LOW CARBON LIVING CRC

RP1009 Closing the Loop, Evidence-Based Design and Systematic Review

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EXECUTIVE SUMMARY

This report articulates, discourses why and how to use evidence from empirical studies to close the loop of design practices. An early effort by RIBA (Royal Institute of British Architects) aiming to bring the stage of "feedback" into the design process was not successful due to the nature of the building practice that is unidirectional and irreversible. However, this endeavor aroused interests and attentions in academia where post-occupancy evaluations (POE)/empirical studies are continuously conducted to look at the impacts of built environments on occupants' use behavior, satisfaction, health and productivity. Arguably, a more sensible way to "closing the loop" is using the lessons from these POEs/empirical studies to inform design brief in the early stage rather than adding a new stage "feedback" in the late stage. The question is: how to draw on these POEs/empirical studies? Learning from Evidence-based Medicine (EBM) that emphasizes the use of evidence from well designed and conducted research for healthcare decision-making, evidence-based design (EBD) is emerging in the built environment area aiming to use evidence from POEs and empirical studies to inform healthcare facilities/workplace design. The EBD research projects conducted by WGBC (World Green Building Council), CMU (Carnegie Mellon University), CABE (Commission for Architecture and the Built Environment) and so on provide useful frameworks to align and present evidence for healthy and productive design. Pros and cons of these frameworks are discussed to imply for the CRCLCL RP 1009. This report also includes theories and methodologies about Systematic Review from social sciences to complement the EBD for better standardization and transparency. To make up for the gap left by previous EBD research, it is expected that the CRCLCL RP 1009 can collage fragmented evidence to identify a larger picture showing what's the role of physical environments in modern workplaces. Last but not least, this report aims to help the coming PhD students better understand this project and conduct the evidence collection work.

THE UNCLOSED LOOP

Building practices have been criticized for lacking understanding the real needs of the people who use buildings for years. There is very little feedback in the building practice. In 1960s, the Royal Institute of British Architects (RIBA) published its Plan of Work for Design Team Operation, which included Stage M – Feedback in the design process of Stage A to M (inception, feasibility, outline proposals, scheme design, detail design, production information, bills of quantities, tender action, project planning, operations on site, completion). Stage M suggested that the designers returned to the building to review the success and failure of what had been done. In spite of this, designers and builders did not engage closely with the performance of the buildings they have created. Sadly, Stage M was withdrawn from RIBA's Architect's Appointment (RIBA, 1991). While the stage M is still present in principle, it is just in name. Experience had shown that most organizations and clients were unable to cope with this and seldom paid for such feedback. The loop of building practices was not really closed.

There are many remarks and comments on the unclosed design loop. Even the erroneous assumption of architectural practice can be disclosed in reality, the design can not be redone and the building can not be dismantled and assembled. Stage M was merely a gesture trying to regulate the business conduct of architectural practice in an increasingly competitive economic environment. As Francis Duffy pointed out in the article "Reflection on Stage M: The Dog that Didn't Bark", a typical office design supply chain, is invisible, top down, unidirectional, practically unstoppable once started, and, worst of all, to all intents and purposes, it is completely feedback free (Duffy, 2012). So, it is difficult, if not completely impossible, to close the loop through the add-hoc feedback when the action of designing and building completed.

POST-OCCUPANCY EVALUATION

In spite of the feedback free design process, the effort brought some excellent building performance assessment work since 1970s (Lorch, 2001). The Probe (Post-occupancy Review Of Buildings and their Engineering) post-occupancy evaluation studies are a landmark in the seminal Post-occupancy Evaluation studies. This series of case studies, known as the Post Occupancy Review of Building Engineering (PROBE) Studies, describe practical evaluation studies on a number of buildings. Probe series of POEs of buildings had been published in Journal of the Chartered Institution of Building Services Engineers (CIBSE) (formerly Building Services Journal), Journal of Building Research and Information (Bordass et al., 2001a, Bordass et al., 2001b, Bordass et al., 2001c), etc. Although that Probe project and other building performance studies in the UK has now ceased, POE has continued as a research activity across the world and the articles on POE has shown the close collaboration between researchers, designers and publishers, shown in Figure 1 and 2. More than 460 articles are found using the keywords “post-occupancy studies/evaluation” and these articles are cited more than 1896 times.

