Designing safer buildings: towards evidence-based decisions

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Abstract

The success of Evidence-Based Medicine has led to the development of Evidence-Based Design (EBD) founded on responsible decisions made after evaluating valid and relevant information taken from scientific literature and best practices. In the field of architecture, the need for quick decisions, the exponential growth in technical information and the limited practical implementation of results has in fact justified drastic and often scientifically questionable simplifications. Since 'simplifying to act' involves assessing many facts concerning probabilistic and multifactorial problems, problems that make it difficult to establish a link between cause and effect, the most 'probable' elements become the most 'reliable'. In the aleatory field par excellence - safety – this has led to rules and procedures that ignore the need for prevention. The effect of this disregard for real problems has, especially in Italy, led to an independent bureaucratic network. Therefore, in the field of building design it is crucial to establish an approach based on a critical and credible evaluation of the best results of research and best practices. In an "Evidence-Based Safety Design" (EBSD) for healthy and safe construction it is important to base design and building choices on the results of statistical risk assessment studies, the preferences of the operators involved and common professional experiences. The use of this design method involving the operators, requiring them to reference the effectiveness of the 'tests' on which it is based, would effectively break the bonds that surround job safety policies.

Keywords: EBD (Evidence Based Design), Results Evaluation, Best Practices, EBSD (Evidence-Based Safety Design).

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1. Context

This paper comes from a research on the relationship between design and safety. This research ended in 2002 with a doctoral thesis, Buccheri (2002), on the development of a model integrating risk assessment in design process. This study was carried on with great difficulty, mostly because the model needed a data record. In Europe, and in Italy in particular, data collection and data records in the field of health and safety management were extremely generic and it was impossible to obtain something to evaluate and assess the risks for the different construction activities. This unaccomplished result moved us to carry on with the question.

'Evidence-based design is the conscientious, explicit and judicious use of current best evidence from research and practice in making critical decisions, together with an informed client, about the design of each individual and unique project.' Hamilton (2003) wrote the second half of this definition, concerning the critical decision-phase taken with the client, the decision taken after the best information available.

The success of Evidence-Based Medicine (Sackett, 1996) led Hamilton to the development of Evidence-Based Design (EBD), a process (not a product) in answer to the many difficult design questions. The architectural establishment moved some critics to the term "EBD", as it is generally assumed that architects have always considered the results of their work, far before the invention of the term "EBD".

When we found the process transfer from EBM (from Medicine) to the EBD (to Design), we thought it could greatly improve the problem of health and safety data. To Deepen the health and Safety Evaluation it is necessary to study the danger of some activities with great detail, by searching similar case-study and by recording the statistics of consequences of some activities in their context. Something similar has always been done by doctors facing clinical cases: case collection and record are constantly updated and are the basis of EBM.

In scientific fields of studies, an objective evaluation of safety is generally considered impossible to obtain. The European Environment Agency (1999) considers four classes of uncertainty to be dealt within a risk assessment:

-framing uncertainty, related to the translation of policy questions into scientific questions,

-modelling uncertainty, related to the realism and the reliability of the model predictions,

-statistical uncertainty when using this type of tools (chance of rejecting a true hypothesis or of accepting a false hypothesis),

-decision theoretic uncertainty related to the use of the worse case scenario or the more likely scenarios.

So, Safety seems not to be linked to parametric measures, and it is also impossible to define measures, based on conventional tests. In these last years, the attention paid to safety in

Construction work sites has led to a set of subjective regulations, which became rules. In this scenario, professionals and responsibles for safety in Building Construction act just keeping and applying rules.

In Italy, the role of the Health and Safety Coordinator is too often a bureaucratic activity that leads professionals to the application of a huge set of rules of questionable utility and effectiveness. The most important document is the PSC (Health and Safety coordination plan), to be drawn up before work begins. It is a comprehensive document to manage all those who work in the construction site (D. Lgs 81/2008). The PSC is developed during the design execution phase, when most design choices are already taken, so the result is kind of a story of the building construction, drawn up after the design phase, telling about all the building site devices and activities. The software tools to support the Health and Safety Coordinator are also based on pre-defined indications and the result is a “copy and paste” tool often out of context.

It is clear that the answer to complex problems through a regulation database is unsatisfactory. It should be really useful a set of information able to associate a risk index (even very simplified) to the different design options, before they become definitive.

In the field of architecture, the need for quick decisions, the exponential growth in technical information and the limited practical implementation of results has in fact justified drastic and often scientifically questionable simplifications. And yet, this professional role could be really interesting, dealing with the estimation of construction phases, and with the evaluation of hazards and harmful activities. It’s possible to compare the health and prevention activities with the whole diagnostic and curative activities of a doctor.

