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The "Costs" of Operable Windows:

On the Question of Operable Windows in Cold Climate Design

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This fine April afternoon, as garden bulbs push their way out from under the winter months, a cool spring breeze blows through the room. I throw my house open to spring, knowing that these beautiful days are precious and few in Minnesota. Throughout the city we're celebrating and relishing the return of the sun and the coming days of summer. On a day such as this, I wonder how it came to be that operable windows are the exception, rather than the norm, in commercial and institutional buildings throughout Minnesota.

Problem Statement

In the United States, the elimination of operable windows is one of the greatest losses in contemporary architecture. Look around the built environment and you will see how rare it is to find operable windows in new commercial and institutional buildings. Despite the increased transparency of the building envelope, our architecture is increasingly impermeable and disconnected from the world in which we live. Yet, this trend is not shared throughout the world. Just as U.S. designers are specifying more nonoperable windows, we find designers in many other countries – from Switzerland to the Netherlands to the United Kingdom – opening their buildings to the world. Threats of the Sick Building Syndrome (SBS), Building Related Illness (BRI), and problems of Indoor Air Quality (IAQ) have lead designers in other countries to explore "design solutions" to these problems (i.e. solutions related to building form, massing, fenestration, material specification, etc.). [1] Throughout Europe natural ventilation (and subsequently operable windows) has been rediscovered as one of several viable solutions to problems with indoor air quality. In contrast, many designers in the U.S. have increasingly turned to "mechanical solutions" to solve the same problems.

Operable windows are important on a variety of levels: they enable physical connection with the outside world, create a sense of personal control, and if properly designed, they can provide natural ventilation to reduce cooling loads and consumption of fossil fuels. The impact of operable windows on psychological and physiological well-being should not be underestimated. Roslyn Lindheim, in her essay "New Design Parameters for Healthy Places," cites the lack of social and natural connections as leading causes of disease.[2] In addition, early IAQ studies from the United Kingdom found a direct correlation between SBS and mechanical ventilation. John Bruening, a writer specializing in issues of health and safety, states: "SBS has been linked with inadequate building ventilation because symptoms usually are more prevalent in air-conditioned buildings than in naturally ventilated buildings with operable windows."[3] Other building scientists argue that tighter buildings and lower ventilation rates, in response to the energy crisis of the 1970s, combined with an increased use of synthetic materials containing volatile organic compounds (VOCs) exacerbated air quality problems. Designers, engineers, and building scientists in the U.K., Scandinavia, Switzerland, Germany, and other countries are seriously considering the relationships between health, daylighting, and naturally ventilated buildings. As Christine Johnson Coffin explains in her essay *Thick Buildings*: "Europeans have taken a stronger stand on workplace windows. In Germany, windows are expected near workstations. In Finland, where at midwinter the few daylight hours occur entirely during the workday, daylighting is a legal requirement in workplaces. The Netherlands also requires windows in workplaces. Indeed, a further Dutch requirement prevents the use of mechanical air conditioning in new structures unless required by machinery or processes."[4] In contrast to European trends toward natural ventilation, operable windows have become the exception, rather than the norm, in contemporary institutional and commercial architecture in the United States.

There are complex challenges for window design if one is to balance energy, IAQ, comfort, and occupant control. This is particularly true in cold climates, where energy efficiency has lead to extremely tight building envelopes and subsequently greater problems with moisture and indoor air quality. Regardless of whether operable windows are intentionally used for light and air, the variability they introduce into the interior environment directly impacts ventilation design, including air quality, humidity control, ventilation rates, air distribution, and integration with HVAC and control systems. With many building types (depending on the design, size, occupant load, and activities), operable windows do not provide sufficient ventilation to meet current building standards. Even residential construction is increasingly dependent on mechanical ventilation due to tighter construction and issues related to IAQ and moisture. In addition, there are relatively few days that natural ventilation is a viable option in a cold climate. There is no doubt that operable windows make ventilation more difficult to address. Yet, is it possible in cold climates to use a “hybrid” solution that combines mechanical and natural ventilation during the cooling period? If so, how, when, and where can this be done?

