



**LOW CARBON LIVING
CRC**

CRC RP1009 Closing the Loop

Navigating the evidence for evidence-based research



Acknowledgements

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Introduction

This paper is to inform the second stage of project development for the Closing The Loop project. The foundation for the project direction was established in the first paper 'Closing the Loop, Evidence-Based Design and Systematic Review. This paper will cover:

- Evidence based design background and learning for the project
- Industry engagement research required
- Research considerations for the Systematic Review and Critical Analysis
- Research considerations for the decision making component
- A review of existing Evidence Based Design centres that reviewing and disseminating evidence based reports and information.
- Potential tools and deliverables from the project

Learning from Evidence Based Design in healthcare facilities

The evidence based design (EBD) movement for healthcare was similar to that which occurred in evidence based medicine, with the aim of linking rigorous research back to practice. EBD for healthcare centres is far more advanced than in other built environment sectors and there are existing processes that can be adapted and built-upon.

An early contributor for evidence based design (EBD) in healthcare centres came from a report published in 1999 by the Institute of Medicine 'To Err is Human: Building a Safer Health System' which found that human errors were contributing to compromises in patient safety (Zborowsky and Bunker-Hellmich, 2010). This report was a catalyst in the EBD movement for healthcare. Similarly we are seeing this catalyst in other built environment sectors with major reports and studies emerging on the impacts working environments have on the health, wellness and productivity of occupants. One such example is the WGBC report reviewed in the first report, *Health well-being and productivity in offices*.

Evidence based design for healthcare facilities is resulting in more patient-centred design, a strategy for these facilities to reduce costs and deliver high-quality healing environments. This approach is described by one industry leader as a convergence of three key areas (Smith, 2015):

- **sustainability**
- **evidence-based design**
- **lean manufacturing**

Essentially, this is an aim of the *Closing the Loop* deliverables. Guiding occupant centered design (Figure 1) of buildings, with an integration of lean delivery and ongoing operation for high sustainability outcomes.

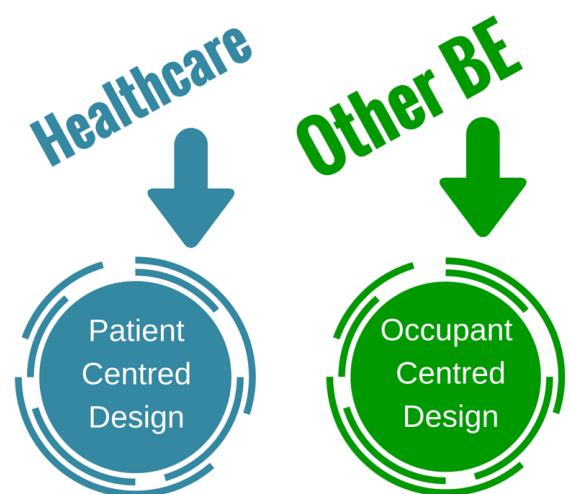


Figure 1: EBD in healthcare to other built environment

Robert Ulrich, a leader in EBD for healthcare facilities, comments that EBD offers data to designers on what works and doesn't work in buildings and *"brings empiricism to the design process to support imagination, judgment, and evaluation"* (Ulrich 2010). It takes away the pure gut instinct to be supported by evaluated evidence.

EBD is being integrated into design and construction processes regularly for healthcare and has become an industry in itself. The Pebble Project by the Centre for Health Design is one such example, which will be explored in this report.

What health and wellness factors are impacted by a building?

The main challenge for EBD, as opposed to EBM, is the multiple confounding variables that can impact operational performance of a building. Rigorous and controlled experiments are more challenging in built environment studies, particularly in non-health care related environments. For example, the testing of productivity and wellness improvements for staff in green buildings is difficult without a consistent measurable indicator such as patient stays. In an office environment, there is the need to differentiate between productivity impacts from the physical environment and from the workplace (i.e. workplace stress, management etc).

Where is the evidence? And how is evidence defined?

Evidence will need to be clearly defined at the start of the project, and will be encompassing evidence related to carbon, and related to health and wellness.

The clear definition is important as evidence as it will have different meanings to various stakeholders *"...the concept of EBD is quite complex, especially as it relates to the gathering and assessment of data and how such data is used to inform the building project. The bulk of the complexity lies with the word 'evidence.' The current literature suggests disparity among researchers and practitioners over the collection, analysis and incorporation of evidence into building projects"*.

Evidence is changing rapidly as new building technologies are applied. Not all types of architectural design will have had academic studies conducted. There must be multiple studies to academically support a design intervention, but there is generally a shortage of replicated studies (Hamilton, 2011). For example Activity Based Working is not yet supported by studies, but it doesn't mean it won't work. There are more research needs than funded research projects, and industry moves far more quickly than academic study. In addition, new evidence may be in the form of real-time data such as sensors.

Another challenge is that companies will keep their own databases, lessons learnt and studies. Government and private organisations house their own data which is not published – for example, CETEC, Office of Environment and Heritage (NABERS), Davis Langdon, JLL, BOSSA and BUS. Therefore, the existing evidence that is reviewed will by no means be exhaustive.

In addition, evidence is collected in various forms, and this will change into the future as data collection becomes more sophisticated with use of real-time data collection.

This research will be strengthened with use of practical examples of high performance building and how and where evidence based design and practice has been integrated into the lifecycle to produce the outcome. This is the reason the fieldwork and research will need to be combined.

Industry engagement

It is important when commencing this research to understand where and how people currently access design information in relation to the built environment. This will be able to inform the depth and quality of research that is currently being accessed (i.e. an industry magazine vs academic publications) as a baseline. This research will also investigate existing decision making processes and inform the development of tools to influence decision-making.

Where are people accessing evidence?

A study aimed at understanding where people source their data from was conducted across attendees to medical conferences. The results are summarised below. A similar approach could be duplicated for the start of this project utilizing conferences such as Green Cities, or surveys through key stakeholder groups (such as PCA).

The results firstly show the top sources of information. It is interesting to note that the Centre for health Design near to the top, an EBD organisation.

RESOURCE	Number of Users												
PubMed Medline	10												
Center Health Design	6												
InformeDesign	6												
Academy Architecture Health	4												
AIA	2												
EBSCO	2												
IHI	2												
PsychInfo	2												
Research Design Connections	2												
ACHA	1												
ACHE	1												

Figure 2: Sources of information

The survey then asked respondents (open comments) what additional information they would like to access (**Error! Reference source not found.** and Figure 3). The author notes the consistent desire for a “comprehensive, peer-reviewed database that provides a single entry point” to information on healthcare architecture (**Error! Reference source not found.**). This is particularly relevant to the built environment, consider all the sources people use, such as PCA, GBCA, WGBC, AIA, UDIA etc. Some organisations have their own internal databases. This project doesn’t need to create another source of information that dilutes the dissemination, it needs to funnel existing information.

- Interface:
 - A consistent user friendly format, linked to international sources.
- Topics:
 - Categories of information should be organized by topic, architectural type, use or function, and outcomes.
- Textual information:
 - Original findings, meta-data, meta-analyses, abstracts, summaries, full text.
- Reports:
 - Executive summaries, conference proceedings, funded reports, and published articles and text.
 - Case studies, systematic reviews, randomized controlled trials, structured abstracts and reviews.
- Practice guidelines:
 - Consensus statements, regulations and codes.
- Numeric data:
 - Statistics on patient volume, occupancy, and satisfaction, staffing levels, recruitment and retention, Medical outcomes, human performance measures, outcome and operational impacts and results.
- Architectural data:
 - Construction details and dates, materials and supplies, site, location, adjacency, plans (categorized by function, size, pre and post changes).
- Economic data:
 - Investment, market, administrative information and reports.
- Data representations:
 - Textual, graphic, rendering, 2D (plans, elevations), 3D imagery, photographs and videos.
- Peer reviewed:
 - Curated and validity / significance ranking.