Metaphorically speaking, it’s like if a doctor would treat a disease only by gaining information from the leaflets given with the available medicines. The use of metaphor is justified by immeasurability of “Safety”, which encouraged us to look into other disciplines and their methods. Medicine, for example, has never counted on reductivist procedures (like Physical Science do). This led to consider a process transfer from Medicine to Architecture: from EBM (Evidence-based Medicine) to EBD (Evidence based Design). This idea came from professionals after working in team with doctors. More recently, Hamilton and Watkins (2008) tried to release the EBM method from medical procedures reliance, and to enhance the opportunities for Engineers and Architects’ approach.

2. Objectives

Evidence-based design means basing design decisions on empirical, replicable scientific research and data. This process model requires the designer to review the best relevant evidence available from credible research. The goal is to create an unbroken chain of logic from research to design concepts, and on to a hypothesis or prediction of an outcome that will result from implementation of the design concept.

Since ‘simplifying to act’ involves assessing many facts concerning probabilistic and multifactorial problems, according with Aven (2012) et al., that make it difficult to establish a

link between cause and effect, the most ‘probable’ elements become the most ‘reliable’. In the aleatory field par excellence - safety – this has led to rules and procedures that ignore the need for prevention. The effect of this disregard for real problems has, especially in Italy, led to an independent bureaucratic network. The prevention and protection service could be a very interesting role when considered in the design approach: it should be based on forecast and risk evaluation of specific cases. Therefore, in the field of building design it is crucial to establish an approach based on a critical and credible evaluation of the best results of research and best practices.

The most important aim is to release professionals in the field of the prevention and protection service from pre-established activities, and to give all the importance to decisions and to the search for the best information available. This paper presents a theoretical contribution to the debate on the use of information in the Health and Safety procedures. Our approach has to be tested and assessed in practice, but we propose its development in the following steps.

3. From the EBD to the EBDS approach

Architects are being asked to be more rigorous and use evidence in new ways, with more rigor, higher standards of measurement, and there are new domains of evidence to be searched. Timely input of design creativity leads to reflection on the assignment and offers the possibility to represent various scenarios and solutions, to start the discussion about a new concept or typology, to make the spatial consequences of property concepts and scenarios transparent in as early a phase as possible, and so to come to an adequate result.

Therefore, interdisciplinary design and research have increasingly been linked over the past few years: government, educational institutions and market parties encourage design-based research and research-based design. The EBD approach is based on some important steps:

Design-based design

Design-based research is doing research by making designs: the design is the study method. This enables us to study the spatial consequences of various locations, programmes or scenarios. Similarly, the design can be used as a means of research to study the spatial consequences of certain programmes and typologies.

Research-based design

Research-based design takes place within the regular design practice. Architects and consultants do research for the benefit of the design to be created. Examples are analysis of the programme, analysis of the location, analysis of typologies already applied, testing concepts and implications for construction and technology, linking the programme to concepts, testing against preconditions and testing the necessity of certain preconditions (performance versus means). This can help start up developments that will lead to rethinking preconditions set earlier, shifting limits and creating new possibilities.

Visualizing scenarios can help make decisions on the consequences and the added value of various options. Therefore, research-based design is a valuable planning and design practice that facilitates particularly administrative decisions based on input from the discipline in a contemporary way. Based on language, everyone visualizes the design, thus creating spatial pictures. The advantage of the visual approach is that various actors can jointly imagine the same outlined world and discuss it. This will lead to a process of mutual deliberation, in which participants will try to learn from each other and understand the issues, to connect aspects by going into the matter more thoroughly and using their expertise, and to convince each other.

From evidence-based design and healing environment to research-informed design

Evidence-based design, originating from healthcare in the USA and introduced by Kirk Hamilton, propagates the use of the best available study results in the design. This holds true not only for the design process of healthcare institutions, but also for other types of buildings and users. It is about the result of research but it could also be about the experience of the principal or users themselves.

Each design assignment is unique

No two assignments have the same environment and the same programme. Each project is fitted into a specific environment, requires the spatial lay-out of that programme, has its own balance between public and private rooms, requires a custom-made structure with proper heights and daylight, and optimum living and working conditions. The challenge is to use a designing method that best fits a certain assignment with ambitions for innovation.

4. Method

The EBD Approach could solve some of the greatest problems of professionals involved in the prevention and protection service. An approach called EBSD (Evidence-Based Safety Design) could lead to a deeper involvement in the working plan real of the building, and this could contribute to a real interest of the involved professionals. Clearing off the huge amount of intricate and illogical procedures and rules, based on “common sense”, procedures should be based on observation of real risk conditions, tested in other building’s work sites.

