On the Adoption of Improved Energy Efficiency in Buildings: Perspective of Design Firms

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ABSTRACT

The adoption of energy efficiency in building design has become a matter of great importance given the links between energy use and global environmental change. While much research has been done on building engineering and science as well as on the benefits of energy efficiency to building owners and investors, little information is available on the process of successful technology adoption among designers. This article proposes that literature on innovation theory can provide insight into the problem of improving the adoption of energy efficient design. An adaptation of innovation theory principles to the adoption of improved energy performance has been developed. The objective is to provide an understanding of key aspects to promoting the technology more effectively among building design firms. The research highlights the importance of addressing designers' informational needs. Problems of imperfect information are identified, and suggestions for reducing barriers in this respect are discussed.

INTRODUCTION

Energy efficiency has not only been associated with lower building operating costs, but also with competitive advantage, corporate prestige and reputation (Robbins, 1986) (E. Source, 1992) (Eley Associates, 1999), greater productivity of workforce (Robbins, 1986) (Ne'eman et al., 1976), economic incentives (NRCan 2003), greenhouse gas emissions reduction, and fossil fuel conservation (Barnett and Browning, 1995). Further, energy-efficient buildings are more likely to comply with longer-term

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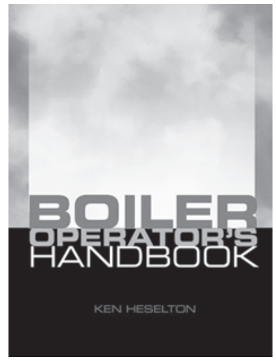

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change to environmental legislation (i.e., it is likely that once enough projects have proven energy efficiency's feasibility, new codes be implemented), thus retaining their value (Larsson, 1998) (Francis, 1998). Ironically, even today many designers fail to consider energy efficiency aspects in their designs (University of Strathclyde, 2000).

There is no doubt that getting a new idea adopted, even when it has obvious advantages, is often difficult (Rogers 1995). This is especially true when high-risk liabilities are involved, as in the case of building design. For instance, because an error in HVAC systems calculations can affect not only comfort conditions but also health, equipment oversizing is sometimes pursued despite the extra costs that inefficient designs impose on owners, occupants, and utility companies (E. Source, 1992).

Several strategies have been used to promote innovation in commercial and institutional buildings. Incentive programs (i.e., The Commercial Building Incentive Program in Canada), building rating programs (i.e. Leadership in Energy and Environmental Design in the U.S.), and financing opportunities (i.e., energy performance contracting opportunities) have emerged as a result of the need to reduce fossil fuel use and reduce greenhouse gas emissions. Even when many of these programs are having increasing demand, it is clear there is still more to be done. For example, as of April, 2004, the U.S. Green Building Council listed one hundred buildings in the U.S. and three in Canada as LEED certified between 2000 and 2003. With respect to CBIP, seventy-nine projects were approved under the program in the fiscal year 2002-2003. The average number of commercial and institutional buildings built per year in the U.S. is 69,000 (based on census 1990-1999) (Energy Information Administration, 2003), while in Canada, an average of 1,930 buildings are built yearly (based on census 1990-1999) (Office of Energy Efficiency, 2004).

Studies (Edwards, 1998) of the potential benefits to the environment and economic savings product of the operation of energy-efficient buildings have been greatly publicized. Research on technical engineering aspects and building science has been used to further promote energy efficiency. Unfortunately, many of these efforts failed and little attention has been given to analyzing the reasons why people decide against adopting the technology.

This article proposes that literature on innovation theory can provide insight to the problem of improving the rate of adoption of energy efficient design. An adaptation of innovation theory principles to the adoption of improved energy performance has been developed. The objective is to provide an understanding of key aspects to promoting the technology more effectively among building design firms.

THE INNOVATION PROCESS

The innovation process is an information seeking and information-processing activity aimed at decreasing uncertainty in five different stages (Rogers 1995). In the context of energy-efficient building design, these stages may be defined as follows.

The first stage is a stage of consciousness in which designers are exposed to the technology and gain an understanding of how it works. This understanding can be either unintentional or as a result of a mindful search for a solution to a problem.