IMAGES	CONTENT
Location	Pre - Post Evaluations
Site	Trends
Plans	Function
Photographs	
Renderings	
Videos	
PUBLICATIONS	INFORMATION
Original research	Dimensions
Publications	Volume
Full text	Occupancy
Abstracts	Procedure
Summaries	Staffing
	Outcomes
REVIEW	PERFORMANCE
Peer reviewed	Operations
Meta-analysis	Impacts
Structured review	Costs
Summary	Investment
Executive summary	Administration
Public overview	Construction
STUDY TYPE	DATA CONTENT
Case	Raw data
Cohort	Charts
Case series	Graphs
Large scale	Data analysis & statistics
Empirical	
Observation	LINKS
Experimentation	Peer review panel
	Professional community
	Public

Figure 3: Additional information people would like to access

The research and information sharing landscape is changing. Databases that have traditionally required expensive subscriptions are being challenged by open source platforms (Edelstein 2008). Figure 4 shows the most frequently accessed databases. Depending on the type of information people are seeking, they will go to different sources.

The author notes the emerging organisations aimed interpreting and disseminating information to serve design, such as Centre of Heath Design, InfomedDesign and Soloso

Figure 4: Commonly used databases

Systematic Reviews & Meta-analyses	Randomized Controlled Trials	Cohort Studies Case Reports Case Series	Structured Abstracts, Expert topic reviews	Practice Guidelines Consensus Statements
Cochrane Library	Cochrane Library DARE CENTRAL	PubMed	ACP Jml Club	Nat'l Guideline Clearinghouse
PubMed Clinical Queries	PubMed Clinical Queries	CINAHL	eMedicine	PubMed
CINAHL	CINAHL		UpToDate	
			Clinical Evidence	
PsychInfo	PsychInfo	PsychInfo		
			Web of Knowledge	
Compendix			Web of Science	
		RIBA	Google Scholar	Facilities Guidelines
		Avery		JACHO
		OSHPD		JACHO
				OSHPD
CHER		Infomedesign	CHD, CHER	

Understanding how people currently access information will be important to inform the research. For example, the project could find current sources of evidence to inform design, plot accessibility vs quality of that evidence and find what level of evidence is informing current design.

What issues prevent EBD decision-making processes?

Evidence based medicine (EBM) underwent processes for acceptance into mainstream medical practices. An article examined 'teaching old dogs new tricks' with examples from EBM (Doherty, 2005). The main issues were thought to be the characteristics of the evidence, ineffective translation and transfer of knowledge, and barriers/resistance to change at individual or organizational levels. Doherty notes an example from a Cochrane collaboration. A meta-analysis of studies on a medical problem (stroke) resulted in recommended treatments that were far too cost-prohibitive, and hence unsuccessful in changing practice.

The author recommends 5 considerations for assessing and applying evidence:

1. What does the evidence say and is it applicable?
2. Does it fit with out current paradigm (*too* far ahead of current knowledge and practice won't be adopted)
3. Is it easy to apply (feasibility and cost)
4. Who is pushing for the change and why? (i.e. improving patient care or marketing value?)
5. Is it distracting us from more important issues?

Industry engagement is necessary to understand the existing 'paradigm' the industry is in, issues they face and importance of this area of research. A true understanding of the 'pain points' will guide the development of tools required.

Reviewing the evidence

The Systematic Review process

The systematic review will be the review and analysis of evidence of studies already conducted to inform the project direction. Approaching the systematic review has already been outlined in the first research report will be used as a guide. The SR has a number of benefits:

- Such an exhaustive review has not been done before with office buildings as a focus
- The outcomes can inform future academic research topics and research design which will directly benefit industry
- Analysis will show themes of research from which we can develop publications for industry as early project deliverables (i.e. performance of green buildings with X design feature)
- A framework will inform fieldwork for the CTL project

There are a number of key areas that need to be agreed upon in conducting the review and will be informed by the industry engagement:

1. What question(s) are we trying to answer?
2. Where are we searching?
3. What are the key words to search for?
4. What conditions are in place (i.e. is a WGBC report admissible?, peer reviewed papers only, non-english?)

Ulrich's framework

A landmark study was conducted in 2008 by Roger Ulrich, considered a leader in EBD for healthcare that assessed a large quantity of evidence. This study can be used as a model for this project. Authors investigated 3 key areas:

- (1) What can rigorous research tell us about "good" and "bad" hospital design?
- (2) Can improved design make hospitals less risky and stressful and promote more healing for patients, their families, and staff?
- (3) Is there scientifically credible evidence that design affects clinical outcomes and staff effectiveness in delivering care?

This study involved a massive literature review through existing studies with a 32 key word search process referring to patient outcomes, physical environment, and other healthcare related issues. The studies were then screened for research design and quality. The outcomes were able to show what design features support improved patient outcomes, with the intent of making this information accessible to practitioners. A table below summarises the findings.

Healthcare Outcomes	Design Strategies or Environmental Interventions										
	Single-bed rooms	Access to daylight	Appropriate lighting	Views of nature	Family zone in patient rooms	Carpeting	Noise-reducing finishes	Ceiling lifts	Nursing floor layout	Decentralized supplies	Acuity-adaptable rooms
Reduced hospital-acquired infections	**										
Reduced medical errors	*		*				*				*
Reduced patient falls	*		*		*	*			*		*
Reduced pain		*	*	**			*				
Improved patient sleep	**	*	*				*				
Reduced patient stress	*	*	*	**	*		**				
Reduced depression		**	**	*	*						
Reduced length of stay		*	*	*							*
Improved patient privacy and confidentiality	**				*		*				
Improved communication with patients & family members	**				*		*				
Improved social support	*				*	*					
Increased patient satisfaction	**	*	*	*	*	*	*				
Decreased staff injuries								**			*
Decreased staff stress	*	*	*	*			*				
Increased staff effectiveness	*		*				*		*	*	*
Increased staff satisfaction	*	*	*	*			*				

Figure 5: Ulrich's study outcomes on healthcare EBD

What questions are we answering?

Population: Occupants of green office buildings, green office buildings going through a major renovation

Intervention: Certified green buildings as compared to conventional buildings

Phenomena being investigated: Improved occupant health, improved carbon outcomes.

- Is there evidence that certified green buildings improve occupant health and productivity?
- What design elements are in certified green buildings that improve occupant health and productivity?
- Is there evidence that certified green buildings reduce energy use and improve occupant health and productivity

Where are we searching?

Journals which relate to architecture, construction, sustainability and productivity. Some are listed below

- Architecture Australia
- Architectural Design
- Architectural Research Quarterly
- Interiors: Design, Architecture, Culture
- Journal of Architecture

- Smart and Sustainable Built Environment
- Design Studies
- Journal of Interior Design
- Journal of Green Building
- Architectural Theory Review
- Australian National Construction Review
- Building Design and Construction
- Journal of Facilities Management
- Journal of Construction Engineering and Management
- Design.build
- International Journal of Project Management
- Engineering, Construction and Architectural Management
- Australasian Journal of Construction Economics and Building
- Construction Management and Economics
- Automation in Construction
- International Journal of Construction Supply Chain Management
- International Journal of Construction Project Management
- HER

The relevant databases will include

- Proquest
- Emerald
- Science Direct
- Informit
- OECDiLibrary
- Wiley Online Library

What keywords are we using?

Keywords will need to be selected for each area being searched

Asset type	Physical performance	Occupant performance	Financial performance	Research type
Office	Daylighting	Health	Capital cost	Evidence based design
Commercial building	Ventilation	Wellness	Savings	Post-occupancy evaluation
Green certified	Acoustics	Productivity		
LEED	Layout	Concentration		
Green Star	Temperature	Absenteeism		
BREEAM	Indoor Environment Quality	Collaboration		
Other certifications	Sustainable	Thermal comfort		
Built environment	Energy efficient	Stress		
	Carbon neutral/positive/negative			

What conditions/exclusions are in place?

- Publication type: Scholarly journals peer reviewed
- Excluded: Government reports, advocacy body report, individual organization reports excluded (i.e. CETEC)
- Date range?
- Language: English
-?