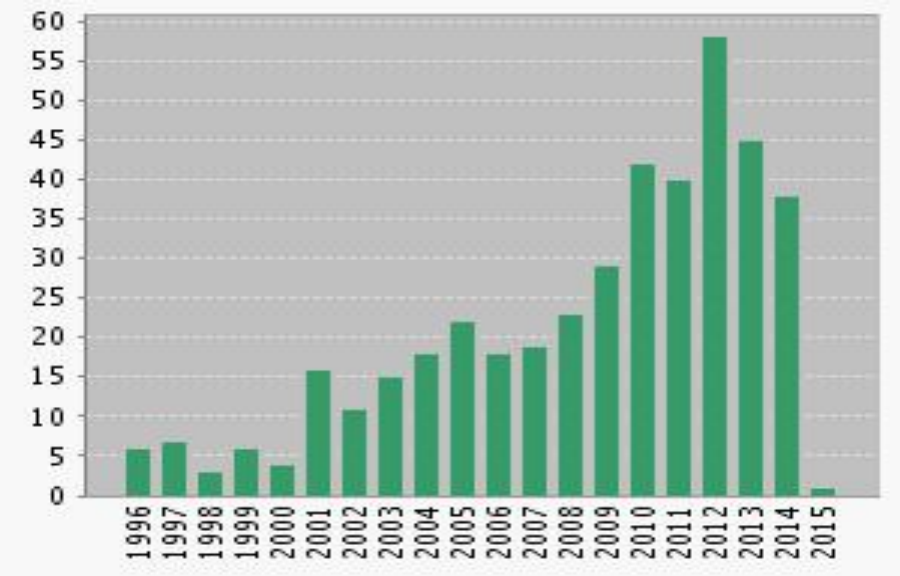

Figure 1: Number of Peer-reviewed articles on Post-occupancy Evaluation

Source: Web of Science

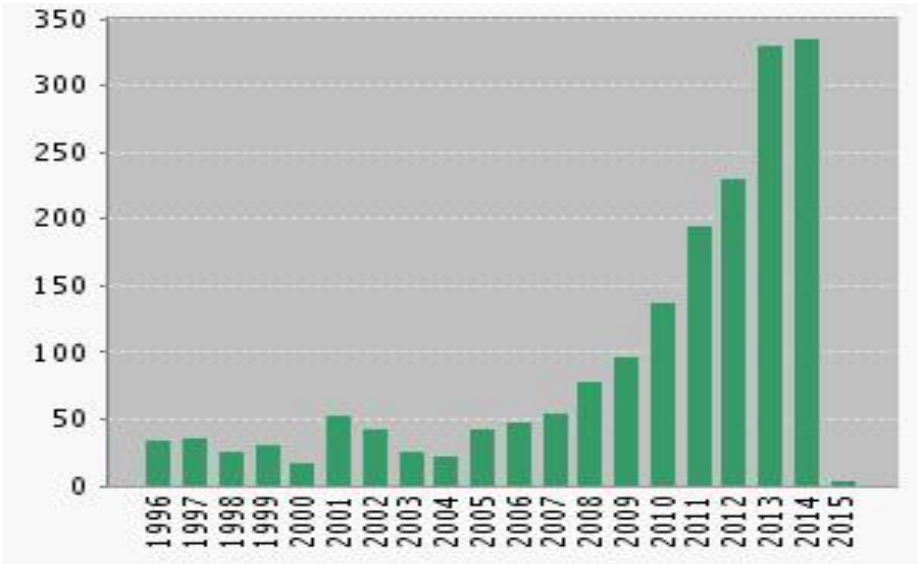

Figure 2: Times of citations of the articles in Figure 1

Source: Web of Science

Figure 3 lists out journals where POE articles are published. Figure 4 shows the research areas of these journals. Figure 5 further analyses the locations where these studies are conducted. Most of these journals are in the area of construction building technology and engineering. Those studies were conducted via environment and behaviour research to understand the experience of building occupants (Preiser, 2001, Preiser, 2003). The topics included in a typical POE are health, safety, security, function, efficiency, work flow, and occupants' psychological, social and cultural needs (Eley, 2001, Karim and Crozier, 2009, Kooymans and Haylock, 2006). The main use of POE turned to office buildings, with a new emphasis on the advanced role of POE in assessing worker productivity or performance in the workplace. The main attributes of these POE instruments are to measure occupant productivity, health, and satisfaction with the IEQ (Indoor Environment Qualities) including overall comfort, temperature, air quality, lighting, noise, space layout, workstation and furnishings as well as facilities maintenance.

View Records / Exclude Records	Field: Source Titles	Record Count	% of 322	Bar Chart
☐	BUILDING RESEARCH AND INFORMATION	45	13.975 %	
☐	BUILDING AND ENVIRONMENT	21	6.522 %	
☐	JOURNAL OF ARCHITECTURAL AND PLANNING RESEARCH	18	5.590 %	
☐	PROCEDIA SOCIAL AND BEHAVIORAL SCIENCES	17	5.280 %	
☐	ENERGY AND BUILDINGS	13	4.037 %	
☐	HERD HEALTH ENVIRONMENTS RESEARCH DESIGN JOURNAL	12	3.727 %	
☐	ARCHITECTURAL SCIENCE REVIEW	8	2.484 %	
☐	INDOOR AND BUILT ENVIRONMENT	8	2.484 %	
☐	OPEN HOUSE INTERNATIONAL	6	1.863 %	
☐	PROCEEDINGS OF THE NATIONAL PASSIVE SOLAR CONFERENCE	5	1.553 %	
View Records / Exclude Records	Field: Source Titles	Record Count	% of 322	Bar Chart

Figure 3: Journals where post-occupancy evaluation articles published

Source: Web of Science

Use the checkboxes below to view the records. You can choose to view those selected records, or you can exclude them (and view the others).

View Records / Exclude Records	Field: Research Areas	Record Count	% of 322	Bar Chart	Save Analysis Data to File: Data rows displayed in table / All data rows (up to 200,000)
☐	CONSTRUCTION BUILDING TECHNOLOGY	132	40.994 %		
☐	ENGINEERING	88	27.329 %		
☐	ENVIRONMENTAL SCIENCES ECOLOGY	60	18.634 %		
☐	ARCHITECTURE	54	16.770 %		
☐	URBAN STUDIES	46	14.286 %		
☐	ENERGY FUELS	35	10.870 %		
☐	PUBLIC ENVIRONMENTAL OCCUPATIONAL HEALTH	34	10.559 %		
☐	PSYCHOLOGY	14	4.348 %		
☐	PUBLIC ADMINISTRATION	12	3.727 %		
☐	EDUCATION EDUCATIONAL RESEARCH	11	3.416 %		
View Records / Exclude Records	Field: Research Areas	Record Count	% of 322	Bar Chart	Save Analysis Data to File: Data rows displayed in table / All data rows (up to 200,000)

Figure 4: Categorizations of these journals

View Records / Exclude Records	Field: Countries/Territories	Record Count	% of 322	Bar Chart	Save Analysis Data to File: Data rows displayed in table / All data rows (up to 200,000)
☐	USA	105	32.609 %		
☐	ENGLAND	64	19.876 %		
☐	PEOPLES R CHINA	18	5.590 %		
☐	AUSTRALIA	15	4.658 %		
☐	MALAYSIA	13	4.037 %		
☐	CANADA	12	3.727 %		
☐	BRAZIL	9	2.795 %		
☐	NEW ZEALAND	9	2.795 %		
☐	NETHERLANDS	8	2.484 %		
☐	TURKEY	8	2.484 %		
View Records / Exclude Records	Field: Countries/Territories	Record Count	% of 322	Bar Chart	Save Analysis Data to File: Data rows displayed in table / All data rows (up to 200,000)

Figure 5: Locations of these studies

Among these journals, a new but important journal dedicated to EBD research is The Health Environments Research & Design Journal (HERD) whose mission is to enhance the knowledge and practice of evidence-based healthcare design by disseminating research findings, discussing issues and trends, and translating research to practice. HERD is the only journal featuring papers on evidence-based design of health environments and the relationship of the environment to clinical outcomes, as well as outcomes related to organizational performance and the human experience. The articles covers the healthcare (including nursing, medicine and administration), the design industry (architecture, engineering, interiors, graphics), environmental and behavioral psychology, neurosciences, systems and organizational effectiveness, art and music fields, and other complementary fields. See more: https://www.herdjournal.com/.

The search and count are based on Web of Science by Thomson Reuters where most journal databases are included. Actually, the articles on this topic are far from these numbers. There are some other important databases that are not included and cited by Thomson Reuters. An ignored while important online database where many POEs can be found is Emerald. Three journals are most relevant: Journal of Facilities, Journal of Facilities Management and Journal of Corporate Real Estate. Journal of Facilities (http://www.emeraldinsight.com/loi/f) investigates how people, property and process management expertise can underpin successful organizational functions in the workplace. Journal of Facilities Management (http://www.emeraldinsight.com/loi/jfm) is another important journal that publishes case studies on how facilities can and do play a vital part in helping deliver corporate strategy. Journal of Corporate Real Estate (http://emeraldgrouppublishing.com/products/journals/journals.htm?id=JCRE) contains some interesting case studies about current best practice as well as key issues of tomorrow that the corporate real estate executive needs to be aware of. These Journals provide articles to inform workplace administrators, facilities managers, architects and other property stakeholders of the latest developments in topics such as post-occupancy evaluation, relocation and change management, ergonomics and workplace design, environmental and workplace psychology etc.