The second stage is a stage of interest, which occurs when a favorable attitude towards energy efficiency is taken and information with which to evaluate the new technology is gathered. At first, designers will be interested in the technological aspects of the innovation (what it is and how it works). Once the technology has been understood, they will become interested in the advantages and disadvantages of the innovation in their specific situation.

In the third stage, also known as stage of evaluation, the design team decides to engage in activities to adopt the technology. It normally includes feasibility studies based on the adopter's own situation, trying to assess advantages and disadvantages through the recognition of external and internal innovation factors. *External innovation factors* refer to technological, institutional, and cultural innovation drivers and barriers (Van de Ven 1986). They include laws, government regulations, distribution of knowledge and resources, as well as the structure of the industry in which the innovation takes place. External factors will therefore be seen differently depending on the nature of the adopter. Usually, the larger the firm, the longer it may take to move through the innovation process, as more people are involved in the taking of decisions. *Internal innovation factors*, on the other hand, are defined as the firm's capabilities or organizational change needed to adopt the new technology (Alange et al. 1998). For instance, it can mean innovations in management practices, administrative processes, or innovations in the organizational structure of the firm. The structure, competencies and culture of the firm will determine its capacity to sustain and exploit innovation opportunities (Del Rio Soto, 2002).

The fourth stage occurs when the technology is actually put into use. This stage of trial itself involves risk since it is difficult to use or test energy efficiency in buildings in a limited scale. Although computer modeling can be used to assess approaches, it is not until the building is constructed that energy performance can be fully evaluated. It is hence essential that the three previous stages be fully understood beforehand.

Finally, the stage of adoption, as its name suggests, is when designers decide to continue with the innovation. During this stage, adopters evaluate benefits with respect to potential barriers and decisions are made regarding the desirability of the technology. In this stage designers commit themselves to full-scale use the technology.

The five stages of innovation clearly recognize the need to address the technological and societal aspects of energy efficiency. In terms of the technological aspects, it is evident that unless the technology is fully understood, it is likely that the innovation process will be precluded. With respect to the societal aspects, internal and external innovation factors will greatly influence the adopter's decision to bring innovation into practice. The speed in which innovation is accepted will be determined by perceived relative advantage, complexity, compatibility, divisibility or triability, and observability of the technology (Rogers, 1995). In the energy efficiency context, one can argue that:

- *Relative advantage* is the degree to which the technology is perceived as superior to preceding practices usually measured in terms of profitability and corporate image.

- C*omplexity*, on the other hand, relates to the extent to which the innovation can be easily understood and put into practice. This means that the faster the principles and practices of energy efficiency are understood, the faster the innovation will be adopted.

- *Compatibility* relates to the degree to which the technology is consistent with existing practices, values, and needs. The ability of management to drive innovation supported by the firm's core competencies will determine its competitive advantage (Del Rio

Soto, 2002). Alange et al. (1998) argue that what the design team can hope to do technologically in the future is influenced by what it has been capable of doing in the past. It can be assumed that firms which have been innovative in the past will be more open to adopting the new technology (Vredenburg and Wesley, 1997).

- *Divisibility* or *triability* is defined as the degree to which the innovation can be tried on a limited basis. Unfortunately, as mentioned briefly earlier, this is limited in buildings. Certainly, some technologies can be tested individually (i.e. luminaire and blind efficiency). However, the analysis of a whole-building design approach is more complex. Thus, it is of great importance to have a clear understanding of the technology beforehand, as in most cases, small-scale experimentation is impossible.

- Finally, *observability* is defined as the extent to which results can be perceived. In this respect, building performance is usually evaluated on a twelve-month basis through monitoring and/or building auditing.

