REFRAMING ENVIRONMENTAL BUILDING DESIGN GUIDELINES TO ACCOUNT FOR USER'S ATTITUDES AND BEHAVIOUR

by

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ABSTRACT

The construction of a building negatively impacts the environment; however, its operation and use places an even greater burden on natural systems. Most environmental design guidelines provide recommendations that address the former issue, but not the latter. Despite the importance of understanding human-building interactions, this aspect is currently not well reflected in office building design guidance, and the fact that an environmentally responsive building's success relies in large part on user behaviour, needs to be made more explicit. As such, the behaviour of workers in a Swiss and Canadian office building was studied through questionnaires. There are two important findings from the research. First, since most environmentally responsive buildings have most of their control features along the perimeter, a design that places individuals in close proximity to a window is successful because it results in greater user satisfaction with the ability to regulate thermal conditions, ventilation, and daylighting. Due to the fact that the reluctance to freely alter indoor conditions is proportional to the number of people working in a shared office, the most ideal situation – at least from a user control perspective – is an individual office for occupants. Second, the building users best dictate the extent to which technological systems should be incorporated into a design. Technology is applied most sensibly when it is able to minimize energy use without being perceptible by occupants, or compromising the users' sense of control over his/her environment. Based on this insight, certain recommendations in a set of guidelines were reframed to better acknowledge and respond to users' expectations and needs.
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1. INTRODUCTION

The history of human population growth is staggering. By the 1800's the world population was 1 billion people; it then took only 130 years for the population to reach 2 billion; another 30 years to reach 3 billion; and 15 years to reach 4 billion. There are currently close to 6 billion people on this planet. Predictions suggest that with an annual growth rate of 1.7%, by the year 2025 the human population will have reached between 7.5 and 9 billion. The time required to double the current population in more developed countries is between 60 to 70 years, while for less developed nations it is only 15 years (Harper, 1996:151).

The continuing and alarming trend in population growth has serious implications for global and regional ecosystems. The amount of food, water, housing, infrastructures and social services Western industrialized societies currently require will have to double over the next 6-7 decades. In tandem, the waste materials and noxious emissions that arise in the production of these necessities and amenities will likewise increase by 50% unless societies change their current consumption and behaviour patterns.

The geographic distribution of human population is also shifting. "Urbanization" is a growing phenomenon, as people leave the rural areas behind and move to cities. In all likelihood, the majority of the projected 7.5 - 9 billion people will live in cities. The problems associated with urbanization stem from the fact
that in order to sustain itself, a city is dependent on remote biological and geological resources. The energy and resource flows that city dwellers require can be thought of as "land- and water-area equivalents" (Rees, 1998:8). Rees and Wackernagel (1994) have introduced the concept of an "ecological footprint": "[The] ecological footprint is the area of land/water required to produce the resources consumed, and to assimilate the wastes generated, by that population on a continuous basis, wherever on Earth that land may be located" (Rees, 1998:8). Increasing ecological footprints are accompanied by diminishing concern for natural systems: "[The] resultant separation of production from consumption renders urbanites blind to the degradation that results from their consumer lifestyles and unconscious of their increasing dependence on a deteriorating resource base" (Rees, 1998:8).

If the "ecological carrying systems" are currently stressed, then further exponential population growth and urbanization will be catastrophic. It is therefore vital that the current course of human development is altered to align it with the capabilities of natural systems. "Global sustainability" will permit humankind to persist over generations without undermining either its physical or its social systems. According to Harper (1996:269-271), the requirements for a sustainable society are as follows:

1. Dampen population growth and stabilize its size.
2. Conserve and restore its biological base, including fertile soil, grasslands, fisheries, forests, and freshwater and water tables.
3. Gradually minimize or phase out the use of fossil fuels.
4. Make work more economically efficient in all senses. Appropriate technology. Produce durable goods rather than consumable ones. In a sustainable economy the principle resource would be recycled goods.
5. Dampen population growth and stabilize its size.
6. Conserve and restore its biological base, including fertile soil, grasslands, fisheries, forests, and freshwater and water tables.
7. Cooperate in the negotiation of sustainability in other societies, since societies are connected with each other and to a shared environment.

Although not explicitly stated, most of the requirements for a sustainable society have significance for architecture. The construction phase of a building certainly has an affect on the "biological base", since the extraction, transportation, manufacturing and assembly of materials
is accompanied by toxic emissions and waste production. The operation and use of buildings places an even greater burden on natural systems. Typically, the energy required to condition indoor environments to specified levels, and the current excess amounts of air emissions, waste water, and solid waste are not compatible with the dictates of sustainability.

1.1 DEFINING "SUSTAINABLE ARCHITECTURE"

The term "sustainable architecture" is widely used to refer to a building that responds to the goal of sustainability. "Sustainable", "green", "environmentally sensitive", "environmentally friendly", and "ecological" (or eco- as a prefix) are all additional labels subscribed to identify a type of architecture that has a sustainable agenda. Architecture appropriate for a sustainable society is not easy to define – even the term used to describe it is somewhat inappropriate. Technically speaking, a building cannot be sustainable. Since humans degrade the environment through their actions, it is only the act of constructing and the act of operating and maintaining a building that can become sustainable. A more appropriate term is "environmentally responsive" architecture. This term implies that a building is responsive to both human health and well-being, and ecological concerns.

The criteria of environmentally responsive architecture are still emerging and have consensus neither among clients nor designers. Due to its flexible definition, it is necessary to establish the attributes that environmentally responsive architecture manifests. Describing a building as either environmentally responsive or not, seems far too limiting. It is more appropriate, given the broad definition of the term, to look at the degree to which a building is environmentally responsive. Somewhere in between the energy consumptive, dehumanizing modern building and the "ideal" environmentally responsive building lies a realistically attainable "environmental" building within current economic and regulatory constraints. With reference to Table 1.1, by contrasting the characteristics of a "non-environmentally responsive" building to a description of
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<td><strong>A CONTEMPORARY BUILDING DEVOID OF ENVIRONMENTAL RESPONSIVENESS</strong></td>
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<tr>
<td>Manipulates nature</td>
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<tr>
<td>It does not make concessions to the natural environment. Furthermore, through mechanical systems, it nullifies both negative and positive external climatic conditions.</td>
</tr>
<tr>
<td>Is energy and material intensive</td>
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<tr>
<td>It relies on energy derived from fossil fuels and contains energy inefficient equipment, and extensive finishing materials.</td>
</tr>
<tr>
<td>Contains building materials with high embodied energy</td>
</tr>
<tr>
<td>It is constructed and finished with new materials that have a high embodied energy, are not from a local source, and are neither reusable or recyclable.</td>
</tr>
<tr>
<td>Has the potential to negatively affect the health of its occupants</td>
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<tr>
<td>The materials, and the way they are installed, emit toxic gases. The building also has a completely sealed envelope. There is no means of opening a window and toxic emissions from materials and equipment are frequently contained. Consequently, if poorly maintained, the air conditioning and heating units needed to create an artificial atmosphere can jeopardize the health of the occupants.</td>
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<tr>
<td>Focuses on short-term finances</td>
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<tr>
<td>It is fixated on minimal initial costs, rather than long-term economic benefits.</td>
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<tr>
<td>Forgets to address the needs of the users</td>
</tr>
<tr>
<td>Oftentimes, the interiors offer little to enhance the psychological well-being of the building users. Many lack a spatial scale in reference to the users.</td>
</tr>
<tr>
<td>Is single-purposed</td>
</tr>
<tr>
<td>It is built with one specific use in mind. This often means that a building is unoccupied for a considerable period of time (evenings, weekends, etc.) — even though it is still being partially conditioned at this time. All too frequently when such buildings have outlived their purpose, they are simply demolished and replaced by new structures.</td>
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an ideal environmentally responsive building, the boundaries for a practical environmentally responsive building can be defined.

1.2 TECHNICAL ASPECTS VERSUS SOCIAL ASPECTS BEHIND ENVIRONMENTALLY RESPONSIVE ARCHITECTURE

An environmentally responsive building acknowledges that the understanding of human behaviour will define the success of the building. It may contain design features that initially challenge the users, but in the long-term are not beyond their acceptability. Documentation on environmentally responsive architecture focuses mainly on the technical means by which energy and environmentally efficient buildings are created. It discusses technical progress, or economic incentives, but not the human and social aspects, in terms of people's acceptance and attitudes within environmentally responsive buildings. One can find considerable information on the technical aspects of buildings such as: solar panels, low emissivity glazing or composting toilets, etc.; the effectiveness of various building materials in resisting heat loss; the significance of creating buildings that respond to local climatic conditions; or the importance of designing overhangs that will strategically admit or block sunlight. Unfortunately there is little acknowledgement of how the users interact with these building features and systems. The role of human behaviour has been largely overlooked in the technology-based analysis of environmentally responsive buildings, despite the fact that users may significantly influence the success of environmentally responsive design and technological features.

For the most part [environmentally responsive architectural] research has been dominated by an engineering approach, where the notion that a building performs at a certain level of efficiency is a central idea, as are related beliefs that research can specify the real-world performance consequences of, for example, insulation levels, the square footage, thickness and location of glass, variations in climate (and microclimate), the siting of the building, and furnace types – and it can specify the interactions between these variables in mathematical models of home energy consumption. This research tradition has favored the use of unoccupied “test” houses as a source of data for its models. When such data are used to predict the amounts of energy consumed by occupied structures, however, the differences observed between actual consumption and predicted levels are typically large, sometimes by a factor of two or three (Hackett & Lutzenhiser, 1991:451).
1.3 BEHAVIOURAL SCIENCE

There is a consensus in social-science literature that, "an understanding of energy and behaviour must include an understanding of the social context of individual action" (Bell, Lowe & Roberts, 1996:101). Here, research attempts to understand the cause of people's energy use habits, and to identify ways of encouraging efficient practices.

Despite its importance, the understanding of human behaviour, whether it be the decision to invest in an environmentally responsive building or the use of heating controls, is still somewhat sketchy. Because it is people rather than buildings which use energy, consumption will always be significantly influenced by behaviour, and the effectiveness of technological and innovative design solutions will depend to a significant degree on how they are applied (Bell, Lowe & Roberts, 1996:87). This notion is reinforced by the research of Seligman, Darley and Becker (1981:325), who examined the energy consumption patterns found in 28 comparable U.S. homes, and discovered that:

1. In a sample of 28 identical townhouses, variation in energy consumption was found to be as great as two to one.
2. In houses where there has been a change in residents, it has been found that the energy consumption of the house with the new residents cannot be predicted from the energy consumption of the same house with the previous residents.
3. Even after houses had been successfully retrofitted (with 20–50 % savings), the variance in energy consumption among the houses remained almost the same as it was before the retrofits took place and the rank order hardly changed.

Although behavioural scientists have for the most part focussed on the variations in energy consumption models, they also study how behaviour influences the amount of water consumed, how much waste is produced, and how destructive the building is on natural systems.

1.4 TECHNOLOGY

An issue that permeates all levels of discussion on environmental solutions revolves around technology. Environmental sociologists note that there is a so-called "duality of human
existence” supporting two different views on technology and how a sustainable society can be attained.

From one point of view, there is the belief that humans are inherently embedded in the broader webs of life. Harper (1996:34), explains this viewpoint as follows: “We are one species among many, both in terms of our biological makeup and our ultimate dependence for food and energy transformations on the resources of the earth and other species”. Those who support this view often elect to lead a lifestyle termed “voluntary simplicity”. They feel that environmental problems are best tackled through a decreased reliance on technological supports, for it is assumed that a future that acknowledges real limits is critical, if only because the costs of failure are not nearly as great as the technological route would imply.

A contrasting view holds the belief that, “humans are the unique creators of technologies and socio-cultural environments that have the singular power to change, manipulate, destroy and sometimes to transcend natural environmental limits” (Harper, 1996:35). Subscribers of this outlook maintain that it is only a matter of time before humans invent the technological capacity that will allow them to compensate for the imbalances they have created within the natural landscape. Resources — whether soil, water, energy, or biological — are never really scarce, and through human ingenuity, we can keep finding new supplies or alternatives. Furthermore, human inventiveness has always developed ways to circumvent or resolve existing scarcities (Harper, 1996:9).

There are compelling arguments for both positions. In practice however, the two paradigms demand considerably different degrees of human participation and action. If the first scenario is to be effective, then the onus to actively curtail consumption rests with each individual to: consume less energy, consider the lifecycle of material goods, and respect nature. Alternatively, with the second scenario the responsibility of environmental conservation resides
mainly with the science and technological community. Building owners will have to purchase, install and operate the new technology, but involvement by individual building users would be far less taxing. The implication is that the two different outlooks each cast a distinct role for individuals: the active and directly responsible role versus the passive and indirectly responsible role.

Regardless of which view one subscribes to, if technology is to be used to its full potential, its designers must better understand human desires and actions. Recent history is full of examples, which illustrate time and again, that the impact technological advances have on the social dynamic -- and vice versa -- has been underestimated. Well-intended solutions for the environmental imbalance sometimes unintentionally worsen the situation because of the lack of understanding of human behaviour. This rift between the expectations of technology and its social ramifications can be minimized if the proposed technology becomes more aligned with the user's acceptance of it. If we intend to minimize the negative impact on natural systems, the human reaction to, and acceptance of, progress cannot be ignored.

1.5 TECHNOLOGY AND ARCHITECTURE

Arguments similar to those raised above can be made for environmentally responsive architecture. There are those architects who are committed to low-tech solutions that rely on a great deal of user involvement, in contrast to those who place their faith in sophisticated technology and implicitly attempt to create "behaviour-proof" buildings. Perhaps, it should be user behaviour that cues designers as to which (or combination) of the two approaches is most effective.