However, these studies are drown in the flooding of academic publications and never came to the industry to influence the building practice. A question may rise: how to draw on these studies to inform the design brief in the early stage instead of late stage?

EVIDENCE-BASED DESIGN

Evidence-based design research is emerging as a new field of study in the built environment area to emphasize credible evidence to influence design. This approach has become popular in healthcare to improve patient and staff well-being, patient healing, stress reduction and safety. The idea is originally from medical research: Evidence-based medicine (EBM) that emphasizes the use of evidence from well designed and conducted research in healthcare decision-making (Evidence-Based Medicine Working Group, 1992). The term was originally used to describe an approach to teaching the practice of medicine and improving decisions by individual physicians. It is a systematic process of evaluating scientific research which is used as the basis for clinical treatment choices. It is defined as a conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients. Now, it is more widely used in the social and business industry to emphasize the use of evidence in the design of guidelines and policies that apply to populations ("Evidence-based Policies") (Eddy, 1990). The Evidence-based Policies are to convince decision-makers to invest the time and money to build better infrastructure, adopt effective intervention as well as to realize strategic business advantages (Gray, 2009).

In the built environment area, evidence-based design is a multi-disciplinary research involving environmental psychology, architecture, neuroscience and behavioral economics. Since evidence-based design is to base design decisions on the best available research findings, reviewing, the research mainly involves assessing, and synthesizing existing research literature, selecting significant findings and recommendations, matching referenced findings with data gathered from site visits, survey results and subject-matter experts, predicting the outcome of design decisions, tracking positive outcomes for design implementation. There are some important evidence-based design research projects that sum up the POEs/empirical studies and generalise some guidelines for healthy and productive building design. One of common features of these research projects is that a framework must be established to align and present the evidence from each study. In order to look at what's the appropriate framework to gather evidence for design decision making, three projects are reviewed: World Green Building Council "Health, Wellbeing and Productivity in Offices: The Next Chapter for Green Building", Commission for Architecture and Built Environment "The Impact of Office Design on Business Performance", and Carnegie Mellon University "Building Investment Decision Support". The three reports all try to measure and quantify the human benefits of green or sustainable design. The hypothesis is that staff costs, especially their salaries and benefits, typically account for around 90% of business operational costs. Hence, a modest improvement in staff health and productivity can lead to a huge financial implication for employers.

WGBC Report

Recently, World Green Building Council (WGBC) published a report on "Health, Wellbeing and Productivity in Offices: The Next Chapter for Green Building" (WGBC, 2014). This report proposes a high level framework for measuring organizational outcomes and relating those back to the physical features of buildings and employee perceptions. This updates with latest information on the building design features that are known to have positive impacts on the health, wellbeing and productivity of office building occupants. As shown in Figure 6, 13 aspects are pointed out as the potential design opportunities. This report includes design aspects such as indoor air quality, thermal comfort, lighting and views of nature, noise and acoustics, interior layout, active design and exercise, which have a long track of evidence; it also covers some potential aspects such as look and feel, access to transport and amenities and so on, which do not have much supportive evidence but are treated equally important in the perspective of design professionals.

Furthermore, the report provides a high-level framework for building owners, occupiers and their advisors to start tracking the impacts of buildings on employee health, wellbeing and productivity. The panel initially proposed a list of almost 40 possible health, wellbeing and productivity outcome metrics, and then screened the metrics through a number of categories in terms of applicability across business types, ease of measurement, ease of relation to building features, cost to measure, financial impact of metric to business, and manifestation time (how long it takes for the metric to appear: for example, immediate illness vs. long-term health impact). Based on these criteria, the list of outcome metrics are compiled in a 4-quadrant schematic (Figure 7) to separate out the outcomes by ease of measurement and impact on business. Finally, seven metrics are selected: Absenteeism; Staff Turnover/Retention; Revenue breakdown; Medical costs; Medical complaints; Physical complaints, and Self-perceptions as determined by a survey.

In sum, we can find three matrices in this report: the first is physical metrics that are direct measures of the physical office environment, such as temperature, are key to measuring the effect on the health, wellbeing and productivity of workers; the second is financial metrics including absenteeism, staff turnover, revenue breakdown (by department or per building), medical costs and complaints, and physical complaints; the third is perceptual metrics referring to studies which test a range of self-reported attitudes into health, wellbeing and productivity in the workplace can contain a wealth of information for improving office performance.

Figure 6: Design Aspects Covered by the WGBC Report

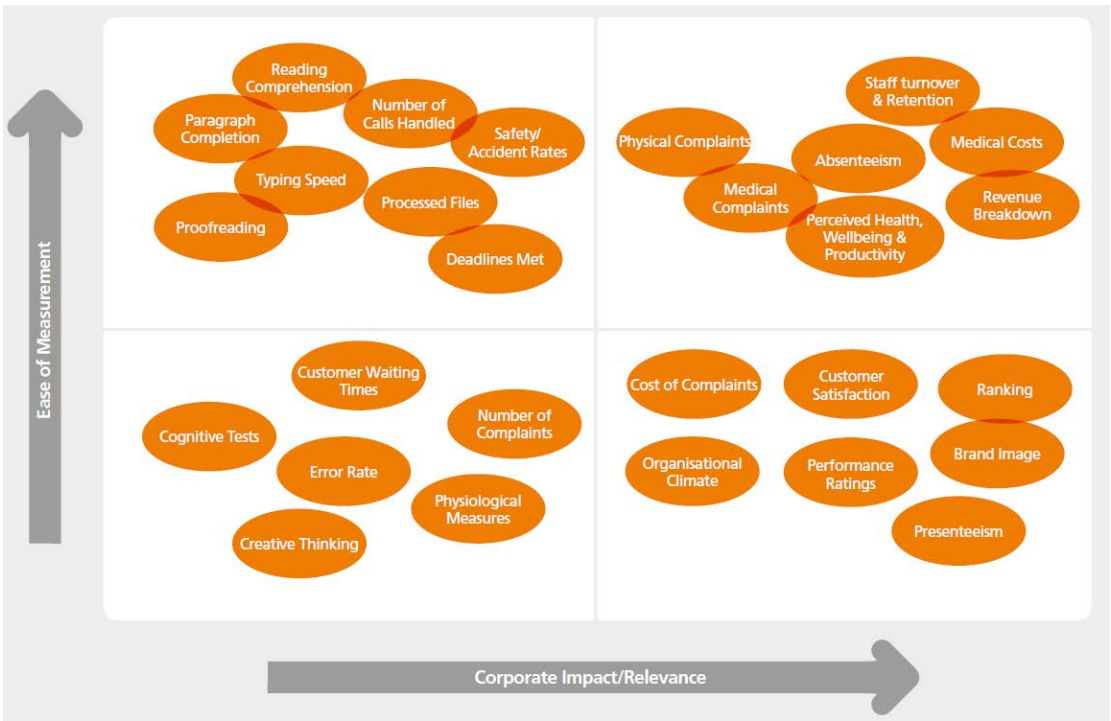

Figure 7: Performance matrix to measure health, productivity and well-being

CABE Report

An early report by CABE (Commission for Architecture and the Built Environment), entitled with “The impact of office design on business performance” is an important exploration of the relationships between design variables, business performance factors and measured performance (CABE, 2005). This report contributes a feedback link between the strategic aims of the organization, namely the ‘Business Strategy’ and the results that the strategy delivers namely the ‘Business Performance Measures’. As shown in Figure 8, it illustrates this relationship between business strategy and business performance and shows the intermediary role that variables in the design of offices play, and it provides the over-arching framework by which these design variables can be considered as an aid to strategy and performance. Business strategies and priorities determine the best way to pursue business levers, including office designs, to influence Business Performance Factors, which must be measured in terms of the degree to which the goals of the original strategy are achieved. Office design is just one business lever available to businesses to affect change.