Interviews were conducted with leading designers, engineers, and building researchers in Minnesota to understand the breadth of design issues and related "costs" of operable windows in cold climates. The findings of the study are organized into seven critical design issues that emerged from the interviews: 1) priorities and values, 2) definition of comfort, 3) myths of mechanical ventilation control, 4) liability, 5) economics and energy, 6) precedents, and 7) design opportunities. The following discussion considers possible opportunities, challenges, and solutions to the design of operable windows in contemporary architectural design.

Research Findings

1. Question priorities and values

The question of operable windows is in part a question of values and priorities. For Sarah Nettleton, principal of Sarah Nettleton Architects, it’s a philosophical question: “To choose operable windows is to choose connection to the world.” As Nettleton explains: “We’ve become indoor creatures. Many people don’t have a desire to connect to the outside. Nature is ‘inconvenient,’ it bites, messes-up your hair, causes sunburn. Non-operable windows are symptomatic of our deep loss of connection with nature, creation, and life.” Nettleton sees many factors that have led us to this disconnect, from our market-driven world to our increased dependence on technology. As a result we no longer expect or perhaps even want operable windows.

According to Jeff Sherer, Principal of Meyer, Sherer, and Rockcastle and President of AIA Minnesota, the issue of operable windows is a classic argument between quality and quantity. While acknowledging the challenges of operable windows, he believes that issues of systems balancing, safety, and comfort can be met. He argues: “ There’s no reason you can’t put operable windows in a building and maintain performance. The question is how will performance be effected and how will the system compensate?” Sherer argues that the choice of operable windows is dependent on the values and priorities of the client and design team: “Clients need to be approached properly. You need to know the possible objections and the bottom line. Be informed and smart. Set goals. You need to break down the reasons and arguments. Provide a process and way of thinking that will help owners and designers. Success depends on how you start the process.”

2. Our definition of comfort is too narrow; we need to accept unpredictability

Peter Herzog, engineer and Partner at Herzog-Wheeler Associates, often works with designers, building operators, and building occupants. He finds it difficult to keep everyone happy and comfortable: “Operators try to keep the building within an agreed specification; usually a narrow range between 72-75º. Still some people are too hot and some are too cold.” Given this narrow tolerance, comfort can be a losing battle for building operators and a frustration for occupants. Sarah Nettleton also acknowledged that comfort is narrowly defined in the U.S. “Today many people have become unwilling to accommodate changes in heat or light. We want the buildings to accommodate.” This approach puts a heavy demand on the building and in many cases, one could argue, has led to a narrower definition of acceptable ranges of comfort and a greater desire for “mechanical control.” We need to reconsider appropriate standards of comfort as well as the related roles of occupant expectations and responsibility.

The mistake is to assume that operable windows make it impossible to meet today’s performance and comfort standards, and that they can be met only through mechanical means. Jeff Sherer notes that most people are willing to accept greater variability in light in exchange for a window view; he suggests that people do the same with ventilation and comfort – they’ll compensate when there’s variability. Peter Herzog explains: “To open a window is to accept a broader comfort zone (a broader specification). Operable windows introduce greater ranges in temperature and humidity. We seal our buildings to control them.”

Herzog also raises the questions of variability and human dynamics when operable windows are introduced: “For example, in an office building with ten occupants, some people might get natural ventilation while some might get mechanical ventilation. Who controls the windows? How uniform is the air? How do you come to a consensus on comfort? Are the potential conflicts worth the effort?” Yet, Tom McDougall, engineer and Vice-president of the Weidt Group, a design and energy-consulting firm, cautions us to remember that even if mechanical ventilation reduces the problem of group dynamics, it doesn’t necessarily solve the problem of comfort: “Mechanical ventilation doesn’t provide comfort for everyone; some people fall outside the comfort charts.” McDougall also sees variability in the thermal environment as an opportunity rather than necessarily something to alleviate. While most people focus on “controlling” the interior environment, McDougall suggests that the possible change and variability provided by operable windows connects the building envelope to human sensory experiences.