Challenges in the evidence review

The first CTL report outlines some existing projects in the built environment for gathering and collating evidence, such as the BIDS project, but outlines that these projects are “not transparent in their process of sourcing and assessing evidence”. A clear and transparent methodology behind the systematic review and critical analysis is important. However, the data review process is complicated and needs to consider a number of variables:

1. Complexity and causation

The evidence to be reviewed for this project will be complex and broad. It is likely that there will be few studies that provide statistically sound causation between productivity improvements in occupants, and green building features. Complex analytical techniques, such as randomized controlled trials, are essentially the only way to test causation. These have been deployed in healthcare facilities to test patient outcomes but unlikely to have occurred in office buildings.

As human factors in relation to design cross many disciplines and data sources, seeking information on a single architectural feature is challenging (Edelstein 2008). The types of studies that have been conducted from a research perspective are likely to have inconsistent methodological approaches.

To overcome this issue, Dr Even Edelstein recommends to “go to research at the level of bio-medical and ethnographic data that may not test design installations themselves, but nonetheless reveal the impact of physical attributes on outcomes¹”. Essentially this is focusing on the health outcomes (i.e. increased productivity from daylighting) rather than the design feature itself (i.e. glass types). The systematic review will need to consider study types.

In addition, there are two performance areas this project is considering (1) Carbon and (2) health and wellness. Whether the SR takes studies into account that prove both within the same study, or separately needs to be defined.

2. How far we spread the net

There are considerations to the types of studies included:

- Single features (ie. Window design) as well as whole building performance studies

¹ Personal communication, Dr Eve Edelstein, 9 September 2015

Whilst tempting to align to a single design feature as part of the DR, the benefit will come from a wide search of information to start. Once there is an understanding of the types of information we can re-assess the SR and go into a more refined and targeted search.

- Pre and post-occupancy studies
In order to prove productivity improvements, a baseline will need to be used for comparison. Studies will need to show what the performance improvements are measured against a conventional building.
- Certified green vs built to green standard
Some buildings may have green features but not be certified. The judgment for their inclusion will need some guidelines otherwise it will be largely subjective based on the researchers perception of green.

3. The data sources

There are many databases housing information that will not be published in academic studies. Organisations conduct their own studies and retain this data for their IP. An example is shown in Figure 6 where Gensler are a design company undertaking and publishing their own research. Studies from sources such as are not going to be included in the research.

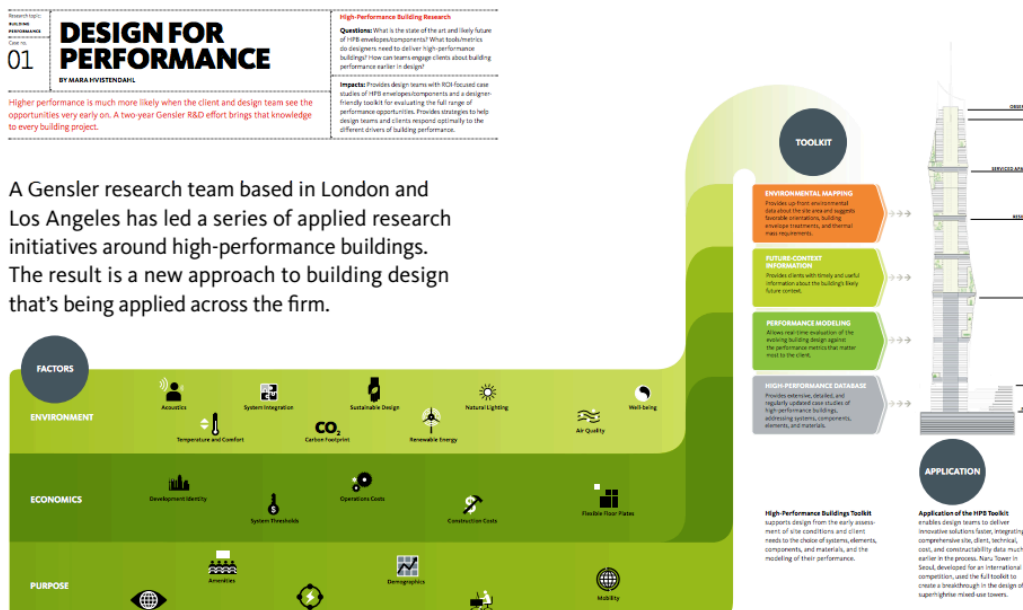


Figure 6: In-house databases and research summaries (Gensler)

4. Uncontrolled environments

The findings from academic studies that do prove to have a rigorous research methodology may not give the same results when applied. For example, thermal comfort and productivity studies have focused around call centres. These are controlled environments. For example, setting an environment with the ideal temperature of 22-23 degrees and above 10L/s air exchange reflects studies, but may not cause a lift in productivity due to other variables (i.e. low

workplace morale). A part of this work will be to remove what productivity impacts come from the physical environment, and from the working environment.

Weighing and analyzing the evidence

The first research report introduces strategies for weighing evidence. In the lead up to weighing the evidence it is important to assess the evidence. Ellen Taylor, the head of research for Centre of Health Design comments that EBD “needs a foundation of critical (quality) appraisal as part of the design process”.² The project will need to establish a critical analysis process considering the low maturity of evidence based research in this area.

A paper that Taylor published uses a MMAT (Mixed Methods Appraisal Tool) to assess evidence that is collected (Taylor and Hignett, 2014). Authors use a flowchart for analysis and also recommend a visual representation of study type and quality to help practitioners evaluate research as part of evidence based design.

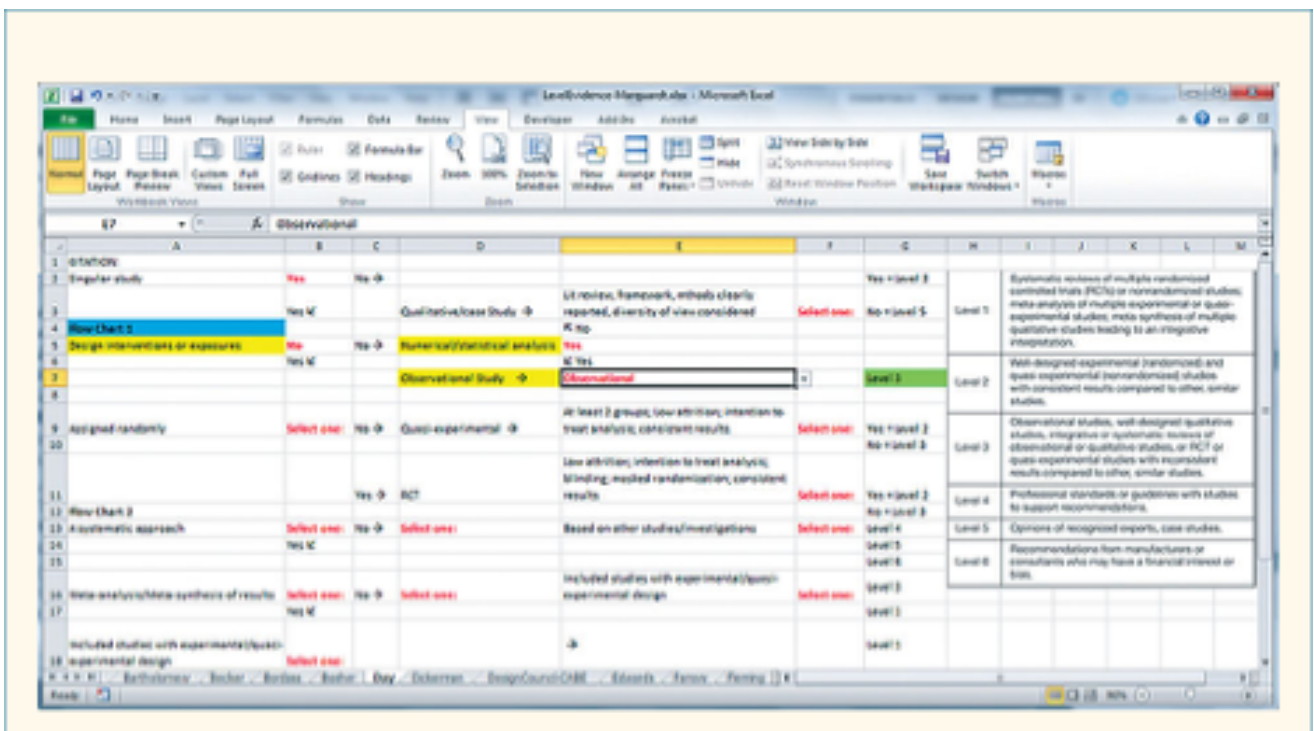


Figure 7: Critical appraisal process

When assessing the evidence the project can use a flowchart, as was applied in Taylor’s review above can be used – this will need to defined specifically for the project, an example in Figure 8.