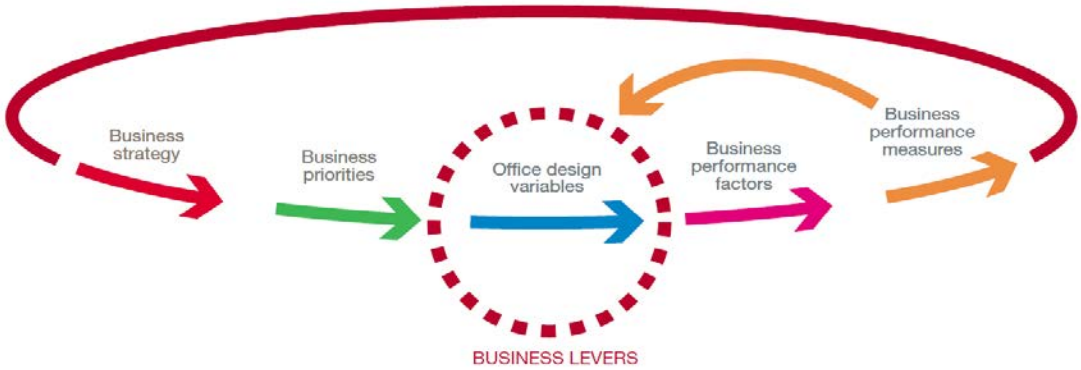

Figure 8: Feedback linking business strategies with business performance using design variables

In this framework, business strategy includes Corporate Strategy such as opening up new markets, Market Strategy such as ways of improving market share by expansion or consolidation and Functional Strategy such as outsourcing, partnering, etc. Shaped by strategy, business priorities determine the targets which are used to measure whether the strategy has been achieved, e.g. increasing the number of products on offer, adapting services so they can be applied in new markets etc. Business priorities follow three E’s principles: efficiency, effectiveness and expression. Business levers are the resources that a business can manipulate to achieve targets, including both physical resources (e.g. office design, IT services, infrastructure) and non-physical business disciplines (e.g .Human Resource policies and practices, marketing initiatives, etc). Office design variables as a kind of physical business lever embrace both buildings and their environment. The report categorised them as a series of seven layers defined by Building Life Cycles, each of which has a different longevity: Building’s context for infinite time impact – location, landscaping, site density; Shell/Structure for 50–70 years defining shape, size and built form; Skin/Building Cladding for 25 years; Services (heating, ventilation, lighting and cable distribution, etc.) for 15–20 years; Scenery that is the fitting out of the internal elements such as ceiling, partitions and finishes for 7–10 years; Systems of accommodation and of Information and Communication Technology around 3 years; Day to day settings and management of the furniture and equipment.

Site	Shell	Skin	Services	Scenery	Systems	Settings
Telecoms infrastructure; Local amenities; Access; Car parking; Site Security; Aspect	Thermal strategy, Structural grid, Planning grid, Floor size, Space efficiency, Tenant efficiency, imposed floor loading, Floor depth and sectional height, Atrium provision, Communications infrastructure, Good access, Exterior/ internal maintainability	Natural ventilation, Solar control, natural lighting, views, energy efficiency	Lighting, temperature, environmental control, ventilation, HVAC, BMS, small power	Choice and quality of materials, Provision of meeting facilities, Restaurant/dining facilities, Provision of vending/break areas, Internal landscaping/ planting, support facilities	Network access, Floor mounted power, data connections (Wireless)	Furniture, group size

Figure 9: Seven layers of office design variables defined by Building Life Cycles

Business Performance Factors are measures that evaluate the business consequences of the application of office design and other levers. The report used a list of measures of business performance proposed by Bradley (2001) that can be linked to real estate and workplace performance: stakeholder perception (e.g. customer satisfaction and loyalty, community sentiment); financial health (e.g. economic or market value added); organisation development (e.g. innovation quality and quantity, cultural factors, team formation and new process introduction rate); productivity (e.g. space utilisation, process speed and quality, waste levels); environmental responsibility, and cost efficiency (e.g. total occupancy cost related to revenue generation). Finally, the report proposes the framework in Figure 10 to align evidence with business strategies and performance. The framework discloses the nature of the links that exist between office design and business performance.