At any rate, an important point must be considered as strategies become more technologically sophisticated. As technology is refined, mechanical systems and high precision state-sensing devices will become more efficient and involve less time by (and likely less opportunity for)
users to operate. Such devices can measure environmental conditions such as temperature, humidity, amount of available daylight, and human presence, but not human activities. Where the operation of a building is concerned, there are many aspects of human participation that technology will likely not replace. Either people will have to become aware of the need to modify their behaviour through their own conscious effort, or through frequent credible feedback. So while technology may eliminate the need for the manual shutting off of mechanical and electrical systems whenever the outside temperature dictates, people will likely still require awareness or feedback for reducing material and water consumption, recycling and/or reducing materials, or dressing appropriately (Bell, Lowe & Roberts, 1996:94).

1.6 SOCIAL AND CULTURAL ASPECTS BEHIND ENVIRONMENTALLY RESPONSIVE ARCHITECTURE

Presently, user “buy-in” of environmentally responsive buildings is met with varying success. There are many elements that play a role in a society’s acceptance of an innovative building design, such as a population’s culture, density, tradition, economic status, political climate, and availability of resources. As such, several behavioural scientists have examined the link between social context and energy consumption. Hackett and Lutzenhiser (1991) argue that:

Energy consumption is to some extent ‘built in’ to social identities and that within those identities consumption is ‘obligatory’. So much so that when people from other cultures enter an existing setting there are a number of social pressures which obliged them to change behaviours so as to match the consumption associated with their new social identities. Homes and their intrinsic energy characteristics are also powerful expressions of membership of, and status within, a community and society (Stern and Aronson 1984). Appliances must conform to status expectations and energy efficiency is only one of the many issues in social settings (Lutzenheimer 1993). To ignore the idea that energy efficiency must be congruent with the social context is to miss an important piece of the jigsaw that makes up the totality of domestic and non-domestic energy consumption. (Bell, Lowe & Roberts, 1996:54).

Architecture is increasingly following global trends of diversification, and designers are exposed to all sorts of international building designs and technology in the technical literature. As such, the time-honoured features of vernacular architecture are often set aside, as architects “borrow” design characteristics from foreign places. This trend may have profound implications for the
success of an environmentally responsive building. For example, if a design was taken from a society that is accustomed to interacting with its buildings, and is placed in a setting where people are used to a fully lit and conditioned space, it is possible that the difference between expectations and what is provided will lead to problems with occupant satisfaction. Likewise, when a fully automated building is situated in a society that enjoys the freedom of opening windows and turning on/off lights, a mismatch likely occurred. Therefore, as political, geographical and cultural boundaries are transcended, the need to study the appropriate application of foreign design concepts becomes more pressing. So, not only must designers better understand the social context they design for, but also the mindset of the culture whose ideas they are extrapolating from.

1.7 THE FOCUS OF THIS THESIS

The lack of local environmentally responsive buildings, our increasing dependence on technological solutions, including designs that fail to address the importance of human behaviour are all issues that have served as a starting premise for this thesis. This prompted a search to find a culture that has moved beyond laying the foundations of a willingness to build “sustainably”, to serve as a “mentor” for environmentally responsive designers in other, less advanced regions. The users’ behaviour within foreign environmentally responsive buildings, as well as their acceptance of them was expected to reveal valuable information for local designers. Granted that these lessons would be appropriate for the architecture of the Greater Vancouver Regional District (GVRD), they could then be used to critique local design practices, and to perhaps even modify them.

Concern for the environment has been integrated into Swiss daily life to a considerable extent and was selected to form the direction of this thesis. In Switzerland, the number of environmentally responsive buildings is generally higher than in Canada. Here, this type of architecture is currently limited to a few demonstration government buildings and residential
houses. Individuals may indeed be committed to the ideas behind environmentally responsive building design, yet there is no widespread acceptance and practice within the GVRD.

Although broad discussions on "sustainable" issues take place in both Switzerland and Canada, the responses to environmentally responsive buildings differ, both in the degree and the way in which they are handled. First, as mentioned, there are considerably more environmentally responsive buildings constructed in Switzerland than there are in Canada. Second, the North American approach to technological building systems is somewhat different than the Swiss approach, since most local non-residential buildings — environmentally responsive and standard — tend to be more highly automated than their Swiss counterparts.

1.8 BUILDING CASE-STUDIES

Although environmentally responsive architecture is not limited to any particular building type, the scope of this thesis has been narrowed to environmentally responsive office buildings. An office building offers a setting in which a fairly consistent group of building users spends a large portion of its day on a regular basis. As such, the occupants become familiar with the building's spaces and features.

The use of case-study buildings is a valid means of exploring issues of building acceptance and occupant use. Time, cost, and practical constraints in the end limited the study to one Swiss office building and one Canadian office building. In the course of the thesis evolution, case-study buildings were involuntarily and voluntarily eliminated from the research. Initially, two suitable Swiss office buildings were selected, but unfortunately, the Basler & Hofmann firm eventually retracted its offer to participate in this study. As well, the residents of two Swiss residential complexes (Im Schlehdorn and Prosa) were chosen to be part of a case-study, and had filled out a customized questionnaire. The presentation of these residential buildings, and the interpretation of the questionnaire results have not been included in this thesis due to a shift
in focus from a general comparison between Swiss and Canadian environmentally responsive buildings, to a specific examination of a Swiss and Canadian office building with the intent of critiquing a set of environmental design guidelines for office buildings.

1.8.1 The selection process

Discussions with architects, engineers and other contacts were the main sources of information regarding the location of recently built environmentally responsive buildings. Given the diverse approaches to environmentally responsive building design, the criteria for selecting such a building was equally non-prescriptive. Essentially, buildings that contain a number of the following characteristics were sought for the case studies:

- Abundant use of natural daylight
- South facing façade with numerous windows, and north facing façade with few windows
- Orientation dependent external shading devices
- Recycled materials
- Recyclable materials
- Natural, durable materials
- Local building products
- Rainwater harvesting capability
- Photovoltaic panels for electricity
- Solar panels for hot water
- Living (sod) roof

Table 1.2 lists the two office buildings used in this research:

<table>
<thead>
<tr>
<th>TABLE 1.2 The Name and Location of the Two Case-Study Buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUILDING NAME</td>
</tr>
<tr>
<td>Tenum</td>
</tr>
<tr>
<td>C.K. Choi</td>
</tr>
<tr>
<td>(Institute for Asian Research)</td>
</tr>
</tbody>
</table>

1.8.2 Questionnaire Distribution and Collection

The questionnaire was translated into German and then sent to the Swiss contact person, who works for the firm that designed the Tenum and had agreed to be responsible for the disseminating and collecting of the surveys. I myself distributed the C.K. Choi building
questionnaires to all the offices on the ground floor, and to all the mailboxes on the upper floors of the building.

In order to promote a higher return rate, I returned to Switzerland to collect the questionnaires from the contact person. In Canada, the surveys were returned to the main office in the C.K. Choi building.

1.9 ENVIRONMENTAL BUILDING DESIGN GUIDELINES

In an effort to arrive at thesis findings that are more meaningful and practical for design professionals, the exploration was narrowed from taking lessons from the case-studies and applying them to the GVRD context, to applying them to a particular set of environmental office building design guidelines. The need for an approach that takes into account the relationship between technical and human aspects of a fully operating building has been identified as a necessary part of design. Despite the obvious importance of understanding human-building interactions, this aspect is currently not well reflected in building design guidance. Several sets of environmental building design guidelines have emerged in the Canadian context, but these typically outline design strategies that will yield a building with lower energy use, material consumption, and water use. Embodied within those guidelines, however, is the implication of a user, whose impact on the success of a building needs to be made more explicit.

The thesis research involved looking at the user behaviour in the two office building case-studies, and determining which implications hold meaning for a particular set of Canadian office building design guidelines. Based on the insight from the Swiss and Canadian research, these guidelines were reframed to better acknowledge and respond to users' expectations and needs. It is hoped that they have become more comprehensive from a building user perspective.

1 Since the idea of examining environmental design guidelines entered the research only after the questionnaires were designed and filled out, there are limitations on the applicability of the questionnaire findings to the analysis of the very specific, selected guidelines.
Although the case studies will not produce statistically valid results that can be easily
generalized, there are certain ideas of human behaviour, which transcend cultural distinctions.
The difficulty lies in determining which findings are transferable, and which are not. In other
words, which conclusions from a specific study regarding the behaviour in two specific buildings,
can be applied to other environmentally responsive office building designs for the GVRD?

The expectation is that research literature, and the direct experience gained from the two case-
studies will offer positive direction for Canadian buildings and their users. Whether these will
lead to applicable solutions is difficult to tell, but they will certainly identify a more appropriate
set of questions that designers may ask during design development.

In short, social and human aspects must be embraced much more profoundly in the way we
discuss environmentally responsive buildings. This thesis is an attempt at redressing the
current imbalance. Even if it only serves as a series of warnings and draws attention to some of
the potential pitfalls of the technical solution being advocated, then it will be a valuable
contribution.
2. DESCRIPTION OF CASE-STUDY BUILDINGS

This chapter describes the two case-study office buildings in detail (see Appendix I for a concise summary of the buildings). Although they were built in different physical and cultural contexts, they both use natural conditioning to achieve comfort requirements, and both entail a similar extent of user involvement.

2.1 TENUM OFFICE BUILDING

The concept behind the Swiss Tenum office building was to create a facility that could house over 40 different firms and foster synergy between them. Since most of these firms specialize in promoting "ecologically friendly" technology and design, the Tenum office building is expressive of an environmental belief system. Artevetro, which designed the project, is one of the firms that own office space in the Tenum. An ideal site close to the train station in the Liestal city center was not attainable. As such, an easily accessible estate, which the canton Basel-Landschaft made available for leasing, became the chosen site. A drawback with this location is that the 77 parking stalls (3 of which are solar fuel stations) are typically filled, since access to mass transportation is not immediate. However, there are several bicycle racks located directly by the front entrance.

The construction of the 3200 m² Tenum office building cost SFr.1,679 per m² and was completed in 1991. Approximately 100 workspaces are accommodated on the five different floor levels.
2.2 CONFIGURATION AND PROGRAM

The architectural team sought innovative ways of incorporating ecological issues into the planning and construction of the Tenum building. Artevetro examined three phases of the building life-cycle:

1. Material and building production;
2. Maintenance and operation (e.g. reduced heating use, electricity saving elevators, rain water use for toilet flushing, and daylighting);

The architects strongly felt that in addition to energy and ecological considerations, the building's "human component" (Tenum AG, 1996:2) is a critical issue. They believed that the employees of the various firms should feel comfortable and enjoy working in the building. Generous glazing, French windows, flexible floor plans, and communication and relaxation zones were some measures towards providing a comfortable atmosphere.

The Tenum building is essentially a modified rectangular box, organized around a central atrium space that is flooded by daylight (see Figures 2.1 and 2.2). The characteristics of the various floor levels are listed below in Table 2.1.

<table>
<thead>
<tr>
<th>TABLE 2.1 Description of the Tenum Floor Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof: Rainwater collection</td>
</tr>
<tr>
<td>Attic: Ventilation system, solar and photovoltaic collectors</td>
</tr>
<tr>
<td>Upper floors: Light-well, offices, conference room, 1 apartment on the 5th floor</td>
</tr>
<tr>
<td>Ground floor: Reception area, small auditorium, and offices</td>
</tr>
<tr>
<td>Basement: Storage area, rain water tank, heating system</td>
</tr>
<tr>
<td>Surroundings: 74 parking stalls, 3 solar fuel stations, and bike racks</td>
</tr>
</tbody>
</table>
FIGURE 2.1  Tenum Floor Plans
(Tenum AG, 1996:6-7)
FIGURE 2.2  Tenum Cross Section: Along SE-NW Axis
(from artevetro AG)

FIGURE 2.3  Stairwell Seen from Interior Courtyard
(Tenum AG, 1996:cover)
A well-planned circulation design can promote energy-conservational behaviour. The staircase contained by the light-well is actively used (see Figure 2.3). The open arrangement and central location of the stairwell, combined with its inviting gesture, are successes in the sense that the stairs are well liked and used by the occupants. In addition to providing a 35% reduction of the total electricity use, this measure fosters social encounters and physical exercise. A study\(^1\) (1993) has revealed that 60 – 70 % of all the movement between the various levels occurs via the stairs. Since the two elevators are used relatively infrequently -- about 300 rides per day (relative to 800-1000 rides in an average Swiss office building) -- the Tenum building could easily function without one of its elevators.

The individual small firms in the Tenum building have a number of communal office infrastructures and services available to them. The independent body, Tenum Management, is responsible for all the maintenance and servicing of the shared services (see Table 2.2). According to the owners, the resulting savings in maintenance and operating energy costs are considerable compared to if they had been all provided by the individual offices.

<table>
<thead>
<tr>
<th>TABLE 2.2</th>
<th>Shared Services and Office Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROVIDED SERVICES:</strong></td>
<td><strong>SHARED OFFICE INFRASTRUCTURE:</strong></td>
</tr>
<tr>
<td>• Reception service</td>
<td>• Photo copiers</td>
</tr>
<tr>
<td>• Phone service</td>
<td>• Fax machines</td>
</tr>
<tr>
<td>• Word processing service</td>
<td></td>
</tr>
<tr>
<td>• Cafeteria</td>
<td></td>
</tr>
<tr>
<td>• Building tours</td>
<td></td>
</tr>
<tr>
<td>• Organized events</td>
<td></td>
</tr>
</tbody>
</table>

2.3 STRUCTURE AND ENVELOPE

Whenever possible, the building material palette consisted of "green" products. For example, in order to reduce the amount of on-site waste materials, the building envelope was constructed from pre-fabricated elements. For insulation, a recycled paper product was blown into the wall

\(^1\) Ökobilanzierung des Tenum Gebaeudes nach der EPFL-Methode, Liestal, 1993
elements, which meant that a stable sandwich construction was required. Moisture resistant, gypsum covered cellulose sheets were applied to the exterior surfaces, while gypsum covered agglomerated boards were used on the interior. Due to their mass, these gypsum boards have a good thermal and moisture storage capacity. With this type of construction it was not necessary to insert a vapor barrier, thus vapor diffusion may occur without hindrance and without causing interstitial moisture damage.