² Personal communication – Ellen Taylor

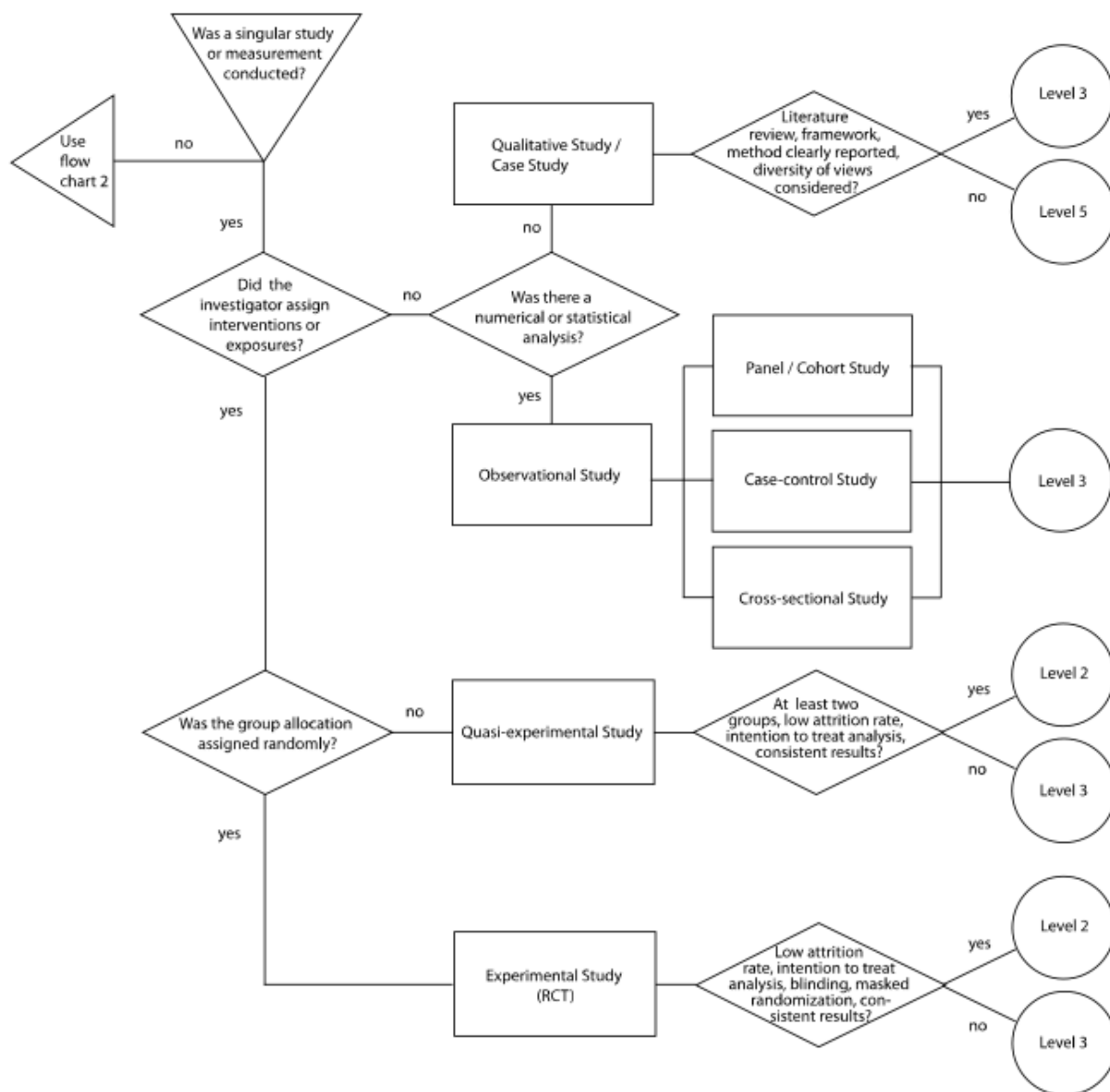


Figure 8: Example of flowchart for analysis (Marquardt and Motzek, 2013)

Critical Appraisal Tools (CATs) are available for use with a wide range of study types. A 2010 study reviewed 44 CATs (Crowe and Sheppard, 2011) that can be searched for applicability.

The type of appraisal conducted on the systematic review will need to be carefully selected given the expected types of evidence that will not be near as advanced as the medical industry. This will require input from academic experts and use of existing projects, such as Catherine Bridge’s Home Modifications project.

There may be scope to undertake a meta-analysis on the findings from the SR as part of the critical analysis, but it will depend on the quality of evidence. A similar study was conducted *“The Effect of Certified Green Office Buildings on Occupant Health: A Systematic Review and Meta-Analysis, explores the connections between certified green office buildings and their impacts on*

occupant health via the application of a systematic review and meta-analysis" (Haddox, 2013). 68 studies were identified but with the search criteria applied, only 2 were used in a meta-analyses.

Applying and trialling a framework - Fieldwork

The findings from the SR will no doubt be highly relevant and useful in supporting the need for evidence based design. It has the potential to demonstrate where designers may have thought they were relying on statistically sound evidence for design interventions.

The systematic review of evidence will need to be considered as a look at the past, with a set up for experiments to test findings and develop more robust research into the future. Once the SR and analysis is completed, the fieldwork can be reviewed.

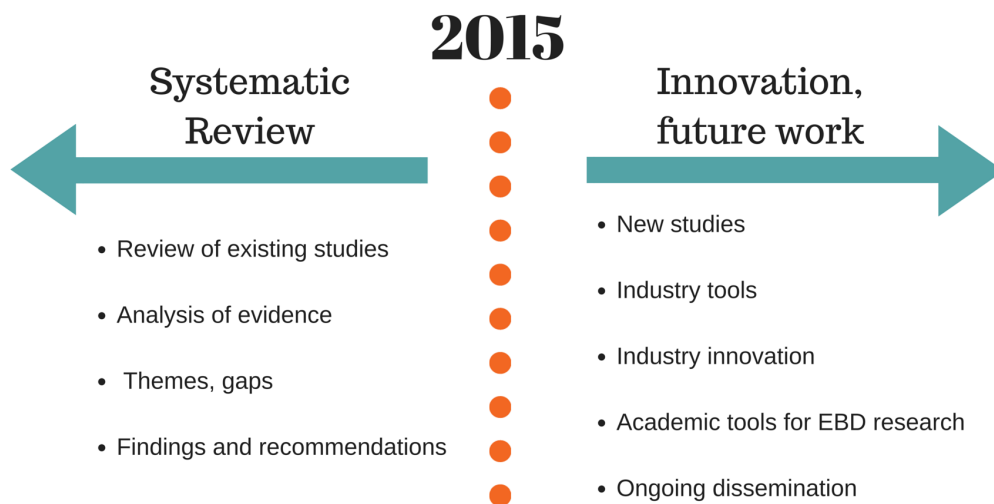


Figure 9: Systematic review process is looking back on existing evidence

Fieldwork conducted will use findings from the SR and establish testing the framework used. If possible, the fieldwork should be based on control and treatment groups to eliminate confounding variables. This can be a landmark study as it will remove the bias that often comes in productivity studies for office buildings. By selecting random samples in conventional and green buildings (or building projects) interventions can be effectively trialed. Some examples might include:

- Evidence based decision making tools trialed on control and treatment design teams
- Productivity assessments of occupants in certified green vs conventional buildings (preferably the same organisation or very similar organisations)
- Application of Rate My Space to control and treatment groups to see if feedback on space creates change within organisations

The future of evidence – Big Data and automation

'Big data' innovations are beginning to occur in the property sector. Network sensors are increasingly being used in buildings for real-time data results. Some examples include the SAMBA tool, Buildings Alive and Ovass. There are also tools to measure occupant productivity, such as 'Workplace-Analytics'. RICS identify that decision making in the built environment sector can be largely assisted with use of big data (Sawhney, 2015) and organisations are now building digital strategies as a normal part of business.