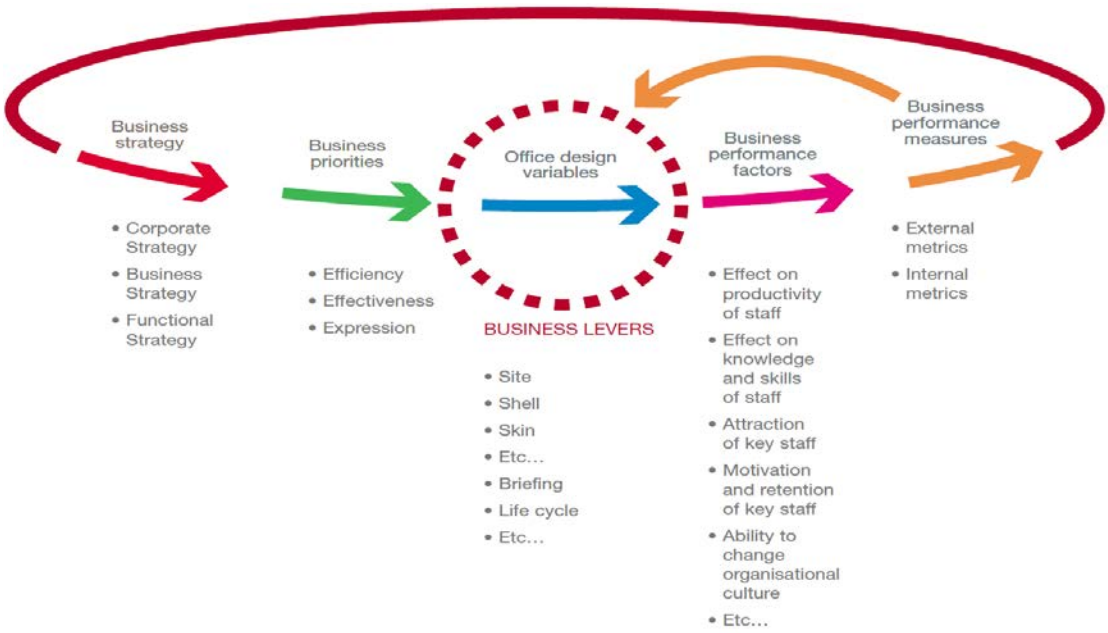

Figure 10: Alignment of evidence in the framework

BIDS Report

The project of BIDS (Building Investment Decision Support) by Centre for Building Performance Diagnostics at Carnegie Mellon University is an academic effort on this report, featured by its literature review (CBPD, 2006). The BIDS standardized the business performance in terms of costs ($), taking into account office first cost, operations/energy, individual productivity, organizational productivity, health, attraction, retention, churn, technological churn, tax, litigation, insurance, salvage, waste, etc. Figure 11 show the cost estimation for different types of buildings proposed by BIDS.

Offices	Schools	Hospitals
O&M, Energy & Water	O&M, Energy & Water	O&M, Energy & Water
Worker Health	Teacher Health Student Health	Patient Health/ Recovery Rates Patient Falls Staff Health
Attraction/ Retention	Teacher Turnover	Staff Turnover
Individual Productivity	Student Test Scores College Placement	
Absenteeism/ Presenteeism	Absenteeism/ Presenteeism	Absenteeism/ Presenteeism
Organizational Productivity Market Share/ Customer Speed to Market	 Drop-out Rates No Child Left Behind	Bed Vacancies Cost/Bed Profit/Bed
Waste Cost/Benefits	Waste Cost/Benefits	Waste Cost/Benefits
Litigation Insurance/ Tax SBS		Medication Errors

Figure 11: The true cost different types of buildings

The project reviewed over 130 case studies: 20 on air quality/ventilation control; 11 on temperature control; 25 on lighting control; 4 on flexible connectivity; 24 on privacy and interaction; 20 on ergonomics; 19 on access to natural environment; 15 on whole building. These case studies are sourced from 1000 abstracts and100 refereed journals, books, research reports, Ph.D. dissertations. To link these studies to the outcome, BIDS categorised these design options and standardised their benefits. Furthermore, BIDS made scenarios using staitsitcail data such as health insurance per employee, salary per hours and so on to estimate the potential benefits in dollars (Figure 12).

The outcome of the BIDS is a set of guidelines for high performance building, including High Performance Siting& Massing; High Performance Enclosure Systems; High Performance HVAC; High Performance Lighting; High Performance Interior Systems; High Performance Connectivity. As shown in Figure 13, each guideline or suggestion is linked to its corresponding evidence and scenarios on productivity gains.

Figure 12: Framework by BIDS to link design and scenarios

Figure 13: BIDS outcomes

SYSTEMATIC REVIEW

Cochrane Methodology

The abovementioned projects in the built environment provide useful framework to align evidence; however, they are not transparent in their process of sourcing and assessing evidence. For this purpose, we need to look at some more stringent methodology in social sciences. There are many evidence-based policy or medicine projects, which can be referenced for their step-by-step systematic review. Normally, a systematic review process should follow five steps: Formulating the review question; Identifying and collecting evidence; Evaluating the quality of the evidence; Extracting, processing and systematizing data; Disseminating findings. There are two key books that offer step-by-step guidance for a systematic review. See Figure 14. The key points summarised from the two books are :

- Systematic reviews seek to collate all evidence that fits pre-specified eligibility criteria in order to address a specific research question
- Systematic reviews aim to minimise bias by using explicit, systematic methods

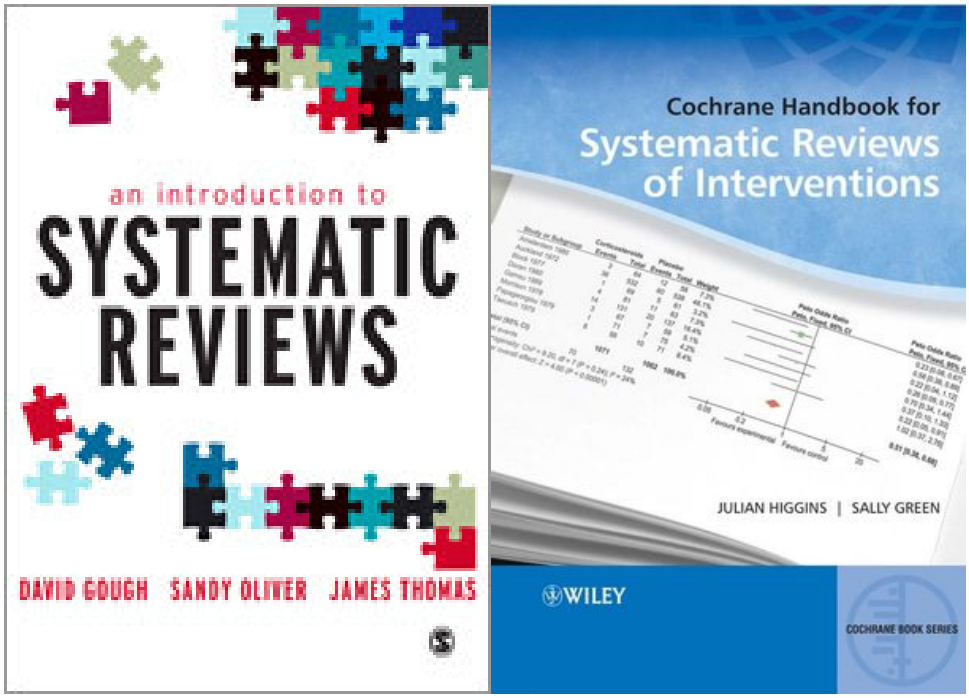

Figure 14: Key books that provide guidance for a systematic review

Figure 15 summarises the step-by-step approach mentioned in the two books. The three common stages in a systematic review are:

- Identifying and describing the relevant research through mapping the research
- Critically appraising research reports in a systematic manner
- Bringing together the findings into a coherent statement: synthesis

For a systematic review, the most important part is to formulate a review question. There are three types review questions dependent on the research objective. If it is to test a theory or hypothesis, the question could be: does intervention x work better or worse than intervention y? if it is to explore a range of possible answers and approaches within a given theoretical framework, the question would be: which interventions are most effective at reducing problem x within population y? if it is to generate new theories, conceptualisations and understandings, the question could be: what are the meanings of phenomenon x within population y? Typical conceptual frameworks for reviews of effects specify a causal link between who the review is about (the population), what the review is about (an intervention and what it is being compared with), and the possible consequences of intervening in the lives of these people (desirable and undesirable outcomes). For example, we want to know about the effects of indoor plants. There are two important questions to ask: Do occupants in offices where there are indoor plants are more productive? Why (How can we conceptualise the way that) the presence of indoor plants improves indoor environment quality or other aspects contributing to the improved productivity?