PROMOTING ENERGY EFFICIENCY IN BUILDINGS

Although many aspects will influence innovation (i.e., economics, market receptiveness, availability of resources, the firm's inter-organizational relationships), it is evident that informational needs should be prioritized. Following innovation theory principles, an understanding of the first and second stages described above will determine whether or not the design firm will be successful in adopting the technology. The argument is consistent with McKenzie-Mohr (1995) and Webster (1991), who argue that new ideas can only be introduced into the innovation process if these are familiar to the adopter. If the design team decides to implement the innovation despite possible informational constraints, failures caused by inadequate planning and problem understanding are likely to occur. Further, the introduction of an incomplete product to the market where the technology fails to perform as expected can cause a significant delay in the adoption as skepticism develops (Webster, 1991). For instance, when electronic ballasts (assembly responsible for proper start and operation of fluorescent lamps) first appeared in the market, their performance was quite questionable due to distortions produced in electric power. Even when the problem was overcome, skepticism prevailed for several years. (Love, 2000).

Elder (1984) posits that most barriers to adopting energy efficiency are due to lack of experience and information. He recognizes that the lack of clear and reliable information on technology performance and ways to integrate energy efficiency in the design raises barriers at different levels of activity (i.e. research, development, and the marketplace). This argument was further confirmed in a study conducted by Andrus et al. (2002) where one of the main barriers to adopting improved energy performance in buildings was fear of change due to lack of clear understanding of the technology.

On the other hand, Hillier et al. (1984) suggest that the quality of architecture has been reduced due to the lack of understanding of building design. Scientists have relied on designers' ability to integrate research results into design, assuming that they will use the same systematic methodology scientists do to generate knowledge. While in the case of scientists, theories are derived through logical analyses of facts, designers use a more intuitive way of dealing with problems. In other words, scientists routinely analyze, assimilate, and rationalize facts by decomposing a problem into sub-problems through a set of logical procedures. Further, each sub-problem is studied separately and solutions are later generated through synthesis. Designers, on the other hand, use an approach based on the study of precedents. Design is achieved through structuring problems either by knowledge of solution types or by knowledge of building technologies in relation to solution types. Hence it does not come as a surprise that designers feel overwhelmed with technologies that have proven to work on their own but have little relation to the overall design process.

The above discussions point towards key aspects to successful technology adoption. However, most recent research has ignored this by focusing on isolated technical problems in engineering and building science, disregarding how these affect the overall building design process (Blumstein et al., 2000) (Watson and Labs, 1983). That is, most studies have concentrated on isolated elements of building performance rather than integrated systems. On the other hand, as noted by Hayman et al. (2000), the design community is unlikely to be able to address in-depth research in a "business-as-usual" environment and concur with Hillier et al. (1984) and Francis (1998) that information must be readily available in the form of useful guides researchers can follow if technology implementation is to be promoted.

ADDRESSING DESIGNERS' INFORMATIONAL NEEDS

Innovation has certainly been precluded because designers have not been able to apply and assess the technology appropriately. Further, unless research can influence designers at very early stages (pre-structuring stage), its effect on building design may be insignificant. Providing proper channels of communication among disciplines involved in the research, design, and construction of buildings is hence of great importance.

Hillier et al. (1994) suggest that typological models can provide tools that facilitate the transfer of more accurate information on research results among designers. "Additionally, if researchers work with designers in producing experimental solution types, which are monitored and improved, and later publicized, then research itself benefits by becoming part of a dynamic process of continuous learning and concept development."

A typological model may be defined as a set of suggestions where distinctive characteristics involving the design of a building are presented as a pattern of an item to be reproduced. A model should be relevant from the user's point of view, and to the problem in question, maintain sufficient relation with reality while providing the insights that come from simplifying the problem. It should be a means that provides professionals with tools to reduce the risks involved in the adoption of energy efficiency by avoiding the need for designers to test approaches with no guidance, jeopardizing the desired result. Hence the innovation process.

However, it is clear that attention must be directed to specifying the extent to which these models may be used. Principles of energy efficiency may be alike when compared to buildings that serve the same purpose in similar geographic locations. For instance, there are two underlying factors that are consistent throughout northern regions: cold temperatures and low sun angles. As a result, for most small-size buildings, heating will play a major role in energy use. In terms of daylighting and shading solutions, glare and light penetration problems due to low sun angles will be common.

Nevertheless, each case requires specific attention. There is clearly a risk that designers rely exclusively on the information provided, and that problems of poor interpretation and model degradation arise. Innumerable factors will influence the design process (e.g., design teams may decide to follow different paths to achieve the energy goal); therefore, typologies that include a description of the methodology followed to identify best practice solutions are likely to help designers adapt and improve solutions more effectively.