In this project it is important to consider digital disruption risks, and where 'Big data' will be evidence in the future. Clients are demanding data from architects, and from buildings as energy reporting standards increase (Davis, 2015). This type of real time data may not appear in academic studies now, but the field of built environment research will start to change to adapt to new forms of data. Whatever tools and outputs are delivered, if they do not consider data in the future they risk being outdated.

This type of data can influence behavior. Tim Flannery recently commented on change occurring due to social currency³. Applications such as Uber and AirBnB allow people to leave feedback. The app Houzz is similar, where people can leave feedback about residential designs and professionals. Flannery notes the scalability of such technology and the ability for social currency to influence behaviour. Similarly, Rate My Space was developed as a disruptive tool for the property industry. This is an occupancy survey where people rate their space, and receive an immediate wellness rating that can be forwarded to colleagues or building managers. The ratings will be aggregated to spatially map poor performing buildings from the occupant's perspective.

Occupancy evaluations are often manual and infrequently implemented on a regular basis. The growth of BOSSA, BUS and CBE surveys are starting to bring more attention to occupant centred design. When undertaking research for Rate My Space we found that architects/engineers/developers etc wanting ongoing monitoring of occupant experience in buildings they have designed. These types of data sources have the ability to influence building management practices.

The internet has enabled the growth of a shared economy and ability to access expertise instantaneously. There is scope for increase open access to publications as well as automation. The medical field currently undertake SRs extensive evidence bases and the process is laborious and expensive (Yang *et al.*, 2008) with room for automation. Figure 10 is a screen shot from F1000 a research tool for medical studies, where people can search and post articles for an online faculty to review and recommend. The algorithms in F1000 also search articles for you as it begins to understand your search patterns.

³ Speech at book launch, Perth 22 September 2015

The screenshot shows the F1000Prime website interface. At the top, there is a navigation bar with 'F1000Prime', 'F1000Research', and 'F1000Workspace' links. A search bar contains the term 'neuroplasticity' and an 'Advanced' search option. Below the navigation bar, there are links for 'ARTICLE RECOMMENDATIONS', 'RANKINGS', 'F1000PRIME REPORTS', 'F1000 FACULTY', 'JOURNAL CLUBS', and 'BLOG'. The main content area is titled 'SEARCH RESULTS' and 'Article Recommendations'. It shows that the search for 'neuroplasticity' has 145 results. There are filters for 'Sort by: Relevance' and 'Recommended in the past: All Time'. A sidebar on the left allows refining the search by 'All F1000Prime' (165), 'Article Recommendations' (145), 'F1000Prime Reports' (7), 'Faculty' (13), and 'Blog' (0). The search results list two articles: 'Learning in the fast lane: new insights into neuroplasticity' and 'Can quantitative sensory testing predict responses to analgesic treatment?'.

Figure 10: F1000 online research and review of articles

Evidence based decision-making

Humans are generally resistant to change. As laid out earlier in Doherty's (2005) review of evidence into medical practices, even if the evidence is available it needs to fit into the existing paradigm. It is important that any outcomes from the project are disseminated effectively in order to impact decision making.

Brown and Ecoff (2011) identify that a catalyst is what sets off evidence based design making. This might be a problem, issue or concern that has emerged from practice and can be in a number of formats such as newly published research, a new technology or legislation. For example, EBM was triggered by a publication on human errors. The NABERS protocol was started from a major publication in the 1990's identifying the carbon emissions from buildings. In order for the research to stay current and relevant it is important to understand what the catalysts are and to be aware of future waves of innovation. Authors note that such major catalysts can provide the impetus for practitioners to look beyond their own existing practices.

Integrating evidence into design is summarised in an article on Practice Based Design using key steps listed below (Zborowsky and Bunker-Hellmich, 2010), the author highlights that knowledge generation and dissemination stand out as clear benefits of the EBD movement. This will require collaborative efforts and openness to information. What it also requires is evaluation of hypotheses against design, without this critical step the feedback loop remains unclosed. For example, taking a research finding and applying it (i.e. new building façade) but not testing the outcome.

Table 1: Integrating evidence into decision making, adapted from Zborowsky et al (2010)

Steps for integrating evidence into design	Processes	Tools
Gather rigorous evidence	Generally a world wide web search but time consuming, and difficult for practitioners to assess validity of evidence	Dissemination tools Expert committees Brown bag seminars Education tools
Using evidence in decision making	Research summaries, evaluation of options	Mock ups and prototypes User surveys Research on existing spaces
Implement and test	Establish research criteria and monitor effectiveness	Post-occupancy assessments Space utilisation Productivity measures Sustainability measures
Critically evaluate results	Direct results back into design process	Lacking
Share results	Publishing and sharing is a new concept in firms, generally dissemination remains internal due to IP	Peer reviews publications Databases Conferences and presentations

The take-up of EBD requires further acceleration as practitioners are still not engaged (Martin, 2009). Despite pending climate change threats, it is interesting to look over a cityscape and still not see solar arrays, or strong evidence of buildings reducing their carbon footprints. Martin suggests low uptake of EBD may be due to the perception that the practice of following creativity and intuition is stronger than evidence, but emphasises that the two are synergistic and firms not adopting EBD will be left behind.

It is unlikely that changes will occur if there is not a broad professional consensus about the effectiveness of the decision (Hamilton 2011). Findings from EBD in healthcare show that a team of academics and experts are needed in the evaluation of evidence to provide the rigour and experience needed.

There are strategies for overcoming resistance to change that can be reviewed as part of this research and tools developed around the types of resistance expected. A thesis by Dr Roy Woodhead (1999) examined the influence of paradigms on decision making in construction, and recognised the different roles and influences stakeholders have at different times. Decision making tools will need to consider various decisions and stakeholders across a project life.

Kotter (2008) identified different types of resistance and the resulting implications, shown in Table 2. Applying this to design projects using evidence based design tools (Figure 11) could alleviate resistance to change, and involving stakeholders will be important to gauge acceptance of new concepts and processes.

A process like this could be established for the project and identified stakeholders. As we focus on tenants and designers in the first stage we believe the participation + involvement approach is the most appropriate.

Table 2: Methods for dealing with resistance to change (Kotter, 2008)

Approach	Commonly used in situations	Advantages	Drawbacks
Education + communication	Where there is a lack of information or inaccurate information and analysis.	Once persuaded, people will often help with the implementation of the change.	Can be very time consuming if lots of people are involved.
Participation + involvement	Where the initiators do not have all the information they need to design the change, and where others have considerable power to resist.	People who participate will be committed to implementing change, and any relevant information they have will be integrated into the change plan.	Can be very time consuming if participators design an inappropriate change.
Facilitation + support	Where people are resisting because of adjustment problems.	No other approach works as well with adjustment problems.	Can be time consuming, expensive, and still fail.
Negotiation + agreement	Where someone or some group will clearly lose out in a change, and where that group has considerable power to resist.	Sometimes it is a relatively easy way to avoid major resistance.	Can be too expensive in many cases if it alerts others to negotiate for compliance.
Manipulation + co-optation	Where other tactics will not work or are too expensive.	It can be a relatively quick and inexpensive solution to resistance problems.	Can lead to future problems if people feel manipulated.
Explicit + implicit coercion	Where speed is essential, and the change initiators possess considerable power.	It is speedy and can overcome any kind of resistance.	Can be risky if it leaves people mad at the initiators.

Applying Kotter's concepts to design projects, using evidence based design tools could alleviate resistance to change, and involving stakeholders will be important to gauge acceptance of new concepts and processes.