The window frames were made out of high quality pine wood. To protect them from wear and tear, and ensure their proper seal, the frames were treated with a durable natural resin. All windows are operable. Three different types of glass were used:

1. Silverstar super: U-value of 0.9W/m²K, triple insulating glazing, 2 film covered glass surfaces, filled with Argon.
2. Hyalin: U-value of 0.7W/m²K, triple insulating glazing with 2 film covered surfaces, filled with Argon.

Silverstar Super glass was used for the windows and doors, and Silverstar N glass was utilized for the clerestories. The Haring firm, which owns its office space located in the south corner on the 1st story, installed the Hyalin glazing to examine the performance of their own glass product, relative to the glass in the rest of building.

2.4 NATURAL CONDITIONING

The form and orientation of the Tenum office building permits the use of solar gain, daylight, and natural ventilation. The development of a passive solar design, was prompted by a desire to create a positive environment for the building users:

Humane architecture is achieved when the spatial scale is in reference to a person. It also arises when the building is able to be shaped by its immediate surroundings, and when the effects of nature can be experienced within the building. Nature, however, is shaped and formed by the sun. The sun means life and experience (Tenum AG, 1996:2).
In the Tenum design, responses to the sun’s path can be “read” in the building’s exterior appearance. The differentiation of the four elevations demonstrates a respect for external influences, particularly solar heat gain. Table 2.3 shows the shading techniques tailored for different parts of each façade.

Natural light is used extensively in the Tenum project. Upon entering the building, one is immediately drawn up a set of stairs that lead to a daylight-filled gathering space. This covered courtyard has the character of a small community center, since both workers and visitors use this flexible domain throughout the day. It contains a cafeteria and an open stairwell, and serves as a place where building users can either rest or interact.

There is no mechanical air conditioning system in the building, and all the mechanical systems that heat and ventilate the offices in the fall, winter and spring, are shut off during the summer. At this time, the building relies strictly on window/door ventilation for the introduction of fresh air.

2.5 HVAC² AND ELECTRICAL SYSTEMS

As a compliment to the natural ventilation during the transition seasons, and as the primary ventilation strategy during the winter, a small mechanical, variable-air-volume, displacement ventilation system was installed in combination with a heat exchanger. This provides an average of 1.5 air-changes per hour. Fresh air is dispersed via low-turbulent displacement air outlets near the floor level. A heat recovery unit (70 % efficient) located on the roof, draws heat from exhaust air and transfers it to incoming fresh air. Approximately, 13,000 kWh of electricity or 11 MJ/m² are required to operate the system annually. It is shut off during the summer when the windows are opened, and at nights when the building is typically empty. In the washrooms, the turning on of lights activates a separate decentralized ventilator via a delayed timer.

² "HVAC" stands for Heating, Ventilation and Air Conditioning.
### TABLE 2.3 A Description of the Different Façade Treatments

<table>
<thead>
<tr>
<th>FACADE</th>
<th>CHARACTERISTICS</th>
<th>DESIGN SOLUTIONS</th>
<th>SKETCH</th>
</tr>
</thead>
</table>
| East and southeast façade (east end) | • Low lying morning sun, intensive high afternoon sun  
• Façade is screened from the weather  
• View of grass field. | Simple (yellow) exterior cloth roller-shades evenly disperse the sunlight over the work area, while at the same time providing an unobstructed view.  
(See Figure 2.4) | ![Sketch](image) |
| Southeast (south end) and southwest façade (south end) | • Extensive exposure to high sun  
• Façade is partially susceptible to weathering. | Photovoltaic cells encased in glass laminate form panels that act as a canopy structure and reduce solar gain. Light is filtered through the narrow glass segments of these panels, providing the office spaces behind them with diffuse daylight.  
(See Figure 2.5) | ![Sketch](image) |
| Northwest façade (west end) and southwest façade (west end) | • Early to late afternoon sun  
• West corner has the greatest exposure to weathering  
• The fire escape is a structure along the west corner that doubles as a balcony. | A steel / wood construction serves as an emergency exit stairwell while simultaneously protecting the façade from the rain. The permitted sunlight extends deep into the office space through the structure's lattice-work. For the most part, shadows define glare-free zones.  
(See Figure 2.6) | ![Sketch](image) |
| Northwest façade (north end) | • The early evening sunlight is incident at shallow angles of incidence. | The protruding vertical fins create internal shadows that extend over the entire work area.  
(See Figure 2.7) | ![Sketch](image) |
| Northeast façade | • Potential of brief early morning sunlight striking this façade. | External shading is not necessary. | ![Sketch](image) |
FIGURE 2.4 The Southeast Facade

FIGURE 2.5 The Photovoltaic Panels on the South Corner Facade
FIGURE 2.6  The Balcony/Fire Escape on the West Corner Facade

FIGURE 2.7  The Vertical Shading Fins on the Northwest Facade
The heating system is a fully automatic 120 kW central wood chip furnace, combined with a vapour condensate heating system. When wet wood is burned, energy is required to evaporate the water and dry the wood. This energy is then stored in the water vapour. Most wood heating stoves simply release this vapour; however, with this system the energy is re-captured as the vapour is condensed into water. In this manner, an extra 20% of energy can be recovered. Using dry wood for heating is more expensive and energy intensive, since it would have been pre-dried. It is much more efficient to fell the wood, chop it, and burn it directly.

A primary goal was to shorten the heating period to 3½ months through appropriate construction techniques. Figure 2.8 shows the heating system operation periods of the Tenum building compared to those of standard Swiss office buildings.

![Figure 2.8](image)

**Figure 2.8** A Comparison of the Heating Period in a Standard Swiss Office Building and in the Tenum Office Building *(Tenum AG, 1996:9)*

The washroom facilities and the cafeteria kitchen have a decentralized 15-liter electric boiler directly below the sink. A decentralized strategy is appropriate in this instance for a number of reasons:
• In an office building the overall water requirements are low (approximately 180 l/day), making it difficult to justify the cost of a central hot water supply.

• The material required to install an extensive circulation system necessary with a central design can be avoided.

• The decentralized boilers can be individually regulated. In the Tenum, some of the boiler units are often turned off, since certain users are satisfied with cold water only.

Warm water for the caretaker’s apartment and janitorial rooms is provided via 8m² of solar panels on the roof of the Tenum. During the non-heating seasons an electric boiler acts as a backup, while backup warm water is delivered directly from the central wood chip heating system the remainder of the year.

The overall energy concept aims for minimal heat loss and optimal use of the internal heat source. The energy consumption within the Tenum office building was monitored for a period of two years. The data was analyzed and the energy indices in comparison to SIA 380/1³ values were established. Table 2.4 shows the energy use of the Tenum office building.

| TABLE 2.4 Comparing Various Swiss Annual Heating and Electrical Energy Consumptions (Tenum AG, 1996:8) |
|---------------------------------------------------|---------------------------------------------------|-------------------|-------------------|
| TENUM, AS DESIGNED (MJ/m²a) | TENUM, AS MEASURED (MJ/m²a) | SIA GOAL (MJ/m²a) | SIA UPPER LIMIT (MJ/m²a) |
| Heating | 150 | 126 | 240 | 340 |
| Electrical | 100 | 77⁴ | 175 | 175 |

Compared to other Swiss construction, the Tenum building has a substantially lower overall annual energy consumption. This point is illustrated in Figure 2.9.

³ SIA stands for the Schweizerischer Ingenieur- und Architekten- Verein (Swiss Engineering and Architectural Society) and is a counterpart of the ASHRAE standards used here in North America.
⁴ With the 5 MWh of electricity that they produce, the solar panels provide for 7% of the total electric demand within the building.
2.6 ILLUMINATION

Adjusting to the changing levels of natural light inevitably requires a flexible electric lighting concept and control strategy. As such, the office spaces were organized into three zones:

1. Rear circulation zones
2. Work zones
3. Work stations

The lighting for the circulation zones need only ensure a safe passage and orientation to and from the offices. This function can be fulfilled by permanently installed energy saving lights (PL Downlights). The work zones, however, must be flexibly illuminated in order to avoid hindering individual work habits and requirements, and to respond to the changing nature of daylight. High performance, energy-saving floor lamps with halogen-metal vapour bulbs illuminate the ceiling.
and provide a diffuse, glare-free illumination. ⁵ (One firm which owns its office space (Häring AG) has subsequently installed fluorescent ceiling lamps because it prefers a completely and evenly-lit office space, which the more conventional lighting strategy offers). This lighting is sufficient to work under for most of the occupied period; however, those who find it to be lacking may turn on their personal table lamps.

The design lighting load is 5.8W/m². The annual electricity consumption varies, depending on the office hours and the use pattern, between 6 and 11 MJ/m²a. The electricity consumption within the Tenum is half that of conventional Swiss office lighting.

### 2.7 ENERGY CONSUMPTION DISPLAY MONITORS

Considering that various environmentally oriented firms occupy the Tenum building, it is surprising that there is no direct feedback on energy consumption available to the office workers. Only senior management has access to the consumption data through their monthly fuel, electric and water bills⁶.

### 2.8 WATER CONSUMPTION AND TOILET FACILITIES

On average, 28% of the 70 m³ potable water consumed in the Tenum building per month, is used for cooking and cleaning (see Figure 2.10).

The toilets are supplied with rainwater, and backed-up with domestic water. The rainwater is collected on the roof of the building and flows into a 20 m³ basement storage basin. It provides for 32% of the total water used by the occupants. With a water capacity of 20 m³, the average daily consumption of 2.4 m³ (5 liters of water are needed for each toilet flushing) will be covered.

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⁵ These floor lamps only have an “on” and “off” setting and cannot be dimmed. At the time when the lights were purchased, the cost for dimmable lights was considered too high.

⁶ Included in the water bill is the amount it will cost to clean and treat the water consumed.
for approximately 8 days. During those months with enough precipitation, the water requirement for toilet flushing can almost be completely satisfied. During dry periods, the flushing must be bridged by domestic water.

FIGURE 2.10 Total Water Use in the Tenum Office Building  
(Tenum AG, 1996:15)

2.9 TENUM IN-HOUSE SURVEY RESULTS

To gauge the success of their innovative design strategies, Artevetro, together with the engineering firm Basler & Hofmann (which had designed the displacement ventilation system), performed a post-occupancy evaluation. In order to determine the well-being of the users, three different questionnaires were administrated in 1992 over the summer, fall and winter. Out of the 40 surveys that were handed out each time, the return rate was about 20%. The questionnaires pertained to thermal comfort, air quality, and general attitudes towards the building. Following are the survey findings.

The average amount of rainwater used for toilet flushing was measured from January to August 1993.
2.9.1 Temperature Levels

Since efficient use of the mechanical ventilation and/or heating system varies with the seasons, it was important to determine whether the indoor temperature met the users' approval during the summer, fall and winter.

**Summer**

During the summer, the uncontrolled admission of sunlight may potentially result in high room temperatures in the afternoons. The workers have two options available that maintain their comfort throughout the day: employing interior and/or exterior sun screening devices, and window ventilation (during the summer the mechanical ventilation is not in operation, and there is no air-conditioning in place). Use of these two methods considerably decreases excess solar gain. If the offices are consistently ventilated and shaded during the morning, then the interior temperature will not rise above 29 °C, even when it is warmer than 32 °C outside. It is also important that there is window ventilation during the night to flush out excess heat build-up within the structure. The sun-screens should be lowered over the weekend, otherwise the room temperature will rise above 30 °C. Most people find the morning indoor temperature to be "comfortable" (see Figure 2.11). During summer afternoons and evenings, however, the temperature tends to become excessive when occupants have failed to shade and ventilate prior to this time of the day.

**Fall**

The room temperature is considered to be "comfortable" by the majority of occupants throughout the day during the fall (see Figure 2.12). The passive solar energy use and the mechanical ventilation with heat exchanger raise the room temperature as the day progresses. Thus, the heating system can be turned off at this time.

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This figure would have been greater than 32%, had the rainwater system not been out of order that May.
Winter

During the winter the mechanical ventilation and the heating are both in operation. At this time, the morning room temperature is considered to be cool by some of the occupants (see Figure 2.13). In the course of the day the interior temperature rises and is perceived by most as comfortable. The mechanical introduction of fresh air 1 deg. C cooler than the room temperature does not seem to compromise comfort levels.

2.9.2 Evaluating the Air Quality

The air quality is considered as acceptable by all of the occupants. During the summer opening the windows naturally ventilates the offices. During the transition seasons, the mechanical ventilation is considered adequate; however, the option of individual window ventilation is much appreciated because it allows the users to manually increase ventilation to meet individual needs. Detailed measurements confirmed good interior air quality.

2.9.3 Overall Comfort Levels

Overall, the comfort levels are described by 91% of the office users as being "good" to "very pleasant" (see Table 2.5). Despite the high summer temperatures, an air conditioning system is considered unnecessary.