Despite these challenges, Herzog and McDougall agree that the question for operable windows is: “where and when are they appropriate?” There is no single answer to this question. It requires consideration by the design team, client, occupants, and building operators. The task is to bring the issue to the table. We need to discuss and consider the building types, programs, and activities for which we are willing to accept greater variability in terms of temperature, relative humidity, and comfort.

3. Consider the myths of mechanical ventilation "control"

Is it true that mechanical ventilation offers greater "control"? John Carmody, Director of the Center for Sustainable Building Research notes that post occupancy evaluations (POEs) demonstrate that mechanical systems do not always work as planned: "Spaces are often overheated or underheated, yet we act like mechanical systems take care of everything. It's a fallacy that mechanical systems work all the time." This does not suggest that mechanical ventilation is unsuccessful, it simply reminds us that it is not foolproof. Many of our buildings are chronically too hot or too cold, yet we continue to depend on building operators, rather than design and systems integration, as a means to solve problems. If the comfort issues are chronic, occupants will often take issues into their own hands. (On a recent July day, with an outside Heat Index of 104º, a colleague in an air-conditioned office was wearing a polar fleece vest with a heater running beneath the desk.)

Carmody also sees operable windows as an option for choice, and argues that in a cold climate their greatest benefits are related to human factors of perceived and real comfort: "Operable windows are forgiving. If the mechanical systems are not working, there are choices." Concerning *perceived* comfort, Tom McDougall also notes that the *assumed* benefits of mechanical versus natural ventilation can be distinct from the *actual* benefits. For example, the control of allergens and pollens is often cited as a reason for mechanical ventilation. Yet McDougall notes that many HVAC filtration systems do not deal with pollen unless special filters are specified. However, he emphasizes that typical mechanical ventilation plays a critical role in filtering common air borne particulates in buildings.

4. Liability and inertia are real

Peter Herzog explains that IAQ and moisture problems have lead many designers, engineers, and building owners toward exclusive use of mechanical ventilation. Serious IAQ problems in office buildings and schools have made everyone more wary of approaches that seem less quantifiable. Building owners, office workers, school boards, and building operators want assurances that the system is predictable and dependable. He explains: "In many cases designers are air conditioning all summer and in the spring and fall to alleviate moisture problems (and possible health issues)." As a result, energy use is climbing and the required quantity and rates of air changes in buildings are increasing dramatically. Herzog notes that the baseline for energy efficiency has gone up, meaning that due to new health problems we are using more and more energy to solve the problems mechanically. He argues that due to IAQ concerns we are moving back towards the energy-intensive systems of the 1970s and that designers and engineers are spending more time and money to deal with health concerns such as mold and mildew. Marilou Cheple, Interim Director of the Cold Climate Program at the University of Minnesota, works with residential designers and the building industry to prevent the types of catastrophic building failures that can result from moisture and IAQ problems. Yet Cheple notes that these problems can occur regardless of whether the window is operable, and emphasizes the importance of proper window installation and detailing. She also observes that the desire for increasingly maintenance-free and computerized buildings is biased toward mechanical rather than natural ventilation. Cheple suggests that: "Before air-conditioning, we were wiser about window layout and building design."

Jim Keller, mechanical engineer and Principal of Gausman & Moore, also emphasizes IAQ issues, but stresses that they can be solved in creative ways. Keller admits that inertia is a real challenge when it comes to operable windows: "People go with what they know works. That means nonoperable windows with mechanical ventilation. With today's budget and fees that's usually the first solution." He notes that it often takes an interested client or owner to push other ways of doing things. Jeff Sherer echoes the important role of clients, arguing that operable windows are possible: "If we approach clients properly and accept a degree of unpredictability. Owners are concerned about security and performance; mechanical engineers are concerned with predictability, accountability, and liability." Sherer described the answer to the question of operable windows as a systems issue of quality and performance: "To isolate the parts is not acceptable."