Other means that have been recognized as useful in improving the effectiveness of promoting energy efficiency refer to the development of case studies (Ternoey et al., 1985). Detailed reports on existing projects can contribute to the generation of new ideas and research areas by portraying others' experiences and results. For instance, case studies are particularly useful to evaluate the effectiveness of the technology, including its strengths and weaknesses on real case scenarios. Information gathered through site monitoring and/or computer modeling can be published to help demonstrate new ways of approaching the problem, detect areas where research is required, define approaches that are worthy of replication, and avoid those which are not.

While it is true that trade publications (i.e., ASHRAE and IESNA journals), and organizations such as Natural Resources Canada and the Green Building Council have publicized many case studies, there is a clear tendency to mention only successful approaches. To this respect, researchers (ANZES round table, 1999) have agreed that sometimes more is learned from unsuccessful experiences and there is a need to promote the publicizing of mistakes as part of a learning process. However, it is important to note that especially when dealing with unsuccessful projects, attention should be directed to ethics canons. On the other hand, case studies are rarely directed to analyzing social aspects. It would be helpful to have a clearer understanding of the educational curve that takes place within the design team during the adoption process. For instance, in a study on successful energy efficiency adopters (Andrus et al. 2002), participants mentioned that it was useful to have frequent meetings with other design team members. Further studies directed towards understanding how meetings were conducted and the planning and usage of an agenda would be useful to better promoting the technology. Learning from others' experiences, as argued by Corey (1991), is a way of minimizing problem complexity, hence reducing chances of failure.

Another important aspect in promoting energy efficiency in buildings is directing resources towards education and research. Buildings are complex microcosms of materials, environmental control systems, building automation systems, occupants and the interactions of these. Success in energy-efficient design is hence greatly dependent not only on efficient equipment, but also the way building systems interact. This implies a change in the way future professionals are introduced to the design process, since energy efficiency clearly requires an interdisciplinary perspective to building design. As argued by several authors (Hui, 1997) (Documentation Office for Environmental Studies, 1996), designers are often trained in relatively isolated educational domains. For example, architectural and engineering programs of study often have little relation to each other's disciplines. While efforts have been directed towards including issues regarding interdisciplinary approaches and energy-efficient aspects in today's education programs, there is still more to be done. Some would argue that the world of energy efficiency is complex and that students are already so overwhelmed with the amount of information provided by their university programs that it would be extremely difficult to include these concepts into the curriculum. Still others (Golde and Gallaguer, 1999) have questioned the desirability of such an approach, arguing that it is unlikely that students acquire a sufficiently solid base of knowledge to make significant research contributions (depth is sacrificed for breadth). In this respect, Golde and Gallaguer (1999) suggest interdisciplinary research should be introduced at early stage of university education, but should not be extensively encouraged until graduate levels, when students have had a chance to assimilate information pertaining their own discipline. However, only a small fraction of students take up graduate studies. There is no question that times are changing, and with them, demands on building designers are increasing. While it is certainly difficult to incorporate new knowledge in an already demanding discipline (e.g., architecture, engineering), there is undoubtedly a need for analyzing present curriculums and adapting them according to new realities.

CONCLUDING REMARKS

The study of the innovation in corporations, especially large ones, is quite common. However, innovation has rarely been analyzed in the context of design firms (i.e., engineers, architects). The objective of this article is to shed some light on this topic. The analysis of the innovation process in the building industry has provided insight to elements that play a pivotal role in promoting the adoption of energy efficiency practices. The need to address designers' informational needs seems apparent. Following innovation theory principles, success in the adoption of new technologies and approaches is based on the ability to reduce market failures related to problems resulting from imperfect information. The first step to adoption is acquiring a clear understanding of the technology. In this respect, it has been found that an interdisciplinary approach to research and education, and the development of proper channels of communication to improve information exchange, are needed. The latter definitely sets pressure on governments, schools, researchers, manufactures, marketers, strategists, policy makers, and designers themselves to find ways in which energy efficiency can be better promoted.

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