Seven percent of the users consider the comfort levels as "satisfactory" and only 2% as "unsatisfactory". The poor evaluations can be traced back to the initial design which did not offer sufficient shading and caused overheating in southern exposed rooms. Installing exterior sunscreens in the affected areas subsequently solved this problem. Furthermore, the photovoltaic panels on the south corner façade were installed in the fall of 1993, and offered shade that considerably decreased solar gain through the windows. During the winter a few people considered the overall room temperature to be too cool so they needed to increase the heating slightly.
FIGURE 2.11 Respondents' Judgement of the Room Temperature During the Summer
(Tenum AG, 1996:19)

FIGURE 2.12 Respondents' Judgement of the Room Temperature During the Fall
(Tenum AG, 1996:19)
TABLE 2.5 Survey Findings: User Opinion of Comfort Levels Throughout the Year (Tenum AG, 1996:20)

<table>
<thead>
<tr>
<th>SEASON</th>
<th>USER OPINION OF THE COMFORT LEVELS (IN %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unsatisfactory</td>
</tr>
<tr>
<td>Summer</td>
<td>No mechanical ventilation, Individual window ventilation</td>
</tr>
<tr>
<td>Fall</td>
<td>Mechanical ventilation, Individual window ventilation depending on need</td>
</tr>
<tr>
<td>Winter</td>
<td>Mechanical ventilation, Practically no window ventilation</td>
</tr>
<tr>
<td>Over the whole year</td>
<td>2%</td>
</tr>
</tbody>
</table>
2.9.4 User Behaviour

The majority of the users seem prepared to accept the interior and exterior shading devices, operable windows, an area-specific lighting strategy, prominent staircase, and rainwater flushing. However, acceptance of these building features, does not guarantee their appropriate use. Tenum management recognizes that it is important to provide good user information on the workings of the ventilation, the possibilities of the lighting, the appropriate behaviour by window ventilation, and the operating of the sun-screens, on a regular basis.

2.9.5 Lighting

The combined use of natural and artificial lighting is effective. Extensive use of daylight is especially appreciated by the users and in combination with effective controls, leads to significant electricity savings. With the 3-step lighting concept, the floor lamps (indirect lighting) have been most effective in providing ample lighting with minimal energy consumption. These are generally well-liked by the office workers because they can be physically moved and individually operated. They provide sufficient lighting in the office spaces, and in many cases the personal table lamps are not necessary.
The C.K. Choi building at the University of British Columbia houses the Institute of Asian Research's five research centers (see Figure 2.14 below).
The university wanted to retain an architectural firm that had experience with environmental projects, and felt at ease in a collaborative design process with all the various consultants. Despite no prior in-house experience with environmentally responsive architecture, the firm Matsuzaki Wright Architects Inc. was selected primarily because of their willingness and openness to explore environmental issues. Unique to the design process, was an initial brainstorming session that was held for all the stakeholders, future users, university representatives, consultants and architects, in an effort to establish a set of project goals. The agreed upon objectives – the majority of which were met or exceeded – were (BC Hydro, 1997:2):

- Reduce operational energy consumption by 50% relative to ASHRAE/IES 90.1
- Reduce water consumption by 50%
- Incorporate materials with at least 50% reused and recycled content
- Significantly reduce construction waste
- Attain good indoor air quality
- Create flexible floor plans in order to increase the useful life of the building
- Eliminate the need for a sewer connection
- Promote longevity in the building systems and materials
- Capture 100% of the rain water on site

The $4,500,000 ($1615/m²) cost of the new Institute of Asian Research was paid for through the financial aid of the government, the private sector, and Mr. C.K. Choi and his family. The project was completed in 1996.

### 2.11 CONFIGURATION AND PROGRAM

The site of the Choi building runs southeast and northwest, and was previously a long narrow parking lot in between the West Mall Road and a 100-foot-tall second growth forest. The architects had decided to maintain the growth of trees, and use the old lot for the new building site. Hence, the C.K. Choi has a very elongated form, and is frequently shaded from direct southwestern sunlight (see Figure 2.15). A distinct advantage of this type of massing is that the resulting narrow rooms readily have access to daylight.
Apart from designing an environmentally responsive building, Matsuzaki Wright Architects also had to accommodate five Asian research centers (China, Japan, Korea, Southeast Asia, and India and South Asia): "A physical presence, both on the interior and exterior, was required for each centre while maintaining a unified look with no one centre or culture dominating" (BC Hydro, 1997:1). Although there are six atria with north-west facing clerestory windows above the main roof that enhance daylighting and natural ventilation, and also provide spatial organization, there are exactly five curved roofs, which help to mark the individual centres within the Institute (see Figures 2.16 and 2.17).

The building was designed for up to 218 users\(^1\), and has a gross area of 2,787 m\(^2\).

The section shows numerous windows on all three levels, which are conducive to admitting daylight (see Figure 2.18). For the same purpose, the ground floor has a greater floor to ceiling height than the other upper two floors (except in the atrium areas). Table 2.6 lists the characteristics pertaining to the different floor levels.

<table>
<thead>
<tr>
<th>TABLE 2.6 Description of the C.K. Choi Floor Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Roof:</strong> Facilities are in place for the future installation of photovoltaic panels on each of the 5 curved roofs: &quot;A designated battery storage room has been provided and the compatibility of components ... has been assessed to match the anticipated kilowatts to be collected&quot; (BC Hydro 1997:6).</td>
</tr>
<tr>
<td><strong>Third floor:</strong> Consists of research space -- half of which is a flexible open communal work space, and the other half holds individual offices. There is also a communal research centre with a computer lab and reading room.</td>
</tr>
<tr>
<td><strong>Second floor:</strong> There are 5 research centres which each include a reception, workspace and offices. The administrative centre for the whole institute, with its reception space, boardroom (25 persons) and offices is also located on this floor.</td>
</tr>
<tr>
<td><strong>Ground floor:</strong> Holds a 60-person conference room and a 20-person meeting space. A lounge and exhibit space is adjacent to the building entry. There are also office spaces for visiting faculty.</td>
</tr>
</tbody>
</table>

\(^1\) At the time that the questionnaires were distributed, only about 60 people were working in the building.
FIGURE 2.15 C.K. Choi Floor Plan
(Laquian, 1996:2)

FIGURE 2.16 The C.K. Choi's Northeastern Façade Along West Mall Road
(BC Hydro, 1997:2)
FIGURE 2.17 Axonometric Drawing of the C.K. Choi Building

SECTION: NW-SE Axis

FIGURE 2.18 C.K. Choi Cross Section
(BC Hydro, 1997:5)
There are a number of communal facilities in the Institute. One enters the building directly into a large atrium space that serves as a common lounge area. There are also kitchen facilities for food preparation. On the top floor students and faculty have access to a computer and reading room.

Although the building is located next to a large campus parkade, the main university bus station is about a 10-15 minute walk away. There are 3 sets of bike racks that hold 5 bikes each, located near the front entrance.

2.12 STRUCTURE AND ENVELOPE

A large portion of the building materials used in the C.K. Choi is salvaged. The heavy timber post and beam structure was reclaimed during the demolition of the nearby Armouries building in 1994. Approximately 65% of the primary and secondary wood structure consist of reused timbers from this source. The exterior red brick cladding from the streets of Vancouver gives the Choi building "an aesthetic that is rich in history and energy efficiency" (Laquian, 1996:11). As well, the gravel roof ballast, the doors and their frames, 30 % of the electrical conduit, and washroom furniture (excluding the toilets) were also reused (see Figure 2.19). The salvaging of old building materials saves the initial energy needed to extract, transport, refine, and produce these materials, and meets the target of minimizing new material consumption.

When it was not possible to specify reused building materials, ones that have a high recycled content were used. For example, the structural steel and components contain a large amount of recycled steel. The wood frame exterior walls contain recycled cellulose cavity insulation, and the interior wall boards have a 20 % recycled content. Less than 50% of the materials are new, in which case the architects tried to find ones that are recyclable and/or have a low embodied energy.
FIGURE 2.19 Building Material (Re)Use
(Laquian, 1996:77)
Since there are no windows on the short southeast wall, and the southwest facade is shaded year round by the coniferous forest along the full length of the building, the C.K. Choi has no exterior shading devices. However, because of excessive window brightness on the northwest oriented facade, many building users often lower their internal venetian blinds throughout the year. The exterior windows have clear double glazing with a low emissivity coating. The visible light transmission is 76%, so as to maximize daylighting. The window frames are non-conducting and pressure equalized, multi-chambered modified PVC units.

### 2.13 NATURAL CONDITIONING

The C.K. Choi’s extensive use of natural lighting and ventilation greatly reduce the building’s energy consumption. Daylighting alone enables up to a 70 % saving in the electricity required for lighting. These savings are high due to a number of design strategies (see Figure 2.20):

- Approximately 42% of the southwest facade (see Figure 2.21) and 31% of the northeast facade consists of glazing that permits a high portion of natural light to enter the interior.
- Wherever possible the paint and flooring colours are light, so as to allow the natural light to reflect from these surfaces.
- Where practical, instead of opaque partitions, glass partitions have been installed between corridors and work areas.
- Work stations in the open-plan area on the third floor are at most located within 3 m from the windows, in which case they receive daylight from the clerestory atrium above.
- All the structural and mechanical systems are exposed (see Figure 2.22). With the elimination of a drop ceiling, which masks these systems in conventional buildings, the floor to ceiling height is maximized so as to allow as much daylight in as possible (BC Hydro, 1997:3). However, the effectiveness of this strategy is questionable, since a drop ceiling provides an even, light coloured surface that reflects a lot of light.

The massing and internal spatial organization facilitates 100% natural ventilation within the building. In addition to permitting natural light, the atria provide stack ventilation. Warm air rises through the vertical spaces and is released through louvres at high points in the atria. Simultaneously, cool fresh air is pulled into the building through small ventilation channels.
incorporated into the base of the window frames. This design allows for continual low-flow air change providing 9.44 l/s per person (Perdu, 1998).

These natural ventilation techniques negate the use of a mechanical air handling system in the building (see Figure 2.23), except for the ground floor conference room, where an air-to-air heat exchanger offers local ventilation. The windows are operable, giving the users the option to introduce additional air if desired. The air quality within the building is improved through low VOC emission building materials and finishing products.

2.14 HVAC AND ELECTRICAL SYSTEMS

The building is heated through a hot water radiating system. The water used for space heating is heated passively. A domestic cold water line from the water entry room is fed to the steam/condensate trench beneath West Mall Road. Here an uninsulated copper piping is looped through the trench and the water is heated passively by the existing hot air (+/- 60 °C) within the trench. The piping is then returned back to the building to service the baseboard heaters below the windows (Laquian, 1996:80 & 82).

An electric hot water tank heats the water for domestic use. A “Building Management System” (BMS) schedules and provides a night setback for the heating water system.

2.15 ILLUMINATION

The lighting design in the C.K. Choi building is not wholly regulated by the user (as is the case in the Tenum office building), nor is its operation entirely automated. Instead, it is a hybridization of the two approaches. Although the dimming of the lights is fully automated, they must be switched on manually. Once no longer required, they can be shut off manually, or automatically
SOUTH FACING ROOFS
OPTIMIZE DIRECT GAIN AT
PHOTO-VOLTAIC PANELS

HIGH NORTH FACING
WINDOWS ADMIT
DIFFUSE LIGHT

REFLECTIVE SURFACES
ENHANCE DAYLIGHTING

ATRIA ADMIT DAYLIGHT
WINTO SECOND FLOOR
WORK SPACES

HIGHER CEILINGS
AT GROUND FLOOR
FACILITATE DAYLIGHTING

FIGURE 2.20 An Illustration of How the Design Admits Sunlight
(Laquian, 1996:83)
FIGURE 2.21 The Southwest Façade as Seen Through the Trees

FIGURE 2.22 The Office Corridor On The First Floor Shows The Exposed Structural And Mechanical Systems
FIGURE 2.23 An Illustration of How the Design Facilitates Natural Ventilation
(Laquian, 1996:83)
with the aid of sensors. Hence, the users are given the control over regulating the lights, but technology is there to increase energy efficiency, as described below:

- Installed in the offices are high quality T-8 fluorescent luminaires with low voltage, controllable dimming electronic ballasts.
- 13-Watt compact fluorescent task lights are mounted on the desktops.
- There are 17 light-sensors distributed along the inside perimeter of the building. These multi-point photocells will adjust the electric lighting output according to the available daylight. They have a continuous dimming capability down to 20% of the maximum electric light, while ensuring a minimum of 350-400 Lux of ambient interior illumination.
- There are also wall mounted occupancy sensors, with manual "on" and automatic "off" switches (that have a manual override), which further reduce unnecessary energy waste.
- The BMS shuts off the corridor lights (but not the safety lights) at scheduled times in the evening. The building users cannot override the lights regulated by the BMS.

2.16 ENERGY CONSUMPTION DISPLAY MONITORS

The steam, electricity, and water meters were designed to be read electronically by maintenance staff, through the centralized BMS. The building users do not have access to these meters.

2.17 WATER CONSUMPTION AND TOILET FACILITIES

The C.K. Choi building has a 31,850 liter cistern located below the stairs, which stores rainwater gathered from the roof. The collected water is used externally for irrigating the surrounding landscape.