5. It's more than economics and energy

Tom McDougall admits that the arguments for operable windows, and more specifically natural ventilation, can not be made on an energy basis: "The hours for natural ventilation in Minnesota are modest. Yet it can be used to reduce fan energy. Natural ventilation could save 10-25 percent of the energy for fans, perhaps 2-4 percent of energy costs." According to Peter Herzog: "The energy savings would be in proportion to your willingness to modify the control range in a building. When the systems are off you save energy." Herzog questions whether in a cold climate "the energy benefits are significant." Both Tom McDougall and John Carmody suggest that with operable windows there are possible "indirect savings" related to human factors and increased performance. McDougall notes that building owners spend only $1 per square foot to operate the building compared to $200 per square foot in salaries. Carmody cited the more conservative "1-10-100 rule": for each $1 spent on building construction, $10 is spent on operations, and $100 is spent on salaries. In either case, questions remain concerning the intangible psychological and physiological benefits of operable windows.

Carmody also compares operable windows with the human desire for light and view: "It gives people a sense of connection and a feeling of control." He notes that while it's cheaper to design a room with no windows, few designers would consider creating spaces without no daylight, and he puts non-operable windows in the same category. They may be cheaper, but do they make sense in terms of larger ecological and human factors? Finally, we still do not know the full hidden ecological costs and benefits of mechanical and natural ventilation. Tom McDougall argues: "Why design a building that can't operate without fossil fuels?" Linda Sanders, former Dean of the College of Environmental Design at the California Polytechnic University in Pomona, reinforced this concern. Sanders explained that in the midst of the 2001 energy crisis in California, the skyrocketing cost of electricity forced school closings because buildings were not sufficiently daylit or naturally ventilated. Recent assessments of energy consumption in Minnesota and throughout the U.S. suggest that California may not be an isolated case in the years to come.

6. Precedents: It can and has been done

There are solutions to the challenges of operable windows, but they require new (and some old) approaches to design. Tom McDougall reminds us of the many historic examples throughout Minnesota that have successfully used natural ventilation – from warehouse buildings and courtyard offices to libraries and schools. While many of these buildings might not meet today's standards of comfort and energy efficiency, they still provide valuable lessons concerning building siting, form, and window design. Jim Keller suggests that there are many options for natural ventilation and operable windows that could work in Minnesota. For example, atriums for large buildings and simple cross ventilation, stack effect, and thermal mass for smaller buildings. He also reminds us that "natural ventilation" does not have to come through windows; designers can also use various types of venting strategies in walls, floors, and/or roofs.

Keller emphasizes that we need to shift our thinking from ducts and fans to building design and systems integration: "We're essentially talking about the 'ultimate building,' which minimizes the mechanical system and shapes energy flow through the design of the building envelope." Only a small percentage of windows need to be operable for effective ventilation and connection to the outside. Stephen Carpenter, engineer with Enermodal Engineering Limited in Ontario suggests that in office buildings only 15-20 percent of the windows need to be operable if properly designed and located.[5]

According to Joel Shurke, Principal of Factor 10, a firm specializing in high performance design and development: "The U.S. approach to mechanical systems design combines heating and ventilation. In countries like the U.K., Switzerland, and Germany, designers use "displacement ventilation" which decouples heating and ventilation. This makes it easier to integrate passive cooling and heating without compromising comfort and air quality. In a recent analysis for a proposed building for the Elk River School District, Factor 10 determined that there was a "potential for natural ventilation during 40 percent of school operating hours." In addition to designing the building to optimize natural ventilation, the proposed strategy separated the fresh air supply system from the heating/cooling systems. The system used 100 percent outside air (not remixed air) to provide the required indoor air quality (15 cubic feet per minute per person) for each occupied space; while a water-based supply system provided cooling and heating. According to Shurke, the separation of the fresh air supply from heating and cooling creates new opportunities for design thinking while still optimizing IAQ and energy efficiency. He explains that this approach shifts the focus from mechanical systems to the design of the high performance building shell (the building form, walls, roof, floor, and window size and placement). He admits that while the conceptual idea is simple, the application is complex. The challenges are to integrate the building design with the mechanical systems, balance the ventilation systems with the operable windows, and stay within budget. Finally, Shurke believes a philosophical shift is required to accept this or other feasible models in the U.S. This shift requires a willingness to try new design strategies that more actively engage the building occupants.

