to generalised findings
	• Unclear as to real world applicability of modelled occupant data, inclusion as an assessment criteria needs further investigation

Experiment designs	
• Each study design was individual, very limited similarities between study designs (apart from 2 studies comparing PCM durability) • Descriptions of buildings/ setting varied • Data collection varied (i.e. data logging sensors, field measures, environment measures, temperature variations, questionnaires,	• Not possible to compare study designs, inclusion criteria needs to remain broad • Labelling the study designs is difficult, an evidence hierarchy will need to clearly define different study designs • Individual set up makes it difficult for other researchers to systematically build on findings

• physiological tests) • Many variables being measured within the same experiment • Sometimes unclear how results and findings related	
Bias	
• Sample bias apparent in some studies • Generalised claims in findings with limited validation that these will work in application (i.e. studies with simulated data finding energy efficiency potential in buildings)	• Criteria needed around sample bias • Quality assessment is critical on validity of findings to generalised conclusions and recommendations

The search process highlighted some of the key issues when conducting a traditional systematic review in the built environment. Medical studies repeat the same experiments in the same ways to validate findings. During the scoping phases it was noted that many 'new', 'novel', and 'experimental' studies were conducted. The pressure for new and novel approaches risks not building systematically upon the existing knowledge base. This culture most likely adds to the observed high variability in study designs.

Without the ability to apply strict inclusion and exclusion criteria, the volume of studies to review is very large and these reviews become resource intensive. A refined research question is imperative to narrow down the search but the risk then is that the findings become relevant only to a small industry niche.

A weakness in many studies was the claims made by authors, and the relation back to the data. Some claims seemed overconfident based on the research conducted. One study found a positive link between the measurement of office work performance and evaluation of thermal satisfaction in real offices as a means to boost workplace productivity. The study used 11 businessmen, which presents sample bias in itself and a questionable sample size for the claims made. In several cases it was unclear how the many different variables being measured related to the findings.

3. DISCUSSION AND PROPOSED FRAMEWORK

3.1. Adapting the systematic review approach

Considering the complexity of built environment academic evidence and initial findings from the review process, the direct application of a traditional systematic review is not appropriate. A number of issues arose:

- Inability to establish strict inclusion and exclusion criteria without losing potentially valuable studies
- Diversity in research approaches – qualitative, quantitative, mixed methods and minimal RCTs.
- Many contextual variables, findings could only apply in particular settings (i.e. varied climates, varied air quality)
- Mixed weaknesses and strengths within the same study (i.e. sample gender bias but strong experiment design)

Education and public policy are some areas also adapting EB practices. Criticisms of the use for systematic reviews in education believe it is too difficult to review qualitative studies embedded in social science against hard scientifically rigorous inclusion and exclusion criteria [28]. By excluding studies that do not achieve certain criteria, it unfairly diminishes their validity.

Systematic reviews are attractive as a concept to adapt to various sectors and determine 'What Works', but what this does require is a relation between an intervention (a cause) and outcomes (effects) [29]. This is why RCTs are seen as the most effective research form for evidence based practice [30], as they can prove causation and their rigour is judged on how well they test that causation.

Evidence Based Policy is becoming more frequently used (particular in the UK – i.e. 'What works network') as a way to better channel public spending [31]. Similar issues to education have been faced in policy, with cause and effect being difficult to determine and apply. Sanderson argues the need to understand (1) *feasibility* -of evidence to provide a basis for decisions and (2) *desirability*, the extent to which policy should be guided by evidence [32].

To counter these issues, Pawson's approach to systematic reviews for Evidence Based Policy is to consider *What* is it about a kind of intervention that works, for *whom*, in *what* circumstances, in *what* respects, any *why*? [29, 32, 33]. Pawson emphasises that no intervention is clear cut, and the 'ingredients' around the causation need to be captured as part of the review, as well as lessons for taking causation into generalized findings - his approach is a *realist synthesis* for evidence. The realist synthesis moves away from the PICO (Population-Intervention-Comparison-Outcome) model to understanding underlying mechanisms (M) and contexts (C) related to outcomes (O).

The need to develop 'high performance buildings' comes from the well documented failure of buildings to meet their anticipated performance levels [34-36]. Whilst research may show some interventions (i.e. chilled beams, operable windows, shading devices) as being energy efficient, when implemented there are often issues that result in underperformance, such as commissioning errors or unintended user behaviour. Such knowledge comes from understanding the context around each intervention.

The understanding of the contextual variables and mechanisms in the built environment will require input from experienced and knowledgeable professionals. When there is too much emphasis placed on the role of causal, hard scientific evidence it neglects the importance of human problem solving and knowledge [32]. Research can therefore undermine effective practice by privileging research evidence over the value of practitioner experience [28, 37]. The acquisition of knowledge is a long term investment and therefore a valuable resource, but it is challenging to capture and quantify this knowledge [38] although work on this in other scientific fields can be adapted.

This will require the integration of experience into the evidence hierarchy (Fig.), and that hierarchy will need to be specifically adapted for built environment research. Several academics have raised issues with the concept of a hierarchy of evidence [39]. The hierarchy is a helpful tool as a general guideline and particularly well adapted to evaluate the quality of evidence for questions of causality [40]. However a realist synthesis does not deliver a definitive 'What works' option that examines causal relationships in interventions, and it is generally acknowledged that the hierarchy will be affected by the kind of question that is being asked [41] [42] .