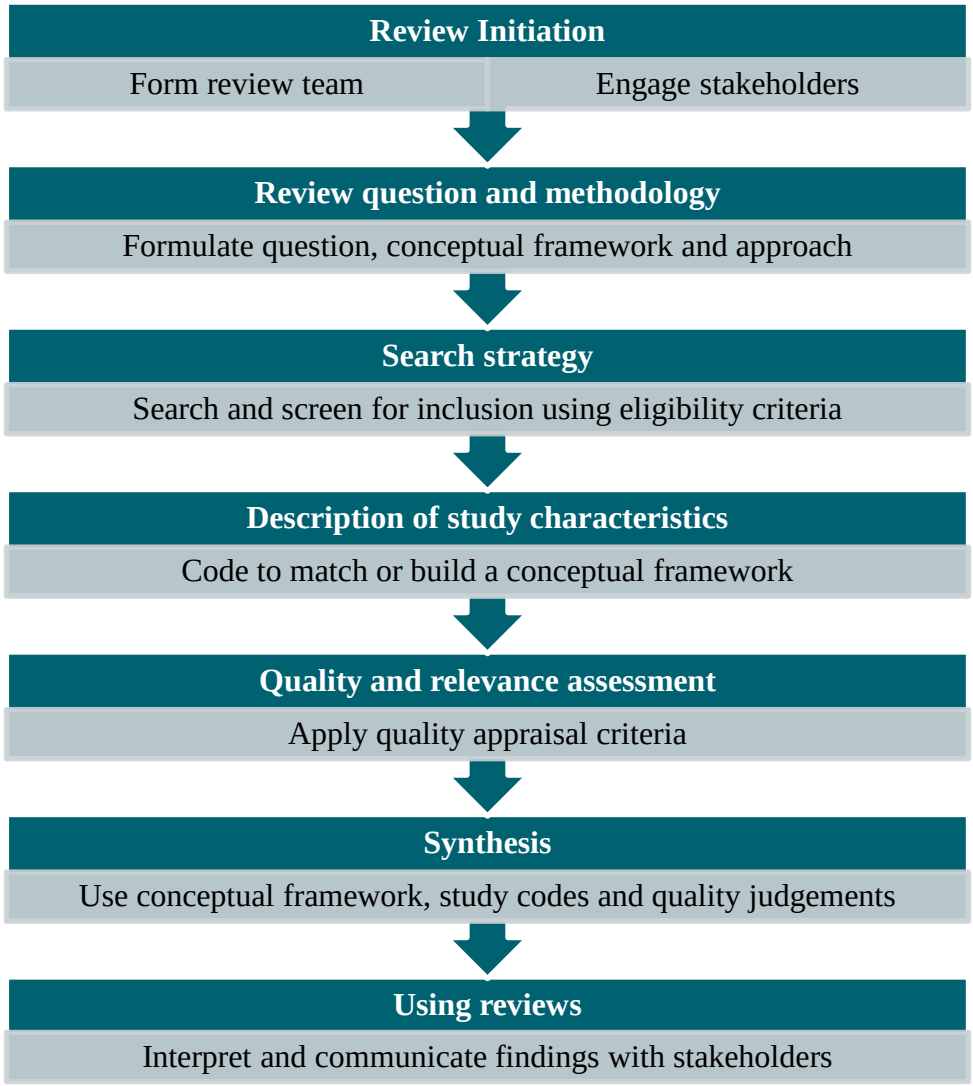

Figure 15: Step-by-step systematic review

The review question would decide which review methods we like to use. If the aim of the review is to test a hypothesis, work begins with the development of the conceptual framework to match the question and include clearly defined concepts to frame a review. Aggregative methods are appropriate. If the aim of the review is to generate or explore a theory, and there are few concepts clearly defined in advance, work begins with delving into the literature for key concepts. Configurative methods are appropriate and employed to build a conceptual framework or theory. If the aim of a review is to explore implicit or partially developed theories, or policy or practice options, initial assumptions are tentative and gradually develop into a stronger theory, and work begins as findings emerge from the research literature. Mixed methods, such as framework synthesis or realist review, are appropriate. If the aim of the review is ultimately to lead to change, work begins: by involving stakeholders to collaborate in developing the hypothesis; with reviewers listening to stakeholders to sensitise themselves to some of the key issues; or by bringing together key stakeholders to contribute to the initial assumptions and framework, and interpret the emerging findings. Taking the example of indoor plants mentioned above. To answer the question: “Do occupants in offices where there are indoor plants are more productive?”, a deductive method can be used based on aggregative review; to answer the second question: “Why (How can we conceptualise the way that) the presence of indoor plants improves indoor environment quality or other aspects contributing to the improved productivity?”, an inductive method should be applied through configurative reviews.

A journal paper “Healing environment: A review of the impact of physical environmental factors on users” reports a study using Cochrane Methodology to collect evidence of the physical environment on the healing process and well-being have proved to be increasingly relevant for patients and their families as well as for healthcare staff (Huisman et al., 2012). The review

structures the scientific research on an evidence-based healthcare facilities for patients and their families and staff outcomes, showing the effects on patients and their facimilies and staff from the perspective of various aspects and dimensions of the physical environmental factors.

The Cochrane Methodology was used to search the data. Potentially relevant literature was identified through computerized searches. The search was performed using the keywords evidence-based design, hospital design, healthcare design, healthcare quality, outcomes, patient safety, staff safety, infection, hand washing, medical errors, falls, pain, sleep, stress, depression, confidentiality, social support, satisfaction, single rooms, noise, nature and daylight. The search criteria were based on characteristics of the several groups in this study. A total of 54 keywords were used and categorised into four groups: patients and their families, staff, (physical) environmental factors, and relevant authors. For a further and more specific search, a combination of keywords was used in the Pubmed and Scopus research databases. The following combinations of keywords were used to do the search: “healing environments” & “patient outcomes”; “healing environments” & “sleep”; "hospital design and construction" & “safety”; “hospital design and construction” & “stress”; "healing environments" & “stress”; "healing environments" & “patient safety”; "evidence based design" & “stress”; "evidence-based design" & “outcomes”; and "evidence-based design" & “physical environment and hospital design”.

As shown in Figure 16, a total of 798 papers were identified that fitted the inclusion criteria for this study. After eliminating duplicate articles, the remaining articles were examined for further selection. At the final stage, articles were selected that referred to the physical environment of healthcare facilities in their titles and abstracts. The references from the identified articles were verified to determine whether they would result in additional literature. Studies were rejected or accepted for further analysis based on the titles and abstracts and the incorporation of the characteristics in one of the four groups of patients and their families, staff, environmental factors or relevant authors. Of these, 65 articles were selected for review: fewer than 50% of these papers were classified with a high level of evidence, and 86% were included in the group of patients and their families outcomes. This study demonstrates that evidence of staff outcomes is scarce and insufficiently substantiated.