The main topic of this paper is the belief that, to develop the necessary know-how for a proper risk and healthy assessment, a certain amount of resources is needed. We believe that these resources could come from the participation of professionals and researchers, and from the involvement of private insurance companies in competition, asked to run the risk on reliable records.

To further detail health and safety assessment, a deep analysis of activities and risks is needed, by searching analogies and recording feedback of specific activities in specific contexts. This is something similar to the medical approach: clinical cases have constantly been recorded and updated , and this is the basis of EBM approach, from which EBSD comes. Withouth a similar data record (today non-existent in construction) it is impossible to

apply the EBSD method. Today is inapplicable, but the EBSD could strongly improve the health and safety question.

In an "Evidence-Based Safety Design" (EBSD) for healthy and safe construction it is important to base design and building choices on the results of statistical risk assessment studies, the preferences of the operators involved and common professional experiences.

It is possible to sketch nine steps to develop an "Evidence-Based Safety Design"; these steps are not gratuitous or unsubstantiated, but they act as correctives of an existing situation, whose irrationality and danger are easily demonstrable:

4.1 Identify the client's goals. Insurance costs reduction for the Construction

Determine the client's goals for which the design is to offer the solution. For an "Evidence-Based Safety Design" (EBSD) for an healthy and safe construction the first step is to concretely identify client's objectives that involve specific risks at work right from the moment when each construction stage is planned through to when these are carried out, or activity management that could affect healthy and safe work conditions. Today the client is not involved in the developer's choices, who is able to take many crucial decisions. So, the client is not able to improve the health and safety conditions.

4.2 Identify the firm's goals. Insurance cost reduction for the single safe project

Identify the involved firm's goals and the goals to be realized for this specific project. It is important to analyse the involved firm's experience and the expertise built in the management of prevention and health. The developer takes almost all the risks and responsibilities of health and safety condition in construction work site, but his choices and decisions could be previously checked and evaluated. Today, parameters to evaluate risks are not available, so it becomes difficult a previous evaluation.

4.3 Identify the key design issue. Identification of pre-construction activities, relevant to Health & Safety

The strength is to find the key design issue with the most crucial contribution to realizing an efficient analysis and assessment of risks to health and safety. Finding that key design issue requires setting priorities. Often, more than one solution can be submitted to realize the goal, but the solution needed is the one that offers the minor level of risks in all the construction process and activities.

We always know that there is a lack of data record about this topic; and this lack enable the process. Only the need of a solution to similar questions could lead to this.

4.4 Convert the key health and safety issue into research questions. Possible options to the risky activities without effects on the whole design

Converting the key issue for a Safe and Healthy Construction site into research questions is necessary for the consultation of information sources. It is impracticable to study everything, so it is necessary to focus on high-impact subjects in respect of which little information is available. An important source for information is the results of statistical risk assessment studies. This is the first step on the road to Evidence Based Design.

Today, some aspects are covered, some others not, because it was determined that some of them were safe, some others hazardous. This determination was based on “common sense”, and not on the basis of accident statistics. The little attention paid to case-study and their critical analysis forces all the matter in a backward condition. When there’ll be a little interest on this phenomena, researchers will investigate about it. It is a long way, but it is necessary to have a scientific knowledge of these phenomena.

4.5 Gather information. Identification and collection of useful information

It is crucial a fit-in collection of information and research data: it is very useful to understand the specific characteristics of the Construction to gather the most useful information. Common professional experience and preferences of the involved professionals may also be used as information.

This means to collect the available information and to record useful data. It is possible to consider some data analysis methods, as the FEMEA (Failure Mode and Effect Analysis), the FMECA (Failure Mode and Effect Critically Analysis), or the AMDEC (Analysis des Modes de Defaillance des Composants, de leurs effects et Criticité), or the APR (Analisi Preliminare dei Rischi), which are inductive techniques, partly similar but useful to develop a preliminary correction on decisions. Unfortunately, these methods are not useful for the risk assessment, because they investigate the unwanted event, but not the hazardous.

4.6 Critical interpretation of the evidence. Interpretation and advisory about activities, relevant to Health and Safety

A critical review of the information found is necessary, for literature will usually not directly answer the research question. The key is to find the balance and creative interpretation of the information to come to a justified answer in terms of risk analysis and assessment, and their management for a successful prevention. After the data collection, calculations and evaluations will be necessary to obtain comparable risk factors

4.7 Create evidence-based security design concept. Eliminate hazards and risks during design, on the basis of the gathered information

The creative interpretation of the information found is the basis for development of a concept. As stated above, the design consists of numerous more choices, but that they should be based on the research for the most safe and healthy construction site. This may

be dealt with in a pragmatic way. The concept should be a conversion of the information found and contribute to realizing the goals formulated in steps 1 and 2.