Evidence based decision making

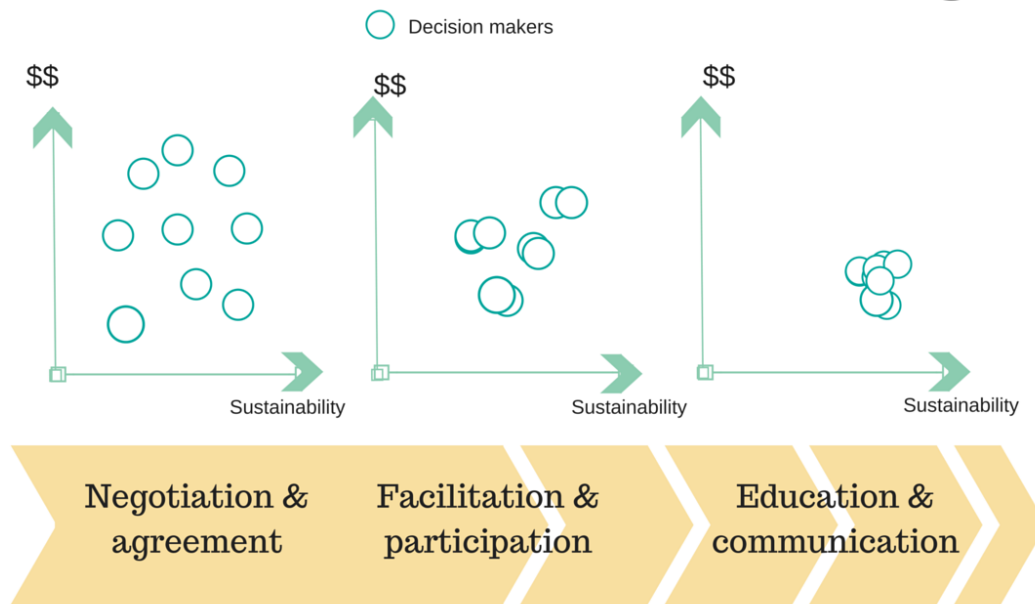


Figure 11: Evidence based decision making approaches to minimise resistance to change

Industry partners recognize that there is an abundance of evidence, but there is a lack of understanding about how and where to intervene with this evidence in a way which influences critical decision-making. In order to respond to this need, the aim is to further understand the existing decision frameworks and investigate the factors that might inhibit or enhance evidence-based decision-making, to facilitate the use of identified evidence. The project presents an ideal context to explore the decision frameworks during a design process, where many stakeholders are involved and time and budget constraints pressure managers to take quick decisions.

The preliminary analysis done on previous research indicates that the literature will give a solid theoretical framework on decision making and EBMgt on which we can base are further studies. However, further research is needed regarding practice-oriented research on EBMgt, from which practitioners can act upon. Furthermore, no studies have been able to analyze the decision framework of a team of managers to further experiment with concrete recommendations in order to foster evidence-based practices. Therefore, we propose to focus on this task to **identify what an organization can do in order to foster more evidence-based decision-making** in their teams.

Keeping this in mind, two complementary phases are proposed:

- An initial phase of science-oriented research will focus on the 'why' and the 'how' by exploring existing theories on decision-making and the mechanisms impacting evidence-based decision-making.
- A second phase with a practice-oriented approach, which will explore and test what works best in a business setting by performing an observational study of the most influential stakeholders, concluding with an experimental phase where changes in the decision framework will be tested.

Common currency - Performance metrics

The health and wellness indicators for building occupants are already largely researched. There are productivity indicators for green buildings, such as absenteeism, turnover and work outputs. Quantifying and comparing these parameters is difficult. The existing frameworks outlined in the first research report can be used as a basis (CABE, WGBC, BIDS) to determine which indicators will be used, and how to create a common currency measurable.

The importance of the common currency is that it defines multiple areas of performance. A challenge in green building research is the fragmentation of studies measuring different parameters. For example, measuring the impact of daylighting is done through various ways:

- lux levels
- occupant satisfaction with light
- organisational performance from varied lighting conditions (staff health & productivity outputs)
- energy performance from the building

A focus on energy efficiency would only need to look at energy performance of the light system, a productivity study would only look at occupant perception and productivity, but 'high performance' needs to encompass all of these variables.

A study which examined overall building performance in the healthcare sector showed that existing tools lack multi-dimensional analysis, Figure 12. The risk of not establishing a common currency with a multi-disciplinary analysis is that it just adds to the existing rating tools, rather than improving. The common currency component has the ability to add rigour to the existing tools.

User	Tool	Financial Performance	Physical Performance	Functional Performance	Service Performance	# of Dimensions Assessed
Planners, Architects, Construction Managers, Administrators	BREEAM		X			1
	BPAT+	X	X			2
	CASBEE		X			1
	SBTool	X	X			2
	LEED®		X			1
	NABERS		X			1
	SEMPER		X			1
Staff & Clients	BestFIT		X	X	X	3
	IEQ Survey		X		X	2
	OLS	X	X	X		3
All Users	AEDET Evolution		X		X	2
	ASPECT			X	X	2
	DQI		X			1
	IDEAS		X	X	X	3
	PATH		X	X	X	3
	ST&M		X	X		2
	EPFS	X	X	X	X	4
Number of tools that assess each dimension		4	16	7	7	

Figure 12: Content analysis of building evaluation tools

Tools such as LEED and Green Star have faced criticism in the past for potentially certifying buildings which may not operate at a ‘greener’ level than conventional buildings. This has led to the introduction of performance tools and more focus on buildings in operation. As health and wellness ratings start to escalate, there is a similar risk. For example, the Delos Wellness rating has very little publicly available transparency behind how the tool assess each of the assessment areas. Could this become a rating without the rigour?

This component could start with a Balanced Scorecard approach, where key indicators are selected and weighted for an overall score. This has been used in healthcare design projects and there are a number of studies we can adapt findings from. Another example is shown in Figure 13 from Ulrich’s work in healthcare centres, where a number of design variables were selected, with performance measures against those variables (Ulrich *et al.*, 2010).