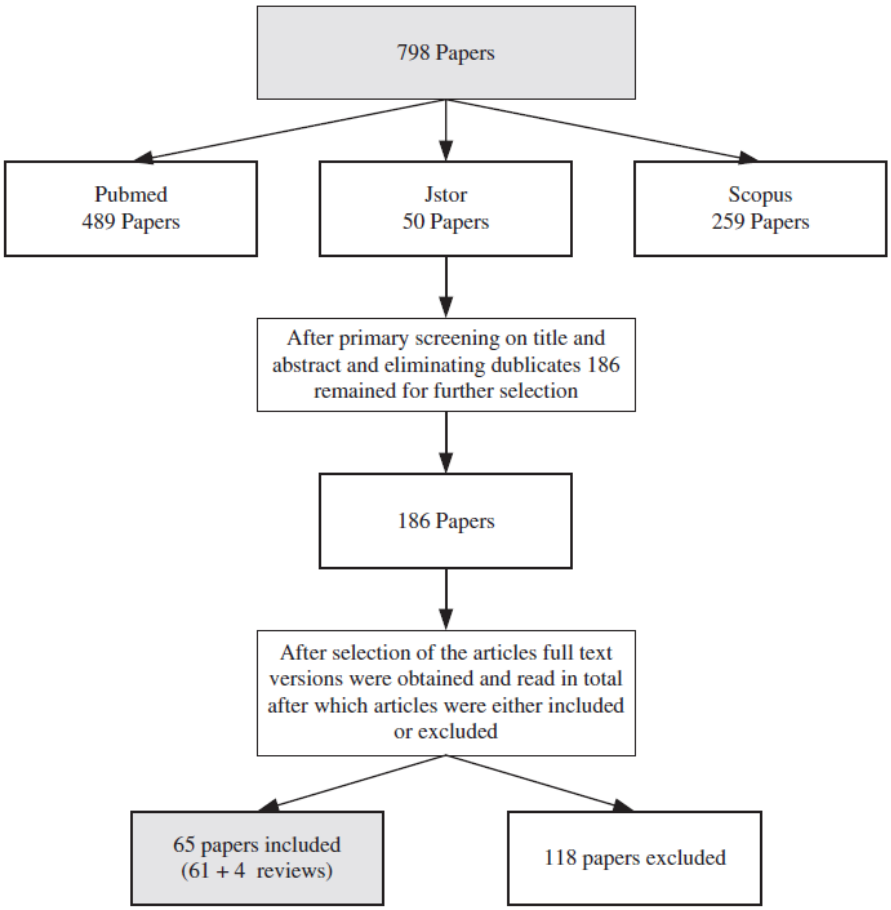

Figure 16: The process of evidence collection

The framework in Figure 17 was used and adapted to order and structure the evidence regarding healing environments. The framework describes a triangular relationship among the building system, the performance, and the users; each single element affects the other two. Within the framework, users are defined as patients and their families, or staff. Within the framework, a building delivers performances that are among the user needs and are installed and fitted to meet those user needs; in turn, the building systems are translated to user outcomes. Each building system has a specific set of functions (which can be seen as solutions) that contribute to the optimization of a particular user need. The success of the final design is the result of how well the needs of the stakeholders are met by the building systems. The aim of the review is to provide an overview of the evidence in the literature on healing environments. The hypothesis is that healing environments, through EBD, make hospitals less stressful and promote faster healing for patients and improve well-being for their families, as well as creating a pleasant, comfortable and safe work environment for staff. Therefore, the following questions are explored in this review: Which findings of research related to patients and their families outcomes and staff outcomes of healthcare design are evidence based or scientifically proven or are not (sufficiently) proven? Which findings of research related to patients and their families outcomes and staff outcomes of healthcare design are under discussion?

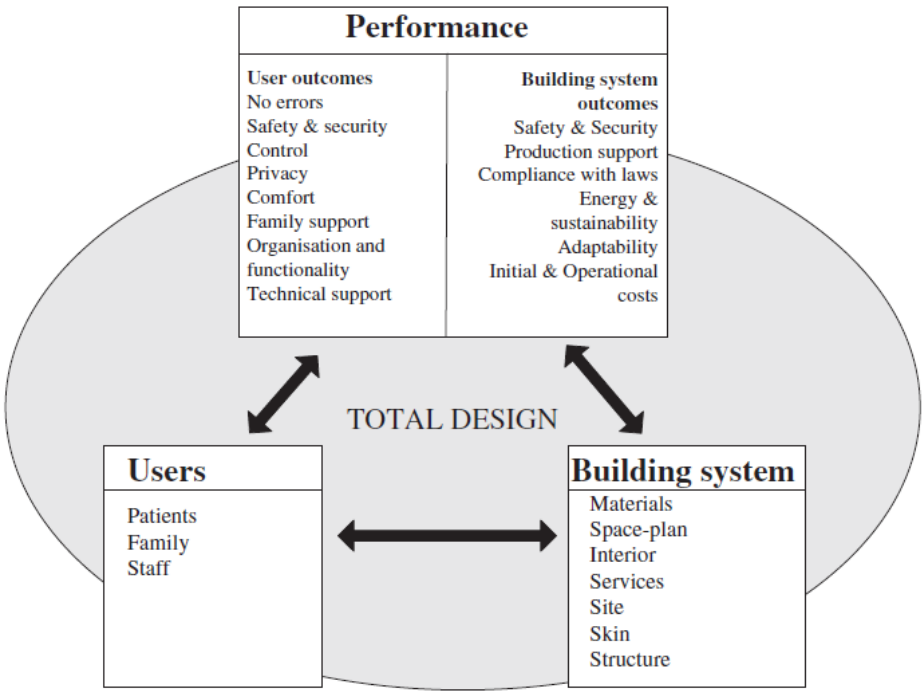

Figure 17: The framework to structure evidence

Weighting Evidence

Weighting evidence is to assess the strength of available evidence regarding the research methodology used to measure the effect of design features on specific outcomes and the quality of the research in its elimination of inherent biases (Stichler, 2010). The result of weighting would be a series of hierarchies or levels individual evidence can fall into. The principle of weighting evidence is to make sure that all evidence be critically appraised for its effectiveness in answering research questions such as “What is the effect of ‘x’ design on ‘y’ outcome?”; appropriateness such as “Are the findings in the study appropriate for the study design and sample used?”; and applicability or feasibility such as “Is it feasible to use the recommendations from this study in our setting, with our population of patients and providers, and with our set of circumstances?”. Evidence-based design is based on the availability and quality of the evidence as well as the consensus of those involved in the process. Not all evidence—regardless of its quality—can be implemented, given the financial or other constraints in the realities of specific situations.