4.8 Develop hypotheses. Development of risk assessment for the designed solution

It is now possible to formulate the expected results of the design for a healthy and safe work site. These are connected with the previous goals. Submitted hypothesis can be tested when the facility is put into operation. This evaluation will provide knowledge that could serve as information for future Health and Safety designs.

4.9 Select measures. Evaluation of the effects on execution costs and insurance costs

The last effort to make sure that the results are measurable, both quantitatively and qualitatively. Highly valuable are studies comparing the situations before and after, which provide an invaluable amount of information and can be conducted for new facilities to be built as well as for renovations. This is the most difficult goal to obtain, due to the existing know-how. The measurement depends on the risk assessment. This is the measure of the hazard by its probability. Both parameters are still unknown.

Professionals of the prevention and protection service could use creativity to properly use good evidence in Health and Safety designs, and to recognize that each project has unique risks and characteristics. It is possible to trace back almost all the real risks for each construction working activity, and to determine the expediency of it. This phase should be decided in concert with the insurance company, who takes, since the early stage, the responsibility for future activities. This kind of procedures is common in France (Loi du 31.12.1993, Loi du 93/1418, FFSA): in a virtuous circle between inspectors and insurers led to high quality standard buildings. The goal is to use the best available knowledge. So Evidence-based design for safety seems obvious.

CHAIN OF LOGIC		
	1	Insurance costs reduction (for the Costruction)
	2	Insurance cost reduction (for the single safe project)
	3	Identification of pre-construction activities, relevant to Health & Safety
	4	Possible options to the risky activities (point 3) without effects on the whole design
	5	Identification and collection of information
	6	Interpretation and advisory about activities, relevant to Health and Safety
	7	Eliminate hazards and risks during design, on the basis of the gathered information
	8	Development of risk assessment for the designed solution
	9	Evaluation of the effects on execution costs and insurance costs

Figure 1: EBDS Chain of logic and steps

5. Conclusion

The key question of this paper is how to change from deterministic to probabilistic processes to assess the Health and Safety risk indicators.

In Italy, an interesting example of the proposed approach can be found in the structural safety regulations: the introduction of probabilistic methods replaced the previous deterministic procedures. This change allow the structural engineers to act in a more scientific way, not only on the basis of computational methods.At first glance it could seem a peaceful change, but it is actually a total change, because this approach make regulations sensitive to the probabilistic aspect of their application.

Especially in the Health and Safety field, it is necessary to introduce probabilistic methods because it is required to define design and construction solutions through the processing of risk assessment data, and these always progress towards a complex becoming. Deterministic approaches cannot be applied because it's impossible to evaluate data and assess their reliability. A keypoint of evidence-based approaches (EBM-EBD) is a method to evaluate data to assess reliability: a shift to Health and Safety field could be logical and useful.

This paper urges a development of risk assessment activities aimed at supporting the early design phases, because they are critical for the health and safety conditions in construction. Although the general trend tends to commit construction options to the engineering and construction phase, some information on the H&S (descending from synthetic risk assessment) could be available for designers through specific software apps to be developed (i.e., linked to a BIM-based model of the construction: based on databases and linked to object families).

Our paper is aimed at contributing to the theoretical knowledge and debate on the use of information in the Health and Safety Construction Design and Management. In the Italian context we found a critical gap, and we proposed an improvement through the introduction of probabilistic procedures in the early design stage; evaluation methods of the proposed approach have been discussed, but not fully developed (A further operazonalization development should involve informatic expertise). In the Italian context it is necessary to promote a debate on the complex knowledge involved in the Health and Safety management, whereas at present there are extremely not-homogeneous data, and very little integration between data and construction options in the different construction phases.

There was a transfer of EBM from Medicine to Design and Construction (EBD): all the more so it should be possible a transfer to the Health and Safety Management. We think that clinical cases are very similar to workplace injuries: in the first case, an unpredictable event (illness) determines an injury, that a given treatment can solve or reduce. The results of this process, compared with other treatments, give important information for further processing. In the case of workplace injuries, an unpredictable event (injury) determines an harm, that a proper analysis of activities and situations could avoid or reduce. The result of this analysis, compared to other considerations, could give important information for further processing.