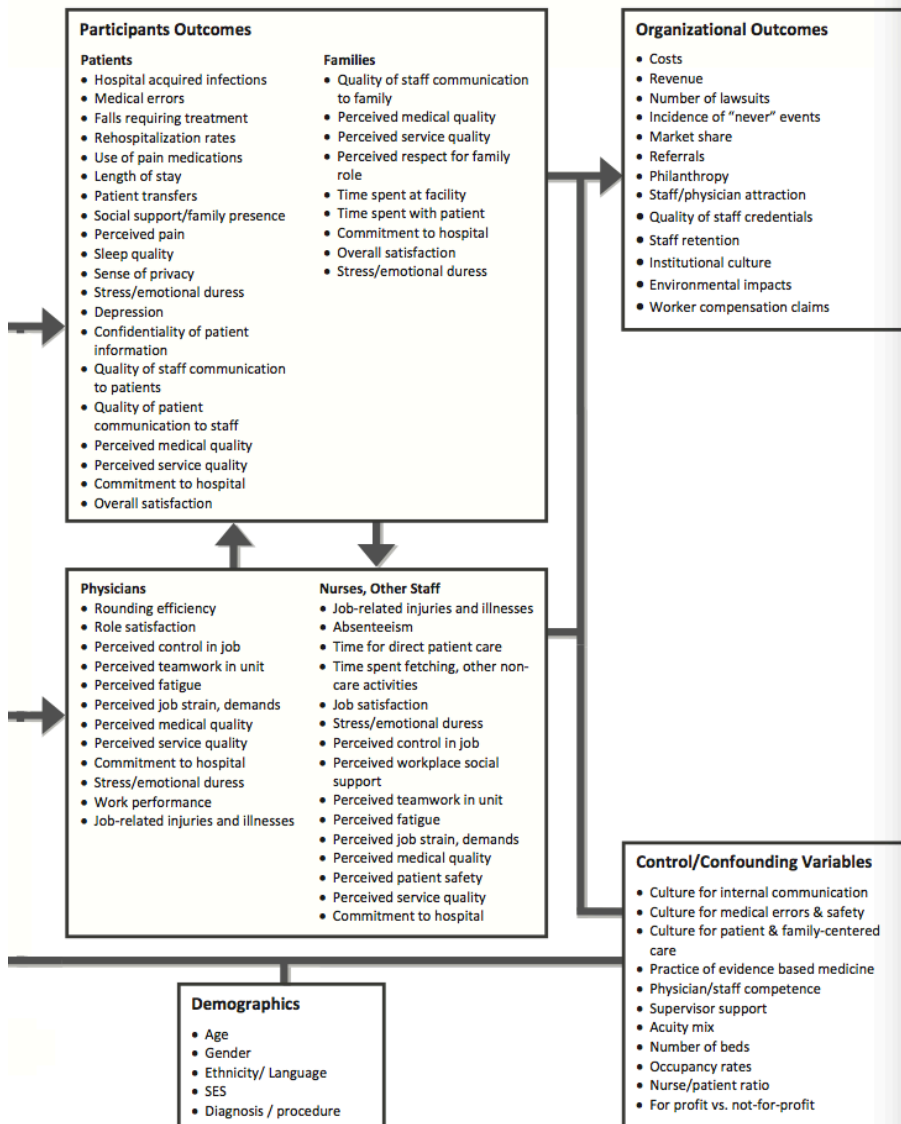
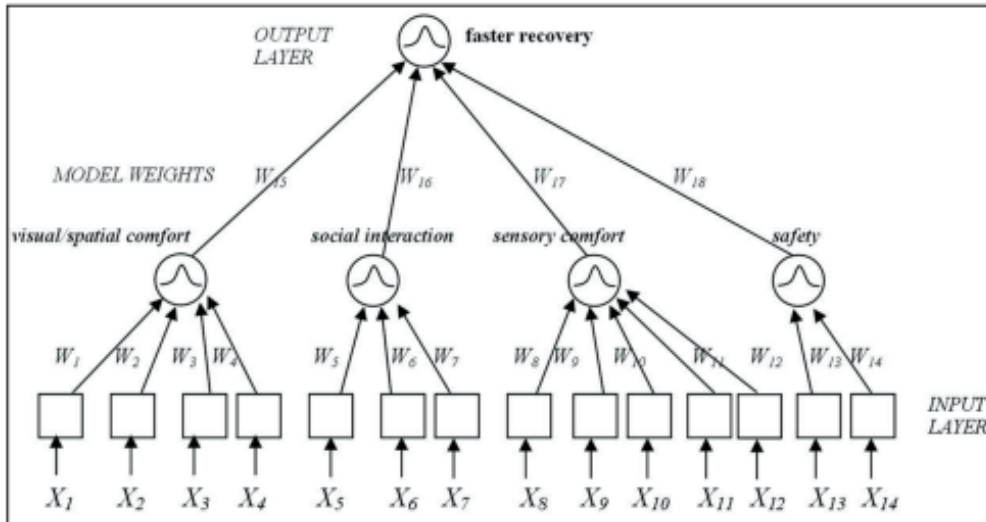


Figure 13: Design outcomes from built environment variables

The new approach will be:

- understanding how to weigh all of these variables
- how this common currency will be applied to projects in the future

A study that looked at how to make existing EBD knowledge more available to the planning and design community developed a knowledge modelling tool (Durmisevic and Ciftcioglu, 2010). This was driven by the 'information explosion' in EBD and the difficulties understanding which mix of design features should be used for patient outcomes. Shown in Figure 14, the model is computational with varied inputs from multiple design features that are graded (in this case a window is used as an example) and then fed into the tool.



View from a window				
grading	0.9	0.7	0.45	0.1

Dimension	Aspect	Characteristics	Grading Case 1 Baseline	Effect of Change for Case1 Improving Lounge	Effect of Change for Case1 Improving Art
Visual/spatial comfort	X ₁ Nature	Mixed view (nature/buildings in distance)	0.75	0.75	0.75
	X ₂ Art	not present	0.1	0.1	0.95
	X ₃ Spatial organization	Privacy	0.95	0.95	0.95
	X ₄ Windows	Informative view	0.95	0.95	0.95
Social interaction	X ₅ Family involvement /interaction with family	Single room	0.95	0.95	0.95
	X ₆ Interaction with staff	Single room not available	0.1	0.95	0.1
	X ₇ Lounge				
Sensory comfort	X ₈ Noise day	38 dB	0.90	0.90	0.90
	X ₉ Noise night	30 dB	0.95	0.95	0.95
	X ₁₀ Temperature	22 C	0.95	0.95	0.95
	X ₁₁ Light	1500 lux	0.95	0.95	0.95
	X ₁₂ Air quality	10 L/s	0.90	0.90	0.90
Safety	X ₁₃ Material	Isolation	0.80	0.80	0.80
	X ₁₄ Spatial organization	Single room	0.95	0.95	0.95

Figure 14: Knowledge modeling tool for common currency

Current centres of EBD

Centre for Health Design

The Centre for Health Design (CHD) was created to link evidence based design into practice. It was started in 1993 by healthcare professionals wanting to advance the concept that design could improve patient outcomes in healthcare environments. CHD are now a knowledge hub for EBD in healthcare and provide publications, toolkits, checklists, training and programs.

CHD ranks information from peer-reviewed articles and creates industry tools and publications to inform the industry. For much of CDH's work they looking across a diverse range of sources for information, with the focus not always on the built environment. For projects they develop a review sheet with the various aspects of the study, population, study design, variables, outcomes, etc.⁴ CDH do not actually complete a critical appraisal of the evidence but review the sources as originating in:

- 1) research or a systematic review;
- 2) some form of white paper or consensus document or
- 3) best practice/expert opinion (usually from a peer-reviewed journal).

The way that studies are selected are visible so readers are able to evaluate the rigour themselves.

This is a sample of some of the publications available on the CDH website:

EDAC Study Guide 1: An Introduction to Evidence-Based Design
EDAC Study Guide 2: Building the Evidence-Base
EDAC Study Guide 3: Integrating Evidence-Based Design
Environment & Behavior
Evidence for Innovation: Transforming Children's Hospitals Through the Physical Environment
Fable Hospital 2.0: The Business Case for Building Better Healthcare Facilities (The Hastings Center Report)
Frontiers: Can Better Buildings Improve Care and Increase Your Financial Returns?
Health Environments Research & Design (HERD) Journal
Health Facilities Management
Health Facility Evaluation for Design Practitioners
Healthcare Construction and Operations
Improving Healthcare with Better Building Design

CDH also have a knowledge repository they continually build upon, from where they distribute relevant peer-reviewed papers to research analysts. The analysts are screened prior to working with them and are tasked to create a systematic summary of the paper, including limitations and design implications. The intention is that this puts others in a position to evaluate the

⁴ Personal correspondence, Ellen Taylor 4 September 2015 – Director of Research, CDH

sources themselves, based on their own context and need. CDH do not post the full text papers themselves due to copyright, but if readers want to see the full text they can access it through their own sources. (<https://www.healthdesign.org/search/articles>)

Pebble Project

The dissemination of information and decision-making influence that CHD has on the industry should be reviewed for this project. They have a number of industry tools including toolkits and occupancy evaluations. The dissemination of project outcomes through mechanisms such as CDH’s Pebble Project® are said to foster sharing and contribute to the sharing of evidence (Brown and Ecoff, 2011). The Pebble Project is a closed forum where industry partners share and learn from experiences, post challenges and receive guidance from a panel of CDH experts.