The C.K. Choi building uses a ventilated, waterless composting toilet system (see Figure 2.24). Certain nutrients in the human waste promote the growth of aerobic bacteria contained in the system's storage tank. In turn these bacteria process the waste into water vapour, carbon dioxide, safe compost, and a liquid end product known as "tea." This "tea" and the waste water from the sinks, drain into a grey water trench with marsh vegetation, and are reused for irrigation. To minimize abuse, above every toilet in the building there is a posted sign that describes the
mechanisms, advantages, and appropriate use of the toilet. The benefits of this system are manifold:

1. It enables the building to be disconnected from the sanitary system, which reduces the load on the existing university infrastructure;

2. Since it is waterless, the system saves an estimated 6,825 liters of potable water per day, compared to conventional flush toilets;

3. The aerobic composting system reduces the volume of sanitary waste water by 90 %;

4. The end product is a humus-like soil amendment product that is rich in nitrogen and other useful elements. Returning nutrient-rich humus to the earth restores depleted soil conditions.

**FIGURE 2.24 A Schematic Diagram of the Waterless Composting**

(Laquian, 1996:81)
3. THE QUESTIONNAIRE RESULTS

In the first part of this chapter, the findings from the questionnaires are presented, as are any conclusions drawn from them. Since the survey responses emanated from two different cultures, these findings are put into context in the second part, through statistical comparisons.

PART I  THE SURVEY FINDINGS

Analysis of the case-study questionnaire results focuses on the responses to questions dealing with the thermal quality, ventilation, and various aspects of lighting in the studied buildings (see Appendix II for the actual survey questions). These are the three major components of a building's operation, and it is important to understand the interplay between the system operation, user behaviour, and energy efficiency. An overview of the results from the two questionnaire sets is presented in the first portion of Part I. In the latter portion, the data is analyzed from a number of perspectives. The responses of the part-time workers are compared to those of the full-time workers. Similarly, the status that the respondents have is examined: for the Tenum surveys, responses from office workers and secretaries are compared to those from owners and managers; for the C.K. Choi surveys, responses from secretaries are compared to those from the administrator, faculty, and research associates, as well as those from students. Further, the number of years people have
worked in their building is compared, as are older and younger user age groups, and user gender.

3.1 OVERVIEW OF TENUM QUESTIONNAIRE RESULTS

Out of the 60 questionnaires that were given to the Tenum occupants in February of 1998, 13 were returned for analysis.

3.1.1 Thermal Quality

Heating is delivered to the rooms via the radiator units mounted below each window. The users can regulate the system with thermostats or radiator valves (both display a temperature scale). There is one thermostat in each of the four sectors per floor level (see Figure 2.1). The thermostat setting determines the general room temperature for the given sector. There is a valve located on each radiator unit, which can be set to specific temperature levels. Whereas the thermostat adjusts the entire room setting, the valves provide a finer-scaled local temperature adjustment. The heating system automatically shuts off at 10:00 p.m. and automatically resumes at 6:00 a.m.

Most people find the room temperature tolerable during the summer, and all find it appropriate during the winter (which tends to be in line with the Tenum in-house survey findings), indicating that the building's thermal quality is generally considered acceptable throughout the year.

Satisfaction with the building's thermal conditions is not closely linked to the perceived ability to control room temperature. Only about one-third of the respondents feel they have enough freedom in regulating the room temperature, yet most find the temperature agreeable. The remaining two-thirds tend to compensate for hot and cold indoors without adjusting the mechanical heating system. Most of them adapt their clothing, while some ventilate, use the cloth blinds, or turn on the lights and computer. Only one individual in this group turns down the
thermostat when too hot. In contrast, many of those who feel they have enough freedom in regulating the room temperature, noted that they adjust the central heating system, in addition to adapting their clothing.

Adjusting the layers of clothing is a prominent action among the Tenum respondents. The results of this act are immediate, and require no interaction with the building. It is a simple response that does not involve technology, and unlike the blinds, windows or heating, affects only the individual and is more convenient than having to walk over to a thermostat or radiator valve and change the setting.

From an energy efficient standpoint, the most effective way of dealing with cool winter interior temperatures is to dress warmer and make use of solar heat gain; while warm temperatures should be dealt with by first reducing the heating, and then adjusting the clothing and reducing solar heat gain. Very few people in the Tenum turn up the thermostat when it is cold, and/or turn it down when it is too warm. There are a number of possible explanations for this:

1. Since there are no individual offices, people may not feel comfortable “deciding” the temperature setting for others in their vicinity.

2. Those individuals sitting away from the windows, and remote from the radiator valve controls, may not feel comfortable accessing someone else’s work space to adjust the setting.

3. The users may not be familiar enough with the heating controls and size of heating zones.

4. Some individuals may want to save energy and resort to other means of warming.

Since the Tenum office building is generously glazed, solar heat gain is an issue. All of the windows and most glass doors have interior roll-out blinds. However, none of the clerestories have any blinds, and depending on their location, some of them admit direct sunlight. The survey results suggest that on their own, the roller-blinds do not effectively hinder solar gain along the interior perimeter of the building. The area most susceptible to solar heat gain is the

51
portion of the southeast side that does not have the shading solar panels affixed externally (sector 1 in Figure 2.1). A worker who sits in this area has reported that the summer temperature is intolerable, and even though he uses the blinds frequently, they do not help to reduce solar heat gain. The problem of overheating was unanticipated in the shading design. Although the clerestories comprise a relatively small component of the total fenestration, the glass has a high U-value and cannot be shaded. As well, these windows were initially only equipped with the internal, perforated, aluminium coated, textile pull-down blinds. The design error lies in the reflectiveness of these internal blinds and the heat absorbing properties of the Silverstar super window panes (two of the three panes are silver coated). The majority of the solar gain through the window is reflected back out by the aluminium coated internal blinds. However, a portion is repeatedly reflected between the silver and aluminium surfaces, creating the problem with overheating. In order to remedy this situation, the exterior yellow retractable cloth awnings were installed (though there is still no shading for the clerestory windows). The aluminium blinds have not been removed, and are still used by the workers.

The user operated blinds combined with permanent shading devices, such as the photovoltaic panels on the south corner, and the balcony/fire escape on the west corner, which protrude a considerable extent from the building envelope, tend to be successful in minimizing solar heat gain. As well, a deep room width prevents direct sunlight from striking those zones removed from the windows, which remain relatively cool. Every respondent working in an area shaded by the photovoltaic panels or balcony/fire escape finds the room temperature acceptable throughout the year. All but one report that the exterior blinds are effective in providing a comfortable indoor atmosphere.

3.1.2 Understanding of the Heating System

In the Tenum building the users are free to adjust the heating via the thermostats and radiator valves, open/close windows, and lower or raise the sun-blinds. Less than half the people listed
controls available to manipulate the inside temperature. These individuals all stated the thermostat or radiator valves as a means of adjusting the temperature. Very few considered opening windows as a way of affecting indoor temperatures, and even fewer listed the blinds. Two-thirds of the people that find summer temperatures intolerable did not identify any ways of influencing the temperature. Perhaps information on various available temperature control strategies would increase their use by building occupants.

3.1.3 Conclusions for Thermal Conditions

Even though the Tenum respondents consider the summer temperatures, and especially the winter temperatures, appropriate several conclusions can be drawn for designers to consider:

1. Although it does not typically influence satisfaction of thermal conditions, many users feel they do not have enough personal control over temperature. This raises some points:
   a) The location of one's work area can influence their perception of the ability to modify the temperature. When a lot of the temperature control devices (such as radiator valves, windows, and blinds) are located along the exterior wall of a deep room, individuals not working in that area may feel that temperature control is mostly out of their “reach”.
   b) Open, communal office spaces have a social dynamic that can affect a person's behaviour and perception of temperature control. The larger sectors in the Tenum have several firms occupying them. Depending on the social atmosphere, some people may not feel comfortable taking actions (such as changing the temperature, raising/lowering blinds, or opening/closing windows) that may affect other (perhaps less known) workers in that area.
   c) Feelings of lack of control over temperature regulation may also stem from not understanding the potential of the building features. Not only can this lack of knowledge compromise thermal conditions, but it may also lead to greater energy consumption.

2. When building features require occupants to operate them, their proper use must result in the desired effect, otherwise the users get frustrated. In the Tenum building, people working on the southeast side correctly lowered the internal blinds to decrease glare and solar heat gain, however this actually increased the latter.

3. For minimizing solar heat gain, an effective shading design combines fixed (or automated) external shading devices that are not user regulated, with flexible internal shading that the user can adjust.
3.1.4 Ventilation

The displacement ventilation system in the Tenum building is regulated by a master control in the attic. During the winter and transition seasons the system on average provides 1.5 air changes per hour. Although mechanical ventilation is supplemented by window ventilation during the spring and fall, it is maintained at this setting in order to effectively move the warm air from the southeast side to the cooler northwest side. In the summer the system is completely shut off, leaving the responsibility of manual window ventilation to the building users.

Overall, the survey respondents gave the quality of air in the Tenum a favourable rating. They all receive enough fresh air during the wintertime, which suggests that the ventilation system is performing optimally. Compared to the conventional office buildings that the occupants worked in previously, the quality of air in the Tenum building is typically preferred.

Just under two-thirds of the respondents make use of the only means of ventilation regulation available to them: the windows. All the individuals who work next to a window take the opportunity to open and close it. Amongst the group of workers that sit away from the windows, almost three-quarters do not regulate the amount of fresh air they receive. There are several possible explanations for their behaviour:

1. Opening a window may involve “intruding” another occupant’s work area. The window could also be located directly by someone’s work surface, and once opened may physically interfere.

2. For some, walking over to a window to open it might be an inconvenience.

3. Since the people sitting by the windows open them to ventilate, it is not necessary for those who work away from them to take action.

None of the respondents explicitly feel they have enough control over ventilation. Over half specifically stated a lack of control, while the rest are uncertain if they have enough of it. What is surprising is that almost half of the respondents who claim to not have enough ventilation control sit by a window. During the colder months the windows are rarely opened, and
everyone depends on the mechanical ventilation system — which cannot be regulated by the users — to service the rooms with fresh air. There are two fresh air outlets per sector located on the interior walls, away from the windows. So not only are the workers who sit by the windows reliant on a fully automated system during the winter, but at this time they are also removed from the source of fresh air. In effect, at different times of the year, the fresh air comes from different sources and different locations.

3.1.5 Electric Lighting

In the office spaces, the users have halogen floor lamps and table lamps available to them. One floor lamp serves at most two people, while each person has a task light on their desk. Both types of lighting can easily be moved around and individually operated. One firm that has replaced this lighting strategy with the conventional fluorescent ceiling luminaires is located on the first floor on the south corner.\(^1\) The remaining areas in the building (such as the circulation zones, washrooms, basement and cafeteria) have ceiling fluorescent lights that can be turned on/off by the occupants.

Overall the Tenum occupants consider the lighting control strategy as appropriate, convenient, and efficient. The flexible lighting was not difficult for most users to accustom to, and meets their needs. The majority of the respondents find the lighting arrangement flexible enough to perform the tasks at hand, and prefer the regulation convenience associated with the lighting strategy in the Tenum building over that in their previous, conventionally lit office buildings.

Almost half of the respondents that worked in previous office buildings were already accustomed to personally turning on and off the lights in their work area. For those who were

\(^1\) Since daylighting, solar heat gain, and proximity to various building features are dependent on the location of a person’s work space, it was essential to find out where each respondent works. In an effort to preserve the anonymity of the respondents, they were only asked to identify their work area on a generic floor plan, and did not disclose on which floor level they work. Hence, it is impossible to establish if any of the respondents belong to the 4-6 person firm with the conventional lighting.
not familiar with this control, getting used to it was an easy adjustment. Direct criticism of the
electric lighting originated from only one individual, who had a difficult time adjusting to turning
on/off the light in his work area, and considered the arrangement not flexible enough.

Only two individuals felt they could help save electricity if they had more control over the
lighting. This may have more to do with social elements that inhibit them from shutting the lights
off, rather than physical limitations, since the light switches are accessible everywhere in the
building.

The findings from this section are as follows:

1. Almost none of the Tenum respondents miss the conventional lighting found in typical office
buildings.

2. The much lower than average electricity consumption, indicates that people can be
accountable in part, for manually regulating the lights.

3. The flexible lighting strategy optimizes the users' ability to limit electricity consumption. Very
few respondents feel they could incur greater savings with more personal control.

3.1.6 Natural Lighting

Ample daylighting is a prominent characteristic of the Tenum building that adds to the well-being
of its users, as well as to electricity savings. Daylight enters the office spaces through the
exterior windows, and somewhat through openings onto the large central daylit atrium space.
The light coloured ceiling and walls aid in brightening the areas removed from direct daylight.

In general, those in the survey group like the daylighting strategy in the Tenum, and think it
effectively reduces their dependence on the electric lighting. Many were already accustomed to
regulating the daylight reaching their area. When the respondents compare the amount of
natural light available in the Tenum building to the amount available in previous office buildings,
they all prefer their current place of work.
More than half of the people that had experience with other office environments did not need to make any adjustments to get used to the Tenum's daylighting strategy. This suggests that this group may have previous experience with controlling the amount of daylight. All but one of the remaining respondents found getting accustomed to regulating daylight was easy. This same person also had difficulties adjusting to turning on/off the electric lighting once he started to work in the Tenum building.

All of the respondents reported that there is sufficient daylight reaching their work space on a sunny day, that they do not have to use the electric lights. Even when the blinds are lowered to reduce glare and/or solar heat gain, they generally do not turn on the electric lights. However, for one firm the nature of their work (i.e. computer drafting) frequently causes them to lower the blinds and have several of the floor lamps on.

The sun-shading devices generally do not cast any unusual shadows onto the work surface, except in a couple of instances. One worker is situated away from the window on the northwest side of the building, where the exterior vertical shading fins do not completely block sunlight in the late afternoon (see Table 2.3). The other worker who sometimes has unusual shadows projected onto his table sits by a window in the south corner. Here the photovoltaic panels create a “tile-patterned” shadow on the work surface.