Medicine and nursing have developed hierarchies that rank the systematic review of multi-site studies at the highest level of reliability and expert opinion, case studies, and descriptive studies at the lowest level. This ranking process can be used to determine the effectiveness, appropriateness, and feasibility of applying the evidence to practice. In its simplest form, evidence can be evaluated as “excellent”, “good”, “fair” and “poor”. Sometimes, the ranking is also called strength of recommendation. For example, good evidence” refers to consistent results from well-designed studies that directly assess prescribed outcomes and use representative populations; “Fair evidence” is described as sufficient to determine the prescribed outcomes, but the study may be limited by the number,

quality, or consistency. Recently the American Association of Critical Care Nurses developed a 12 rating system (Armola et al., 2009) including Level A, meta analysis that is an analysis of the synthesis of multiple quantitative studies and meta-synthesis that is a synthesis of findings for multiple qualitative studies; Level B, well-designed randomized experimental and nonrandomized comparative studies; and Level C, descriptive and correlative studies, qualitative studies, systematic reviews, and integrative reviews. The new rating system also ranks non-research evidence from peer-reviewed professional standards as Level D. Case reports and expert opinions are ranked as Level E, and manufacturer or consulting company recommendations are ranked as Level M.

Based on the hierarchies or levels developed by evidence based medicine research, built environment research proposed a tailored rating scale for healthcare design. Figure 18 shows the hierarchy with sample studies from healthcare design (Stichler, 2010). An expanded version of this hierarchy is proposed by Pati in Figure 19 to separate the evaluation of strength and quality of evidence from the evaluation of appropriateness and feasibility in a specific application context (Pati, 2011). In the literature of evidence based design research, Levels III, IV, VI and VII can be easily found and exhibit the greatest potential for use in practice. Levels I, II and V have yet to emerge in a clear fashion in healthcare design literature; therefore, they are left as levels for future use. For end users unacquainted with research design, simple questions can help determine the exact level of a specific piece of external evidence in healthcare design research. Ask whether the study is attempting to establish causation between a physical design concept/element and outcomes. If the answer is affirmative, the study is either a level III or level IV study. If the study involved random assignment (either researcher-manipulated or naturally occurring), it represents a level III study. If not, it represents a level IV study. If a published study does not attempt to establish causation, it represents one of the remaining classes: levels VI, VII, or VIII.

Level 1	Systematic reviews of multiple randomized controlled trials (RCTs) or nonrandomized studies; meta-analysis of multiple experimental or quasi-experimental studies; meta-synthesis of multiple qualitative studies leading to an integrative interpretation
Level 2	Well-designed experimental (randomized) and quasi-experimental (nonrandomized) studies with consistent results compared to other, similar studies
Level 3	Descriptive correlational studies, qualitative studies, integrative or systematic reviews of correlational or qualitative studies, or RCT or quasi-experimental studies with inconsistent results compared to other, similar studies
Level 4	Peer-reviewed professional standards or guidelines with studies to support recommendations
Level 5	Opinions of recognized experts, multiple case studies
Level 6	Recommendations from manufacturers or consultants who may have a financial interest or bias

Figure 18: Levels of evidence for healthcare design

Source: (Stichler, 2010)

Level	*Source of Evidence*	*Healthcare Design Examples*
Level I (A–D)	Systematic, statistical review of multiple controlled studies (e.g., meta-analysis)	Yet to emerge in healthcare design research
Level II (A–D)	Systematic interpretive, table-based integrative review of multiple studies primarily of quantitative research	Yet to emerge in healthcare design research
Level III (A–D)	Experimental studies	Single experiment (involving random assignment, either researcher-manipulated or natural); single simulation study
Level IV (A–D)	Quasi-experimental studies	Single experiment or natural experiment without random assignment; single before-and-after study; single Lean study involving physical environment manipulation
Level V (A–D)	Systematic, interpretive, tabular integrative review of multiple studies primarily of *qualitative* research	Yet to emerge in healthcare design research
Level VI (A–D)	Nonexperimental studies, such as correlational, descriptive research, as well as qualitative research	Single study using qualitative data; single quantitative noncausal study (e.g., on space optimization or trends)
Level VII (A–D)	Systematically obtained, verifiable evaluation data from the literature	Published findings from POEs; published findings from mock-up studies
Level VIII (A–D)	Consensus opinion of respected authorities, e.g., a nationally known guideline group	Consensus opinion of such bodies as Facilities Guidelines Institute (http://www.fgiguidelines.org/), if any, that has not already been incorporated in published guidelines.

Figure 19: Expanded levels of evidence for healthcare design

Source: (Pati, 2011)

CONCLUSION

This report points out the unclosed loop in the design process and proposes using evidence of feedback in the early design stage. Although there is abundance of empirical studies and post-occupancy studies on how built environment might influence user experience and behaviours, there is a lack of framework and methodology to collect, align, assess and use them. This report reviews three similar frameworks that links design to occupant health and productivity, and includes relevant information for a stringent evidence collection, assessment and alignment.

WGBC Report on “Health, Wellbeing and Productivity in Offices: The Next Chapter for Green Building” identifies more than 40 performance matrics for office productivity, health and well-being, and finally selects 7 key matrics for the measurement. The report also provides a pool of 13 design aspects that to different extents are evidenced for their contributions to a healthy and productive workplace. The framework is comprehensive and dynamic but there is a lack of causal path or link between them.

CABE Report on “The impact of office design on business performance” proposed a framework of causality for linking business strategies, design variables and business performance. The path is clear and analytical. However, the framework can only be used in commercial office sector while can hardly be adapted to educational or healthcare sectors. On the other hand, the proposed pool of design variables is focused on building elements and their life expectancy while does not take into account the larger influences of urban or landscape factors that may have a positive impact such as healing gardens, accessibility and convenience.

CMU Report on “Building Investment Decision Support” standardized evidence in terms of a common language “dollars” and “return of investment”. It is very explicit and eyeballs attracting. However, the methodology is quite problematic. Especially, the transference of satisfaction, absenteeism, retention etc. to single measurement “cost” is opaque and subjective. Anyway, the outcome of a series of guidelines linking to their supportive evidence is a good example to inform design decision making.

Cochrane Methodology provides step-by-step guidelines to do a systematic review for evidence collection. It is featured by a clear causality path linking interventions to outcomes. However, the knowledge is mainly from research areas of medicine or social sciences. Although it is adapted to be used in evidence based healthcare design and many articles can be found in the Health Environments Research & Design Journal (HERD), it has not ye been applied in the commercial office sector where relationship between interventions and outcomes may not be singular or linear. These frameworks have not yet used in project management to test the effectiveness and applicability.

It is expected that the RP 1009 “Closing the loop of evidence-based low carbon design for non-residential buildings” can take into account pros and cons of the three frameworks and develop a more inclusive, integrative and dynamic framework to synthesize evidence with the help of multi-disciplinary perspectives from business, public health and others. It is also expected that the evidence base generated from this project can be testified in project management.

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