What works well network

The What Works Network was established by the British Government to create more evidence-informed policy. Similar to EBD these centers all follow a process of assessing evidence via established metrics, and publishing/disseminating that information in a format that can be understood by relevant policy makers and practitioners. There are 7 independent centres and 2 affiliate members, combined the centres cover policy areas that receive over 200 billion pounds in public spending (Cabinet-Office, 2015). The current centres are:

Table 3: What Works Network Centres (From WWN website)

What works Centre	Policy area
National Institute for Health and Care Excellence (NICE)	Health and social care
Sutton Trust/Educational Endowment Foundation	Educational achievement
College of Policing What Works Centre for Crime Reduction	Crime reduction
Early Intervention Foundation	Early intervention
What Works Centre for Local Economic Growth (hosted by LSE, Arup, Centre for Cities)	Local economic growth
Centre for Ageing Better	Improved quality of life for older people
What Works Centre for Wellbeing	Wellbeing
Affiliates:	
Public Policy Institute for Wales	
What Works Scotland	

As outlined on the WWN website, the networks function by:

- collating existing evidence on how effective policy programmes and practices are
- producing high quality synthesis reports and systematic reviews in areas where they do not currently exist
- assessing how effective policies and practices are against an agreed set of outcomes

- *sharing findings in an accessible way*
- *encouraging practitioners, commissioners and policymakers to use these findings to inform their decisions*

The centres are funded through government and research council funding. Each has different volumes of funding and undertake varied approaches to types of evidence reviewed. An example (Bristow *et al.*, 2015) discuss that the Centre of Local Economic Growth (WWG) review existing research, whereas the Early Intervention Foundations receive sufficient funding to conduct their own trials. The Centre for well-being outsource their reviews. In establishing such a network it is important to consider the funding arrangements and strategies for reviewing and analysing evidence.

The effectiveness of these centres is difficult to determine as of yet, only recently established. (Bristow *et al.*, 2015) have identified three key insights that these centres need to consider for their success:

1. Evidence standards and analysis needs to consider the questions that policy makers have to remain relevant, hence not drifting into theoretical but remaining with practical applied outcomes
2. Consider the complicated policy arena, and contestability issues
3. Information is not enough to change policy, the focus will need to also be on “knowledge mobilisation”

One important note authors make, relevant to this project, is that the focus on existing evidence should not over-shadow others forms of knowledge. If a trial or intervention has not been conducted, it doesn't mean this won't work, there is just no research in that area as of yet. Authors compare this to Evidence Based Medicine and that practice is informed by judgment and expertise, as well as evidence based guidelines.

Planetree.org

Planetree are an NFP on the other side of the research, rather than a design focus they have a patient focus. Planetree conduct focus groups and consultation with end users, such as caregivers and patients to inform policy and design. This model is interesting, in the built environment there are few voices for the occupiers of buildings. For example, there is a Property Council of Australia that represents the views of building owners and stakeholders, but what about the occupants? More formalized processes for collecting patient information has enabled Planetree.org to develop a series of tools for industry to deliver better, more patient centred projects. As health and wellness research grows, occupants will demand a stronger voice to include occupant-centred design considerations into buildings.

Informe Design

Informe Design is a free online databases that was launched in 2003. The mission was to facilitate the use of current research around design and human behavior into practitioners decision making and design processes (Martin, C. 2009).

The organisation had 3 goals when starting:

1. Collect, interpret and disseminate information
2. Improve communication and enhance knowledge amongst researchers and practitioners
3. Utilize input from design practitioners to identify issues and increase perceived value of research

The concept emerged from the recognition that practitioners couldn't locate and access applicable research. Despite this, people (i.e. architectural firms) were not willing to pay fees as these would need to be passed along to a client. Creators conducted due diligence and found many sites with articles and information, but those articles accessible to practitioners were generally created by other practitioners, and may not be backed by scientific research. The centre was established with a major sponsor and relies on external funding.

In selecting the research to be accessed through InformeDesign, it was originally intended to be journal articles as well as industry reports, trade magazines, articles etc but didn't contain the rigour of refereed journals. Hence refereed journals with clear research summaries were chosen as the only input. The articles must clearly include how the findings are transformed into evidence based design, a clear research method. The language and title must also follow a style that easy to understand and access.

In 2009 there were approximately 56,000 research summaries downloaded from Informe Design per month.

Centre for Active Design

The Centre for Active design is a not for profit that support architecture and urban planning for public health. Their role is the translation of health research into design solutions for practitioners.

The centre has published a number of landmark resources including:

- Active Design Guidelines
- Building Healthy Places Toolkit
- Active Design Toolkit for Schools

The Centre disseminates information through consulting services, training and workshops, publications and sharing of other publications, advocacy

The Centre for Active Design do not conduct systematic reviews but have a system in place for conduct literature reviews.⁵ They consult academic and professional literature and collaborate with a series of experts in the field who are often in key in helping to identify the appropriate literature. When synthesizing research publications, they assess the rigor of the studies and whether it should be used as a supporting resource.

⁵ Personal communication, Centre for Active Design Senior Resercher

Some Tools for integrating evidence based design into decision making

Industry tools will evolve as the research is undertaken, and the industry engagement shows gaps in knowledge around which tools can be developed. This section outlines some tools currently being used, or adaptable for use, in the EBD space.

Content and Quality in Briefs instrument

Project briefs also need to be part of the EBD process. The Content and Quality in Briefs Instrument (CQB-I) was designed to assess the content and quality of information in briefs being used for early stages of hospital designs (Elf and Wijk, 2014). Authors state that the pre-design phase is critical for delivery of projects and the document must be systematic, person-oriented and evidence based.

A review of information contained in briefs showed that few briefs contained explicit patient focused goals for the project, measurable patient outcomes and less than half of the briefs studies contained references to new evidence. Planners found that the tool could be a guide in the planning process and help important issues from being overlooked. A tool such as CQB-I has the ability to create more collaborative decision making at the start of projects. The author has been contacted and will be supplying a manual for this tool.

Table 1. Content and Quality in Briefs Instrument (CQB-I) and the Assessed Relevance Measured Using a Content Validity Index (CVI) (n = 9)				
	Quality Level			CVI
	0	1	2	
1. Is there a description of why a new healthcare environment is needed?	0	1	2	1.0
2. Are the needs of the patients included in the description of why a new healthcare environment is being investigated?	0	1	2	0.75
3. Are the needs of the significant others included in the description of why a new healthcare environment is being investigated?	0	1	2	0.5
4. Are the needs of the healthcare personnel included in the description of why a new healthcare environment is being investigated?	0	1	2	1.0
5. Is there a description of the organization?	0	1	2	0.88
6. Is there a description of the healthcare-related activities that are to take place in the new healthcare environment?	0	1	2	0.88
7. Is there a description of the relationships among spaces that are to be housed in the new healthcare environment?	0	1	2	1.0
8. Are there explicitly described outcomes for the new healthcare environment?	0	1	2	0.88
9. Are the needs of patients included in the outcomes for the new healthcare environment?	0	1	2	0.75
10. Are the needs of the significant others included in the outcomes for the new healthcare environment?	0	1	2	0.75
11. Are the needs of the healthcare personnel included in the outcomes for the new healthcare environment?	0	1	2	1.0
12. Is there a description of the types of post-occupancy evaluation of the new healthcare environment?	0	1	2	0.63
13. Is there any reference to evidence?	0	1	2	0.63
14. Is there any reference to the national quality indicators for high-quality healthcare?	0	1	2	0.25
				Σ 0.79

Figure 15: CQB-I tool snapshot

Toolkits

There are opportunities to develop a range of manuals, toolkits and guidelines. Some of these include:

- Manuals and guidelines based on systematic review findings
- Guidelines for designers and architects to rate quality of research (Marquardt and Motzek, 2013)
- Pre and post occupancy toolkits
- Building performance evaluation toolkits
- High Performance Building toolkits

Dissemination of information

- Workshops
- Webinars
- Training
- BIDS equivalent – Centre for High Performance Design

Client tools

- High Performance building management tools
- Staff engagement tools
- Change management guidelines for new design (i.e. Active workplaces)
- Decision making processes/tools

Serious game interventions

Serious gaming is developing as a research area to assist decision making. An example is 'Road Roles' a game being developed to transition contractors who manage road assets from traditional contracts to more long term, performance oriented contracts. Gaming simulation is ideal where multiple decision makers are involved in strategic decisions. Variations of such games to integrate EBD into decision making can be explored as a technique.

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