The findings provide two points for designers to consider:

1. Although all building users appreciate abundant daylighting, it may interfere with certain aspects of office work, and ultimately lead to increased use of electric lighting. Glare on computer display monitors is a common problem in office buildings. The type of internal roll-out blind in the Tenum effectively cut out glare, but cause the members of one firm to often have the lights on when they work. Blinds which the users can fine-tune (such as venetian blinds) may alleviate this problem.
2. Although exterior shading devices can significantly reduce solar heat gain, depending on their design, they may create unusual shadows on the work surface near the windows. Some workers may lower the blind to eliminate this problem, but unfortunately also reduce the amount of daylight entering deeper into the office space.

3.2 OVERVIEW OF C.K. CHOI QUESTIONNAIRE RESULTS

Out of the 60 surveys handed out to the C.K. Choi building users in April of 1998, the results from 15 surveys were analyzed.²

3.2.1 Thermal Quality

Beneath every exterior window (except in the fire stairs and electrical room) there is a radiator unit that supplies heat to the building interior. Each of these units can be regulated by turning the valve to a setting between 1 and 5. Since the BMS regulates the heating output according to the outside temperature, a setting of “5” gives off heat that may vary from one day to the next. Hence, there are no temperature scales on the valves. Apart from the radiator valves, there are no thermostats to control the heating system. The temperature can, however, be modified in two other ways: the ventilation channels built into the window frames can be opened or closed, and the internal venetian blinds can be adjusted to decrease or increase the solar heat gain in the building.

Since the C.K. Choi is a university building, not every respondent uses it throughout the year. In the survey group, there are three individuals who have not been in the building long enough to experience it during summer conditions. A further two respondents work only from the beginning of September to the end of April; however, they have likely experienced periodic summer-like conditions. All of the respondents who have experienced the building on hot days find the room temperature tolerable during this time.

² Although 20 people answered the questionnaire, 5 respondents filled out one questionnaire. As such, only that group’s combined opinions could be determined, rather than individual attitudes and behaviour, rendering the questionnaire unusable.
The C.K. Choi building does not have any external shading features since:

- There are tall trees shading the southwest side;
- No windows on the southeast side;
- Only clerestory windows on the northwest side, through which direct sunlight does not enter;
- Sun only strikes the northeast façade in the morning.

There are also no internal shading devices on the windows along the southwest perimeter – only the five centres have venetian blinds on their southwest-facing corridor windows, presumably as privacy screens. All office windows on the northeast façade have venetian blinds to negate sky glare and problems with overheating.

The absence of external and internal shading devices does not typically have a negative impact on the southwest side of the building. For some individuals working on the northeast side, solar heat gain becomes an issue on sunny mornings, although the internal blinds mitigate this problem. One-third of the respondents – all of which work by a window facing the West Mall Road – use the blinds to shade direct sunlight as well as block unwanted glare and/or solar heat gain. For this group they help provide a comfortable work atmosphere. Of the remaining respondents, those who use the blinds only do so to block direct sunlight. For those working on the side shaded by the forest, solar heat gain and glare is not a problem, although direct sunlight filtered through the trees does require shading. Overall, even though half of the respondents do not use the blinds against glare/overheating, two-thirds reported that they are sufficient in providing a good work atmosphere.

By requirement, the C.K. Choi (like every other building on campus) does not have an air conditioning system. Nonetheless, none of the respondents had a difficult time adjusting to the

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3 In the conference room a ceiling fan is programmed to start operating when the indoor temperature reaches 25.2 °C. In the atria, the BMS automatically opens the louvers to release warm air at 25°C.
absence of this system, even though indoor temperatures can reach up to 28°C in the summer. When solar heat gain occurs, the respondents seem content lowering the blinds, opening the windows, or adjusting layers of clothing.

Two of the respondents have not experienced the building during winter conditions. The overall ratings for indoor winter temperatures are not as favourable as those for summer temperatures. Almost half of the respondents noted that the thermal conditions are too cold.

Most of the respondents who are too cold in the building during the winter also feel they do not have enough control over regulating the temperature. Each of these individuals listed only one strategy for manipulating the thermal conditions (whereas many who have enough freedom listed two or more strategies). Some of these do not involve any of the building features: plugging in a small electric heater, wearing a sweater and two pairs of socks, drinking hot water, and simply going home.

Despite the fact that many believe they have a lack of freedom in regulating the temperature, almost all of the respondents prefer the convenience of regulating the heating in the C.K. Choi, rather than in previous office buildings they have worked/studied.

Even though the majority of respondents have access to the radiator valves, they do not tend to change the valve setting when too hot or cold. As a solution to high indoor temperatures, opening a window is most common, although several also take off layers of clothing. Only two respondents turn down the heating in this situation. Only one-third of all respondents increase the heating to counter cold winter indoor temperatures. Walking through the building at this time of year, it becomes evident that many people already have their radiator valves set on high (even when they have left for the day). This explains in part, why so many individuals reported strategies for warming up, which did not include the heating. It does not explain why the
respondents do not use the built-in features and close the ventilation channels to block incoming cold air, or raise the blinds to admit the sun's warmth.

3.2.2 Conclusions for Thermal Conditions

In summary, all respondents find the summertime temperatures in this building acceptable, yet many consider the temperatures in the winter too cold. With regards to the summer thermal quality, there are two findings that are of interest:

1. In a society where mechanically conditioned office spaces are typical, the C.K. Choi users had no difficulties adjusting to their absence. The site, massing, and orientation of the building prevent excessive solar heat gain. The southwest longitudinal façade faces a small coniferous forest that effectively keeps the building cool. Hence, as long as the building design has made ample provisions for shading and natural cooling, building users are willing to forgo the energy intensive air conditioning system.

2. The building users can be relied upon to personally decrease solar heat gain, and as such, a building design should allow for this behaviour. At those times when overheating is a problem, the respondents effectively use the blinds and windows to lower the room temperature.

The dissatisfaction that many have with the C.K. Choi's winter thermal conditions raises two points:

1. People tend to want instant gratification, and the response time of the heating system may not be immediate enough.

2. Comprehensible controls are important for user satisfaction. The 1-5 scale for the radiator valves (for which a "*" indicates off) may not be as meaningful to users as a temperature scale is. Feeling cold when the temperature setting is at "5", and feeling cold when the temperature setting is at 25°C are two different things. People are likely better able to relate to a temperature setting, than to a scale that is less familiar to them.

3.2.3 Ventilation

The building relies on natural ventilation. The most direct way of getting fresh air flowing into the building is through window ventilation. A background, steady flow of air enters the building
through the ventilation channels (which the users can close\textsuperscript{4}) on each window system, and exits through louvres at the top of the atria. In order to permit the air to move freely through the building, some of the office areas are not fully contained by walls or a ceiling. Each of the second floor reception areas for the five centres, is spatially connected to the atria on the third floor, since they do not have a ceiling overhead. The two large open communal student work areas on the top floor are also open spatially.

The natural ventilation is generally well received. Two-thirds of the respondents prefer the quality of air, and convenience of regulating the ventilation in the Choi building, over that in their previous office building.

Almost all of those surveyed claim they have enough control over ventilation. Although there are a few respondents who don't regulate the amount of fresh air, the rest do so with window ventilation, sometimes in combination with opening their office door. No one in the survey group adjusts the ventilation channels to regulate the fresh air inflow.

During the winter all of the respondents feel as though they receive enough fresh air. However, the downside of the building's natural ventilation design is that the ventilation channels and interconnected spaces, which allow the air to move freely through the building, promote a draughty environment. More than half of the respondents sense uncomfortable draughts in the building, of which almost all consider the indoor thermal conditions during the winter uncomfortable.

\textsuperscript{4} There are ventilation channels on the bottom of each operable window frame, and along the bottom of each entire window unit. Initially, the channels on the operable windows could not be closed. After numerous complaints from the occupants, a hole was strategically drilled into each frame to allow the channels to be opened and closed freely.
In short, the findings confirm that natural ventilation is a valid way of providing the required air supply. There are two points for designers to consider:

1. A building layout which facilitates natural ventilation can result in uncomfortable draughts. A building should aim to provide the occupants with sufficient fresh air, without sacrificing their thermal comfort.

2. When a building has unusual features, such as the ventilation channels, building users need to understand how to use them effectively. In the Choi building, the users have the capability of reducing the infiltration of cold air, yet none in the survey group close the channels.

3.2.4 Electric Lighting

In the individual offices and washrooms a person must manually turn on the lights, while the occupancy sensors automatically shut them off. The building user has the ability to shut the lights off manually.

The majority of the survey group regards the lighting arrangement flexible enough for the tasks they perform. However, despite the Choi's small lighting zones, easy access to the light switches, and automatic shut-off with manual override, only two-thirds of the respondents specifically like the convenience of regulating the lighting better than in their previous office building.

Many office buildings are usually fully lit when the workers enter them but this is not the case in the C.K. Choi building. Almost half of the respondents had no difficulty personally turning on/off the lighting. One-fifth needed to get accustomed to this behaviour, although this was relatively easy. The few remaining respondents found this aspect of lighting difficult to get used to.

3.2.5 Natural Lighting

The daylighting design is fairly successful in the sense that nearly all respondents consider the amount of natural light available in the C.K. Choi superior to the amount in the office buildings
they previously worked in. Also, getting used to controlling the amount of daylight reaching the work area was not an issue for a large number of respondents.

There are daylight sensors that adjust the electric lighting output according to the amount of available natural light. The majority of respondents consider the Choi lighting strategy an efficient one, and believe that more lighting control would not result in greater energy savings.

Nonetheless, in a building that was designed to maximize daylighting and minimize artificial lighting, it is ironic that a number of respondents need to use the electric lighting when it is sunny. These individuals all work on the southwest side of the building, which can be darker than the northwest side, due to the numerous adjacent trees. Regardless of whether or not they lower the blinds, there is not enough sunlight reaching their work area to negate the use of the lights. If it is not bright enough during a sunny day, it is certainly not bright enough during an overcast day. As far as the daylighting strategy is concerned, the trees are an interference. This is in contrast to workers on the northeast side who adjust the venetian blinds to block glare or solar heat gain, and do generally not need to use the electric lighting.

There are two ideas arising from the findings in this section:

1. Extensive exterior shading (in this case by the trees) can sometimes lead to low levels of available daylight, and result in increased use of artificial lighting.

2. It is likely that when people work in an environment where the lighting has a large component of technical regulation, they tend to have a lot of faith in the system's energy saving capability.

### 3.3 THE FIVE DIFFERENT PERSPECTIVES

Thus far the findings from each questionnaire set have been discussed in a general sense, and the overall behaviour and attitudes of each of the four survey groups were characterized. Further insight can be gained by comparing the responses of different types of respondent.
groups. Table 3.1 lists the five different perspectives and the various groups that will be compared in the latter half of Part I.

<table>
<thead>
<tr>
<th>TABLE 3.1</th>
<th>A Tally of the Respondents in the Various Perspective Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TENUM</td>
</tr>
<tr>
<td>TOTAL NUMBER OF RESPONDENTS</td>
<td>13</td>
</tr>
<tr>
<td>WORK TIME</td>
<td></td>
</tr>
<tr>
<td>Part-time</td>
<td>3</td>
</tr>
<tr>
<td>(1-20 hours/week)</td>
<td></td>
</tr>
<tr>
<td>Full-time</td>
<td>10</td>
</tr>
<tr>
<td>USER STATUS</td>
<td></td>
</tr>
<tr>
<td>Office Workers/ Secretaries</td>
<td>6</td>
</tr>
<tr>
<td>Owners/Managers</td>
<td>7</td>
</tr>
<tr>
<td>Students</td>
<td>---</td>
</tr>
<tr>
<td>Administrator</td>
<td>---</td>
</tr>
<tr>
<td>Faculty/Research Associates</td>
<td>---</td>
</tr>
<tr>
<td>Secretaries</td>
<td>---</td>
</tr>
<tr>
<td>YEARS OF BUILDING USE</td>
<td></td>
</tr>
<tr>
<td>Short-time users</td>
<td>6</td>
</tr>
<tr>
<td>(1-3 years)</td>
<td>(2/5-1 1/2 years)</td>
</tr>
<tr>
<td>Long-time users</td>
<td>6</td>
</tr>
<tr>
<td>(5-6/4 years)</td>
<td>(2 plus years)</td>
</tr>
<tr>
<td>AGE</td>
<td></td>
</tr>
<tr>
<td>Younger users</td>
<td>8</td>
</tr>
<tr>
<td>(18-39 years)</td>
<td>(18-39 years)</td>
</tr>
<tr>
<td>Older users</td>
<td>5</td>
</tr>
<tr>
<td>(40-59 years)</td>
<td>(40-60 plus years)</td>
</tr>
<tr>
<td>GENDER</td>
<td></td>
</tr>
<tr>
<td>Male users</td>
<td>8</td>
</tr>
<tr>
<td>Female users</td>
<td>5</td>
</tr>
</tbody>
</table>

The anticipated findings for each comparison are introduced below.

3.5.1 Comparing Part-Time to Full-Time Office Building Users

Whether a person is a full-time or a part-time building user may affect that person's behaviour in a number of ways. First of all, when an individual uses a building on a full-time basis, throughout the day, s/he develops a familiarity with the workings of the building features to a greater degree than a part-time user. Second, in addition to better knowing the physical setting, a full-time user is also more likely to feel at ease in that building's social setting. Hence it is projected that full-time users are more likely to use the building features to modify their work environment than the part-time users are.