The initial approach for this type of research project was a separation of industry and practitioners, using the previously discussed *'embedded research model'* (Table 2). However, it will require elements of all three models, including the *'research practitioner'* and *'organisational excellence'*. The review essentially delivers resources for practitioners to generate change themselves [43] and perhaps not develop an immediate evidence **based** practice but can facilitate the shift towards evidence-**informed** practice.

As an example of applying these models, a recent systematic review on sit stand desks found weak evidence for short term use benefits, and no proven benefits for long term use [44]. Considering Sanderson's (2003) argument against pure reliance on hard evidence, it doesn't necessarily mean that sit-stand desks don't provide health benefits, but the context around what works, for whom, in what circumstances is needed [45]. An alternative approach could be to utilise the *Organisational excellence model*, trialling the desks longitudinally in organisations, collecting feedback from users to supplement initial controlled study findings. This requires industry and academic input.

3.2. A realist synthesis framework

The inference drawn by researchers in some of the abstracts reviewed seemed overconfident and creates risk for industry application. With a realist synthesis of evidence, the inclusion criteria is not solely on study design (such as RCTs), but also upon whether the inference drawn in the study has sufficient weight to make a methodically credible contribution to whatever topic is being investigated [46]. Pawson outlines that all studies have their own flaws and strengths. The practice is to weigh up the contributions of each source, disqualify those that are 'flimsy' and to make sense of different contributions.

Under a realist synthesis, the search does not necessarily target a single element. For example instead of searching for studies about window glazing, the search can be whether natural daylight in buildings improves health. The mechanisms (i.e. glazing) and contexts to enable this can be studied as part of the outcome. This helps to overcome the fragmented study design and synthesise study findings from a broad range of study types.

Drawing from the findings in this paper, the application of a realist synthesis will be attempted in place of a systematic review, to review the evidence base for high performance buildings. In order to place some scope around the project's review, the search will be conducted in categories that encapsulate both health and energy without being technically specific. The key categories to be explored are: light, air, thermal comfort, mobility, layout, acoustics and materials. The first synthesis will focus on light. Each will be investigated for the impact to energy and/or human performance in commercial office buildings. In order to achieve this, the framework in Table 6 is proposed, adapted from [46] and [47, 48].

Table 6: Proposed realist synthesis framework

	Actions	**Involvement**
1. Scoping	• ID research question and sub-questions for each topic • Refine purpose of review with end users • Review underpinning theories on each topic • Discuss initial searches with stakeholders • Design an evaluation framework to be populated • Scoping studies and trial searches • Draft inclusion/ exclusion criteria	Close engagement with research team and industry stakeholder group
2. Search	• Decide sampling strategy • Define sources and strategies for searching • Revise inclusion/exclusion criteria iteratively • Test for relevance • ID experts for interviews and grey literature sources • Run searches	Research team and external experts
3. Re-engage with stakeholders	• Engagement with key stakeholders for perspective on initial findings • Utilise findings as part of the evidence	Research team and industry stakeholder group
4. Extract and synthesise findings	• Extract data from studies using agreed approach • Organise searches into context-mechanisms-outcomes • Compare and contrast • Determine what works, for whom, how, under what circumstances	Research team
5. Make recommendations & disseminate findings	• Make recommendations for relevant stakeholders based on contextual findings	Research team and industry stakeholder group

The outcome of applying this approach is expected to develop a greater understanding of the types of evidence across built environment research and ways to classify and assess this evidence. It is expected results from this trial will determine the suitability of a realist synthesis for applicability to built environment research into the future.

4. CONCLUSION

This paper outlines preliminary research in the development of an adapted systematic review methodology for built environment research. Such reviews are commonplace in medical research and practice, and have revolutionised the field enabling immense statistical power/confidence in determining the efficacy or treatments or health effects due to exposures. In order to develop high performance, low carbon buildings, the use and application of systematic reviews are being explored to facilitate the uptake of evidence based practices. This is particularly relevant with the growing industry interest in healthy buildings resulting in a merging of health/ built environment fields.

Evidence based (EB) practices are most utilised in the design of healthcare buildings but have limited uptake across other built environment fields. This is resulting in a widening research-practice gap. The introduction of EB practice requires a whole systems change within both academic research and industry practice. Understanding the current attitudes and behaviours within industry and relevant stakeholders is imperative to introduce such change, supported by the Diffusion of Innovation theory and other behavioural science models addressed in this paper.

Initial findings from the establishment of a 'systematic review' approach are presented. Authors have identified a number of challenges with their direct implementation into built environment. The key challenge being the multitude of small studies, which makes synthesis of evidence difficult. Built environment studies use varied sample sizes, experimental methods and measured parameters. Furthermore, regional variation in climate and building practice makes comparing results between regions problematic. Many of these features can lead to bias within studies, which a systematic review is typically able to remove when synthesising. In addition, there is pressure for novel approaches, further contributing to this fragmentation and making it difficult to continually build upon the existing evidence base.

Applying the strict assessment criteria of a traditional systematic review to the existing built environment evidence base would eliminate a large volume of possibly valid studies. An alternative evidence review is proposed utilising a 'realist synthesis'. This approach considers the context around the topic being evaluated and rather than evaluating the rigour of studies based on their design, it considers the value of the findings. Whilst a less rigorous approach than a systematic review, it is more suited to the current state of built environment evidence. The framework for a realist synthesis is presented on which the next stage of this research will be conducted.

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