7. Design opportunities: go beyond mechanical systems

The focus on design solutions and systems integration was the common thread that linked the interviews with the designers, engineers, and researchers. The problems of IAQ and comfort are serious *design* challenges that exist in buildings with or without operable windows. Yet Jim Keller noted that IAQ issues are often related to construction or maintenance, rather than the mechanical system or even the design. Do not create the problems to begin with: consider site and building design, eliminate toxins, use no or low-VOC materials, consider design strategies to eliminate moisture problems, look at window installation and detailing, and address maintenance and operations. Keller suggests that problems can not be solved through mechanical systems alone; issues also have to be addressed through design, materials, construction, and operations. Herzog, Keller, McDougall, and Carmody also emphasized the need for additional building science research to understand the potentials of natural ventilation given contemporary health and energy issues. While there are many approaches to operable windows, the single most critical issue is to discuss the questions, concerns, and possible options from the beginning of the design process.

Conclusions

Is it acceptable to shut our buildings to the world because operable windows introduce variability, complexity, and additional costs to building design and operation? The argument for and against operable windows, particularly in cold climates, can be considered on many levels. As the interviews illustrate, designers, engineers, building operators, and occupants are challenged to weigh a complex set of issues. While the challenges are real, and at times daunting, contemporary design can include operable windows without compromising IAQ, energy efficiency, economics, and human comfort. Operable windows require greater attention to the building and window designs, their first costs are higher, they require integration with mechanical systems, and they create greater variability in the thermal environment. Yes, operable windows financially "cost" more (including design time and first costs), yet the economic bottom line rarely considers the intangible and often hidden ecological and human "costs" of nonoperable windows. So, why bother when operable windows take so much effort? The answer is simply that operable windows are the right thing to do. Daylighting coupled with operable windows should be viewed not as a "privilege," but as a "right" that ensures the physical and psychological well-being of building occupants.

Operable windows connect us to life. Given today's environmental concerns, we need to stay connected - perhaps more than ever - to the rhythms and ecology of place. We need to stay connected to the cycles of time, season, climate, and weather. With the average person in the U.S. spending over 90 percent of her or his time inside, it's ever more important that our buildings keep us connected to each other and the world.[6] As Dr. Leland Kaiser, healthcare consultant, author, and Professor Emeritus of the University of Colorado, explains: "In designing buildings, we are designing consciousness…. First we give shape to the buildings, then they begin to shape us."[7] The more distant we are from our environment the easier it is to be indifferent, even apathetic, about the significant toll our species takes on our beautiful Earth. It is only when ecological and human costs are valued as much as the bottom line, that designers, building owners, and operators will accept the financial costs and subsequently the benefits of operable windows.

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ENDNOTES

1 According to the U.S. Environmental Protection Agency (EPA): "The term 'sick building syndrome' [SBS] is used to describe a situation in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified. The complaints may be localized in a particular room or zone, or may be widespread throughout the building. In contrast, the term 'building related illness' [BRI] is used when symptoms of diagnosable illness are identified and can be attributed directly to airborne building contaminants." The U.S. EPA, Office of Radiation and Indoor Air (6607J), *Indoor Air Facts No. 4* (revised), Washington, D.C.: EPA Office of Air and Radiation.

2 Roslyn Lindheim, "New Design Parameters for Healthy Places," *Places*, Vol. 2, Number 4, 17-27.

3 John Bruening, *See the Light: Good Lighting Balances Sources*, http://www.meadhatcher.com.: 2.

4 Christine Johnson Coffin, "Thick Buildings," *Places* 9, no. 3, 71.

5 Stephen Carpenter, "Operable Windows for Offices," *Advanced Building Technologies and Practices*, http//www.advancedbuildings.org: 2.

6 U.S. Environmental Protection Agency, Office of Air and Radiation, *Targeting Indoor Air Pollution*, EPA Document #400-R-92-012.

7 Logsdon, Robert M. "The Human Side: Understanding the Application of Lazure Painting Techniques," *Journal of Healthcare Design*, vol. 7, http://www.healthdesign.org/library/journal/journal7/j728.htm.