The two cases are very similar but the procedures comes from Biology (Wolpert (1992) defines the doctors “biology engineers”).This aspect brings some problems. Many assertions could seem arbitrary or unsubstantiated to those used to work in physical field of studies. Feynman (1989) says that there is a deep link between Physics and Biology , but research methods are very different, due to the high variability in the biological field, and to the impossibility of reductionist experimentations, basis of physical science.

Clinical cases represent a solution to increase knowledge, considering the probability for the event to keep repeating, and EBM is a method which evaluates this probability and make this information available. Data collection and record is a common and well-established practice in Medicine; in Construction, instead, this practice is far from been applied and used to better know the reasons of the situation in workplaces. We think that EBSD could lead to an analytic data record about working site injuries and risks, bridging the existing gap.

First of all, it may be concluded that Evidence-Based Design is much more than just a literature study to find evidence. It is about the entire process, the goal of which is to realize a logical substantiation for the design choices to be made. A crucial condition thereby is that the steps be recorded, as fine-tuning of key design issues is inherent in the process. The second conclusion is that EBD could have a strong impact in Design process, especially in the field of Health and prevention in construction activities. This approach, called EBSD, distinguishes from today’s practice in two essential steps: conversion of a key health and prevention issue into a research question, and evaluation of the design and working plan activities after it has been put into operation. The final conclusion is that the EBS process forces those involved to bring the various decision in managing the Construction work site together at an early stage to formulate the tasks and evaluate the risks. The creation of an Evidence-Based Security Design is a team effort. Therefore, the use of this design process involving the operators, requiring them to reference the effectiveness of the ‘tests’ on which it is based, would effectively break the bonds that surround job safety policies.

References

Accident Prevention Programmes in the Member States of the European Union, available online at: https://osha.europa.eu/en/publications/reports/306/

American Society of Civil Engineers. ASCE Specialty Conference on Probabilistic Methods (2007) *Probabilistic methods in civil engineering: proceedings of the 5th ASCE specialty conference*, Conference Proceedings Serie, s, publisher: American Society of Civil Engineers, 1988

Aven, T. (2012), “The risk concept—historical and recent development trends”, *Reliability Engineering & System Safety*, Elsevier, Volume 99, March 2012, Pages 33-44

Bardelli, P.G., Coppo,S., a cura di (2010) Il Cantiere edile, Palermo, ed. Dario Flaccovio.

Buccheri, C. (2002), *Progettazione e Sicurezza – Sviluppo di un modello che integri la valutazione dei rischi nella progettazione* (*Design and Safety- Development of a model*

integrating risk assessment in the design process) PhD Thesis, University of Rome "La Sapienza", Faculty of Architecture, Department ITACA of Building Technology.

The Construction (Design and Management) Regulations 2007 (CDM), see: http://www.hse.gov.uk/construction/cdm.htm

Commission of The European Comunities, (1993), *Safety and Health in the Construction Sector*, ed. Office for Official publications of the EC.

D. Lgs 81/2008, available online at: http://www.lavoro.gov.it/Lavoro/SicurezzaLavoro/MS/Normativa/norme+di+modifica+del+TU+81.htm

European Environment Agency (1999) http://reports.eea.eu.int/Topic_report_No_131999/en/topic_13_1999.pdf

European Agency for Safety and Health at Work(2002) How to reduce workplace accidents https://osha.europa.eu/it/publications/reports/301

FFSA (Fédération Française des Sociétiés d'Assurances), available online at: https://www.ffsa.fr/webffsa/portailffsa.nsf/html/F0F2C610D04AFDADC12574200042CB28/$file/nomenclatureBTPdec2007.pd

Feynman, P. (1989), *Lectures on physics*, 3: The Relation of Physics to Other Sciences ,.

Giard, V. (1991) Gestion de Projects, Economica, Paris.

Hamilton, D.K. (2007). "Evidence-based design Supports Evidence-Based Medicine in the ICU", ICU Management Journal (Belgium), Autumn, 6(3) 31.

Hamilton, D. K. Watkins, D.H., (2008), *Evidence-Based Design for Multiple Building Types: Applied Research-Based Knowledge for Multiple Building Types*, Ed. John Wiley & Sons.

Hinze, J., Bohner, S., Lew J.(editors), Evolution of and Directions in Construction Safety and Health, Proceedings of CIB W99 International Conference 14th Rinker International Conference, http://www.irbnet.de/daten/iconda/CIB10245.pdf

Loi du 31.12.1993, Loi du 93/1418, available online at: http://legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000361975

Sackett, D.L. (1996) Rosemberg, W., Gray J., et al., *Evidence-based medicine: what it is and what it isn't*. BMJ 1996;312:71-2.

Wolpert, L. (1992) The Unnatural Nature of Science, Faber, London.