---

5 One of the respondents did not state how long she worked in the Tenum office building.
6 One of the respondents did not state how long she worked in the C.K. Choi office building.
3.5.2 Comparing the Status of Office Building Users

The status a person has in an organization may also affect his/her behaviour, which in turn can affect the resulting energy consumption. Since the nature of the occupants' role is different within the two office buildings the significance they have on the users' behaviour will also differ.

The users of the Tenum building can be classified as either those who manage the financial aspects of purchasing, operating and maintaining the building, or those who have no direct financial interest in it. In this case the responses of the owner/manager will be contrasted to those of the office workers and secretaries, respectively. An office owner has made, and continues to make, a financial investment in the building. Both an owner and manager has a vested interest in low operating and maintenance costs. In addition, both oversee monthly water and energy costs, which may act as feedback for the consumption in the building, and provide incentive for "proper" behaviour. On the other hand, the office workers and secretaries have neither a direct financial investment in the building, nor feedback on their consumption patterns. Hence, it is hypothesized that the latter individuals may be somewhat less motivated to behave in a manner that conserves energy.

Since the university owns the C.K. Choi, none of the building users have a direct financial investment in it. Rather, it is the degree of building familiarity, proximity of co-workers (i.e. do they work in individual offices or a communal area) and extent of use inherent with the given user roles that may impact behaviour. The secretaries work in an office space with other people. They are likely to know the building features fairly well from a management perspective. The administrator, faculty and research associates generally work by themselves in their own offices. Since these individuals have insular work spaces their behaviour is less likely to affect the environment of other occupants. They are likely to be quite familiar with their personal office space and to manipulate its condition freely. The students work in a large communal area on the third floor. Relative to those with personal offices, the students are
probably less likely to have an affinity to their work areas, since they are more transient: they may work at their desk, in the computer room, lounge, or in other buildings on campus. The students may be familiar with most of the building features, but not to a great extent. There are three different hypotheses for this comparison:

1. The secretaries may have a good understanding of the building features, but are not as likely to manipulate their work environment as those who work in individual office.
2. The administrator, faculty and research associates are most likely to feel at ease manipulating the heat, ventilation and lighting in their personal environment.
3. The students are least likely to interact with the building features.

3.5.3 Comparing Short-Time to Long-Time Office Building Users

There are two issues associated with the number of years a person has worked in a building, which may affect their behaviour. First, although not typical, those who have used the building since its opening are more likely to have had a formal introduction to the building features and workings than the “newcomers” are. Second, the people that have worked in a building for a long time are more familiar with it. It is anticipated that long-time users are well accustomed to using the building features appropriately, compared to the newcomers who are less familiar with the building and may either misuse or fail to use certain features.

3.5.4 Comparing Younger to Older Office Building Users

Most sociological research has indicated that concern for the environment is negatively correlated to age (Scott & Willits, 1994:255). In other words, the older the individual, the less environmental concern s/he tends to exhibit. Hence, with regards to this study, there are two anticipated findings:

1. The younger respondents are more likely to conserve energy by reducing the heating when too hot, and resorting to other alternatives aside from heating when cold.
2. The younger respondents are more likely to accept natural ventilation and/or the absence of air conditioning.
3.5.5 Comparing Male to Female Office Building Users

Just as being young is a positive predictor of local environmental concern, so too is being female. According to Stern, Dietz and Kalof (1993:338), “Women tend to see environmental quality as more likely than men to have consequences for personal well-being, social welfare, and the health of the biosphere.” Given this information, it is expected that the women in the case-study buildings are more likely than the men to limit energy consumptive behaviour and rely more on the passive ways of conditioning their work areas.

3.4 THE TENUM FINDINGS FROM FIVE DIFFERENT PERSPECTIVES

Table 3.2 summarizes the significant differences between the various Tenum user groups. The responses to questions pertaining to electric lighting and natural lighting are very similar and do not lead to any noteworthy distinctions.

3.6.1 Comparing Part-Time to Full-Time Office Building Users

The findings tend to support the idea that part-time workers use the building features to a lesser extent than full-time employees do. There are several possible explanations for this particular behaviour:

1. The part-time workers may not feel comfortable enough in the social setting to either access someone else’s work area to heat, shade or ventilate, or to make adjustments that may affect other workers around them.

2. When an individual spends less time in an environment, the chances of encountering weather-dependent uncomfortable building conditions decrease.

3. They may not be familiar enough with the blinds.

4. Glare, solar heat gain, or lack of fresh air may not be an issue for them.

Tenum part-time building users are also uncertain if they have enough control over heating and ventilation. This suggests that they do not have a clear understanding of how they can condition their office environment.
**TABLE 3.2** A Tabulation of the Tenum Findings from Five Different Perspectives.

<table>
<thead>
<tr>
<th>Comparing Part-Time to Full-Time Building Users</th>
<th>THERMAL QUALITY</th>
<th>VENTILATION</th>
<th>ELECTRIC LIGHTING</th>
<th>NATURAL LIGHTING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part-time</strong></td>
<td><strong>Summer:</strong></td>
<td><strong>1. 1/3 find the temperature intolerable.</strong></td>
<td>1. None who work away from the windows open them to regulate the amount of fresh air.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td><strong>In General:</strong></td>
<td><strong>2. Uncertain if they have enough freedom in regulating temperature.</strong></td>
<td>2. None are sure if they have enough control over ventilation.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>3. Do not use blinds frequently to block solar heat gain, even though they find them effective.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Full-time</strong></td>
<td><strong>Summer:</strong></td>
<td><strong>1. All find temperature tolerable.</strong></td>
<td>1. More than ½ who work away from windows open them for fresh air.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>In General:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Comparing Various Positions of Office Building Users</strong></td>
<td><strong>Owners/managers</strong></td>
<td><strong>Summer:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1. More of them find summer temperatures intolerable.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Winter:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1. Most lack freedom in regulating temperature.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>2. More of them increase heating when cold.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>3. All dress more warmly when cold.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>5. Most never get too hot.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>6. When overheating is a problem, they don’t reduce the heating.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>In General:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>7. Over ½ use blinds to reduce solar heat gain, but only some find this effective.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Office workers/Secretaries</strong></td>
<td><strong>Winter:</strong></td>
<td><strong>1. ½ listed ways of modifying room temperature.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Throughout year.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>2. ½ find blinds reduce solar heat gain, but most don’t use them frequently.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Comparing Short-Time to Long-Time Building Users</strong></td>
<td><strong>Short-time</strong></td>
<td><strong>In General:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1. ½ question their freedom to control the temperature.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Summer:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>2. 2 people find room temperature intolerable.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Winter:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1. ½ reduce the heating when hot.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>3. 1 person lowers the blinds when hot.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>4. 1 person turns on light and computer when cold.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>In General:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1. Most think they don’t have enough control over ventilation.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Long-time</strong></td>
<td><strong>In General:</strong></td>
<td><strong>1. Listed more strategies for manipulating temperature.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>****</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Comparing Younger to Older Building Users</strong></td>
<td><strong>Younger</strong></td>
<td><strong>Summer:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1. Just under ½ find temperature intolerable.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Winter:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1. ½ reduce the heating when hot.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>3. 1 person lowers the blinds when hot.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>In General:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1. A greater portion don’t regulate the quantity of fresh air.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>2. All of those who sit away from the windows don’t use them to ventilate.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>3. Most don’t have enough control over ventilation.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Older</strong></td>
<td><strong>Summer:</strong></td>
<td><strong>1. All find temperature tolerable.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>In General:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>2. A greater portion have enough freedom in regulating temperature.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>3. A greater portion consider the blinds sufficient in creating a comfortable temperature environment.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Comparing Younger to Older Building Users</strong></td>
<td><strong>Male</strong></td>
<td><strong>In General:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1. Are more likely to use blinds to prevent overheating.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Summer:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>2. All 3 who consider the room temperature intolerable during the summer are men.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Female</strong></td>
<td><strong>In General:</strong></td>
<td><strong>1. None explicitly feel they lack freedom in regulating temperature.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>2. All consider blinds sufficient in providing comfortable thermal atmosphere.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Winter:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1. Those who work away from the window are uncertain if they have enough control over ventilation.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Comparing Male to Female Building Users</strong></td>
<td><strong>Male</strong></td>
<td><strong>In General:</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1. Those who work away from the window don’t have enough control over ventilation.</strong></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Female</strong></td>
<td><strong>In General:</strong></td>
<td><strong>1. Those who work away from the window are uncertain if they have enough control over ventilation.</strong></td>
<td></td>
<td>N/A</td>
</tr>
</tbody>
</table>
3.6.2 Comparing the Various Positions of Office Building Users

There is a tendency for the owners/managers to be more critical of: the thermal quality, the freedom to regulate it, the effectiveness of the building features in achieving comfortable thermal conditions, and their ability to control ventilation. There is also an indication that most of them understand the ways in which they can influence the thermal condition of their work space. However, their behaviour is not more conducive to conserving energy, as was predicted. Although all of them dress more warmly when they are cold in the winter, they are just as likely to increase the heating when cold as the office workers and secretaries. Furthermore, none of the owners/managers turn the heating down when hot in the winter, yet one-third of the office workers and secretaries do. As far as heating is concerned (which is the most energy consumptive method of temperature modification), the behaviour of the office workers and secretaries is slightly more appropriate.

3.6.3 Comparing Short-Time to Long-Time Office Building Users

The findings do not consistently support the hypothesis that the long-time users better understand the controls they have available to manipulate the temperature, than the short-time users do. On one hand, a great number of newcomers are uncertain if they have enough control over the heating and ventilation. As well, not many use the building features to raise the temperature levels. This suggests that they do not fully know what options they have for affecting the conditions of their work space. For instance, one short-time user turns on the lights and computers to warm up during the winter, which is not how the room temperature was designed to be regulated.

On the other hand, none of the long-time building users interact with the building to compensate for hot temperatures during the winter, whereas some of the newcomers reduce the thermostat setting and lower the blinds. Since few of the long-time users listed strategies for dealing with
hot or cold winter temperatures it is not possible to ascertain if their behaviour is generally more appropriate than that of the short-time users.

3.6.4 Comparing Younger to Older Office Building Users

When it comes to energy conservation, the difference between the two age groups is not substantial, however the younger respondents are slightly more inclined to conserve energy. Even though both age groups increase the heating to the same extent when they are cold, it is some of the younger respondents that reduce the heating when they are too hot.

The older respondents appear to be more content with indoor building conditions and the system controls, and also less likely to modify their environment. A number of findings indicate that the older group seems more satisfied with the thermal quality and with the ability to control thermal conditions. It seems they are less likely to facilitate natural ventilation. Most feel they don’t have enough control over ventilation. None of the older workers who sit away from the windows use them to ventilate, whereas half the younger group working in a similar location do. It may be that the younger workers have less inhibition when it comes to accessing a co-worker’s work area.

3.6.5 Comparing Male to Female Office Building Users

There is evidence that the women working in the Tenum building are more accepting of its control features and thermal conditions. They consider the blinds sufficient in providing a comfortable room temperature. The men are more critical of the summer indoor temperatures, as well as their control over the ventilation. However, contrary to the hypothesis, the women are more likely to heat when they are cold, while both sexes are equally likely to reduce the heating when hot in the winter. As well, women are less likely to adjust their blinds to control solar heat gain.
3.5 THE C.K. CHOI FINDINGS FROM FIVE DIFFERENT PERSPECTIVES

The significant differences between the various Choi user comparison groups are summarized in Table 3.3.

3.7.1 Comparing Part-Time to Full-Time Office Building Users

When it comes to warming up during the winter, the part-time users do not tend to use the building features as much as the full-time users do. The part-time workers dress warmer, plug in their heater, or go home when they are cold. To cool off when indoor temperatures are high, none of them reduce the heating, although, they are more likely to open a window.

Where ventilation, electric lighting, and natural lighting are concerned the findings do not indicate that one group interacts with the building features to a greater extent than the other group does. What they do indicate is that more of the part-time workers needed to adjust to turning on/off the lighting, while fewer needed to accustom to regulating daylight.

3.7.2 Comparing the Various Positions of Office Building Users

There is no indication that the secretaries are less likely to manipulate the condition of their environment than the administrator, faculty or research associates are. Perhaps this is because the difference in the two groups' office size is not substantial enough. The secretaries typically work in fairly small areas with only one or two other individuals. This may not be enough people to inhibit an individual's behaviour. However, the secretaries are more likely to question their control over ventilation, which tends to be a more common occurrence for people working in a shared office space.

As predicted, those individuals working in the individual offices tend to be fairly comfortable in that environment. The findings also show that the administrator, faculty or research associates are more likely to perceive enough control for conditioning their environment. However, unlike
the students and secretaries who find the convenience of regulating the lighting superior in the C.K. Choi, half of them consider it to be on par with their previous office buildings (even though they have sole control over the lights).

It is difficult to ascertain the general behaviour of the students, since only two answered the survey – of which one has not used the building during the winter. It does seem that they generally interact less with the building (i.e. they don’t use blinds or heat when cold) than the other two user groups. At the same time, the fact that they work in an open-plan office does not seem to affect their sense of control over ventilation, and they do not report any problems with draughts.

3.7.3 Comparing Short-Time to Long-Time Office Building Users
The understanding of the building features and their appropriate use is only slightly more common among the long-time users. Some of them decrease the heating when hot in the winter, but they are no more likely to use the blinds, windows, or ventilation channels to modify their environment than the short-time users are.

3.7.4 Comparing Younger to Older Office Building Users
Contrary to the hypothesis, the behaviour of the younger C.K. Choi respondents does not seem to reflect a greater tendency to reduce energy consumption and accept natural conditioning. The older group of respondents tends to be more inclined to conserve energy than the younger respondents do. The younger ones are more likely to turn up the heat when cold. As well, fewer of the older respondents needed to adjust to personally turning on/off the lights and to regulating the amount of daylight reaching their work area. They are also more likely to accept the absence of the air conditioning. The natural ventilation is a greater problem for the younger age group, which tends to consider the temperature inappropriate during the winter and sense uncomfortable draughts.
3.7.5 Comparing Male to Female Office Building Users

In general, all building users like the summer temperatures, and approximately the same proportion of women and men dislike the winter temperatures in the C.K. Choi. None of the men interact with the building to warm up when they are cold during the winter – they either dress warmer or go home. Several women on the other hand, tend to have more than one strategy for countering the cold, and almost half of them turn up the heating. It seems the women are not less likely to consume energy, since they use more energy to warm up, and are not more likely to reduce the heating when too hot during the winter.
<table>
<thead>
<tr>
<th>TABLE 3.3  The C.K. Choi Findings from Five Different Perspectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>THERMAL QUALITY</td>
</tr>
<tr>
<td>Winter:</td>
</tr>
<tr>
<td>1. Almost ½ find temperatures inappropriate.</td>
</tr>
<tr>
<td>2. 1 person turns up heating when cold.</td>
</tr>
<tr>
<td>3. 1 person goes home when cold.</td>
</tr>
<tr>
<td>4. 1 person uses electric heater when cold.</td>
</tr>
<tr>
<td>5. Twice as many open windows when hot.</td>
</tr>
<tr>
<td>6. 1 person leaves the building when hot.</td>
</tr>
<tr>
<td>Part-Time Users:</td>
</tr>
<tr>
<td>Winter:</td>
</tr>
<tr>
<td>1. Most needed to adjust to personally turning on/off electric lights.</td>
</tr>
<tr>
<td>2. Some think they could save electricity if they had more control over the lighting.</td>
</tr>
<tr>
<td>3. Twice as many open windows when hot.</td>
</tr>
<tr>
<td>4. 1 person leaves the building when hot.</td>
</tr>
<tr>
<td>Full-Time Users:</td>
</tr>
<tr>
<td>In General:</td>
</tr>
<tr>
<td>1. A greater portion do not feel they have enough freedom in regulating the temperature.</td>
</tr>
<tr>
<td>Winter:</td>
</tr>
<tr>
<td>1. More likely to sense draughts.</td>
</tr>
<tr>
<td>2. Almost ½ turn up heating when cold.</td>
</tr>
<tr>
<td>3. 2 people turn down heating when hot.</td>
</tr>
<tr>
<td>Comparing the Various Positions of Office Building Users:</td>
</tr>
<tr>
<td>Secretaries:</td>
</tr>
<tr>
<td>In General:</td>
</tr>
<tr>
<td>1. ½ prefer convenience of regulating heating in C.K. Choi, and ½ think it is the same in C.K. Choi and previous office buildings.</td>
</tr>
<tr>
<td>Summer:</td>
</tr>
<tr>
<td>1. Tend to find fresh air &amp; convenience of regulating ventilation better in the C.K. Choi.</td>
</tr>
<tr>
<td>2. Some question their control over ventilation.</td>
</tr>
<tr>
<td>3. All sense uncomfortable draughts.</td>
</tr>
<tr>
<td>Comparison the Various Positions of Office Building Users:</td>
</tr>
<tr>
<td>Administrator/Faculty/Research associates:</td>
</tr>
<tr>
<td>In General:</td>
</tr>
<tr>
<td>1. The majority prefer the convenience of regulating heating in C.K. Choi over previous office buildings.</td>
</tr>
<tr>
<td>Summer:</td>
</tr>
<tr>
<td>1. ½ prefer convenience of regulating heating in C.K. Choi, and ½ think it is the same in C.K. Choi and previous office buildings.</td>
</tr>
<tr>
<td>Winter:</td>
</tr>
<tr>
<td>1. ½ think the fresh air &amp; convenience of regulating ventilation are the same in the C.K. Choi. and previous office buildings. ½ think they are better in the C.K. Choi.</td>
</tr>
<tr>
<td>2. Have enough control over ventilation.</td>
</tr>
<tr>
<td>3. ½ have problems with draughts.</td>
</tr>
<tr>
<td>1. 1 person doesn't find lighting arrangement flexible enough.</td>
</tr>
<tr>
<td>2. ½ prefer convenience of regulating lighting in C.K. Choi.</td>
</tr>
<tr>
<td>3. Most did not have to get accustomed to regulating on/off lights.</td>
</tr>
<tr>
<td>4. 2 people could save more electricity with more control over lighting.</td>
</tr>
<tr>
<td>1. Most did not have to get accustomed to regulating daylight.</td>
</tr>
<tr>
<td>2. All find there's enough daylight to negate use of lights.</td>
</tr>
<tr>
<td>3. Most did not have to get accustomed to regulating on/off lights.</td>
</tr>
<tr>
<td>4. 2 people could save more electricity with more control over lighting.</td>
</tr>
<tr>
<td>1. Most did not have to get accustomed to regulating daylight.</td>
</tr>
<tr>
<td>2. All find there's enough daylight to negate use of lights.</td>
</tr>
<tr>
<td>3. Most did not have to get accustomed to regulating on/off lights.</td>
</tr>
<tr>
<td>4. 2 people could save more electricity with more control over lighting.</td>
</tr>
<tr>
<td>Students:</td>
</tr>
<tr>
<td>In General:</td>
</tr>
<tr>
<td>1. ½ prefer convenience of regulating heating in C.K. Choi, and ½ think it is the same in C.K. Choi and previous office buildings.</td>
</tr>
<tr>
<td>Summer:</td>
</tr>
<tr>
<td>1. The students do not tend to use the blinds to prevent overheating and/or glare.</td>
</tr>
<tr>
<td>Winter:</td>
</tr>
<tr>
<td>1. Tend to find fresh air &amp; convenience of regulating ventilation better in the C.K. Choi.</td>
</tr>
<tr>
<td>2. Some question their control over ventilation.</td>
</tr>
<tr>
<td>3. No problems with draughts.</td>
</tr>
<tr>
<td>1. Most did not find lighting arrangement flexible enough.</td>
</tr>
<tr>
<td>2. ½ prefer convenience of regulating lighting in C.K. Choi.</td>
</tr>
<tr>
<td>3. Most did not have to get accustomed to turning on/off lights.</td>
</tr>
<tr>
<td>4. 2 people could save more electricity with more control over lighting.</td>
</tr>
<tr>
<td>1. 1 person doesn't find lighting arrangement flexible enough.</td>
</tr>
<tr>
<td>2. Some think they could save electricity if they had more control over the lighting.</td>
</tr>
<tr>
<td>3. Most did not have to get accustomed to regulating on/off lights.</td>
</tr>
<tr>
<td>4. 2 people could save more electricity with more control over lighting.</td>
</tr>
<tr>
<td>1. Getting accustomed to regulating daylight was easy.</td>
</tr>
<tr>
<td>2. 1 person still needs lights on when sunny.</td>
</tr>
</tbody>
</table>

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### TABLE 3.3 CONTINUED

<table>
<thead>
<tr>
<th>THERMAL QUALITY</th>
<th>VENTILATION</th>
<th>ELECTRIC LIGHTING</th>
<th>NATURAL LIGHTING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Comparing Short-Time to Long-Time Building Users</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Short-time</strong></td>
<td>In General: 1. Consider convenience of regulating heating the same in C.K. Choi and previous office buildings. 2. Tend to feel they don't have enough freedom in regulating temperature. <strong>Winter:</strong> 3. A greater number find temperature in the winter inappropriate. 4. When cold some use electric heater, drink hot water, or go home.</td>
<td>1.½ find air quality better in C.K. Choi, and ½ find it the same as in previous office buildings. 2. 1 person doesn't have enough control over ventilation, while 1 person is uncertain of this. 3. Report uncomfortable draughts in greater numbers.</td>
<td>1. ½ prefer lighting strategy in C.K. Choi to previous office buildings, and almost ½ think it is the same in both places. 2. 1 person found the lighting strategy difficult to get used to.</td>
</tr>
<tr>
<td><strong>Long-time</strong></td>
<td>In General: 1. Consider convenience of regulating heating better in C.K. Choi. 2. Tend to feel they don't have enough freedom in regulating temperature. <strong>Winter:</strong> 3. Most put on clothing layers when cold. 4. 1 person turns heat down when too hot</td>
<td>1. Most consider the air quality better in the C.K. Choi than in previous office buildings. 2. All have enough control over ventilation.</td>
<td>1. Most prefer lighting in C.K. Choi over previous office buildings.</td>
</tr>
<tr>
<td><strong>Comparing Younger to Older Building Users</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Younger</strong></td>
<td>In General: 1. Most consider the air quality better in the CK. Choi than in previous office. 2. Are less likely to use blinds to block glare or solar heat gain. 3. Are more likely to have enough freedom regulating the temperature. <strong>Summer:</strong> 4. Slightly more were used to not having an air conditioner. <strong>Winter:</strong> 5. Tend to consider temperature appropriate. 6. 1 person goes home when cold. 7. Twice as many open windows when hot. 8. 1 person leaves when hot.</td>
<td>1. Almost ½ have enough freedom in regulating ventilation. 2. The majority sense uncomfortable draughts.</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Older</strong></td>
<td>In General: 1. Tend to prefer the convenience of regulating heating in the C.K. Choi over previous office. 2. Are less likely to use blinds to block glare or solar heat gain. 3. Are more likely to have enough freedom regulating the temperature. <strong>Summer:</strong> 4. Slightly more were used to not having an air conditioner. <strong>Winter:</strong> 5. Tend to consider temperature appropriate. 6. 1 person goes home when cold. 7. Twice as many open windows when hot. 8. 1 person leaves when hot.</td>
<td>1. All have enough freedom in regulating ventilation.</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Comparing Male to Female Building Users</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Male</strong></td>
<td>Winter: 1. None of the men interact with the building to warm up when cold (they either dress warmer or go home).</td>
<td>1. All have enough control over ventilation.</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Female</strong></td>
<td>Winter: 1. Almost ½ turn up heating. 2. Several tend to have more than one strategy for countering cold temperatures. 3. ½ take of a layer of clothing when too hot.</td>
<td>1. Tend to find more faults with ventilation strategy. The majority have problems with draughts. 2. 2 don't have enough control over ventilation. 3. A greater number think the convenience of regulating ventilation is the same in the C.K. Choi and previous office buildings.</td>
<td>N/A</td>
</tr>
</tbody>
</table>

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3.6 COMPARING THE FINDINGS FROM THE TENUM TO THE C.K. CHOI RESPONSES

The Tenum and C.K. Choi respondents have a large overlap in age range, are all fairly well educated, and are equally likely to have participated in a local environmental group in the past, or at present. Other important aspects that the two office buildings share are a common design philosophy, and clients who believe in an environmental agenda and have made a conscious effort to optimize the operation of the building.

By all indications the behaviour of the Swiss and Canadian questionnaire respondents, including how they rate their building, is more similar than different. It does not appear that one group's behaviour is more appropriate, in terms of facilitating the building's environmental agenda, than the others. In fact, most differences can be attributed to the different building designs, rather than the different cultural contexts. Due to the extensive shading provided by the forest, and the design of its natural ventilation, the thermal conditions in the C.K. Choi building are satisfactory in the summer, but unsatisfactory during the winter. Conversely, the Tenum building, with its shading problems on the southeast side, and mechanical ventilation during the colder climate, tends to have high summer temperatures, yet adequate winter temperatures. As well, the layout of the floor plan tends to lead to different behaviour. Most of the C.K. Choi respondents work in personal offices, whereas the Tenum has a series of open-plan office layouts with a number of individuals working in the core of the building. Hence, since the majority of C.K. Choi respondents are in close proximity to the windows, it seems reasonable that greater numbers report having sufficient control over ventilation. Likewise, since the proportion of occupants to user controls is greater in the C.K. Choi, it makes sense that there are more individuals who feel they have sufficient control over the heating system.
In a broader sense, the two survey groups have very similar outlooks on social, political and environmental issues. Most of them believe that it is the government's responsibility to even out differences in wealth and to provide public housing for the less fortunate. As well, many feel that the government ought to enforce the "polluters pay" principle to ensure that industry minimizes air and water pollution. Within each survey group opinions on remaining issues such as economic growth, reducing consumption, and the role of science in solving environmental problems, are mixed. However, by and large, there is agreement amongst the Tenum and C.K. Choi respondents that nature is something to be revered and not abused, and many tend to favour an environmental outlook.

3.7 SIMILARITIES BETWEEN THE SWISS AND CANADIAN CHARACTERISTICS

Apart from the similar circumstances they share, overlaps between their cultural settings may help explain the similar views of the respondents. Since Switzerland and Canada are both members of western industrialized society, there are certain standards of living that are common to both countries.

3.7.1 Age Distribution and Life Expectancy

The age distribution and life span found in Swiss culture are to a large extent comparable to Canadian figures. 17.7% of the Swiss population is under 15 years old; the bulk of the population, i.e. 68.1%, is of working age between 15 and 65; and the smallest segment of the population (14.2%) is over 65 years of age. In Canada the statistics are similar: 19.8% of the population is below age 15; 67.9% are between 15 and 65 years old; and 12.3% are 66 or older.

In both countries, trends reveal that the population has been aging over the past 50 years. The main causes for these changes are declining fertility rates and a high availability of quality
medical care. On average, the life expectancy for Swiss women is 81.7 years, and for men it is 75.3, while Canadians reach the ages of 81.4 and 74.9, respectively.\textsuperscript{7}

3.7.2 Education

The level of education is also comparative, shown by school attendance figures and the percentage of literacy amongst the population. Swiss gross primary enrollment of the school-aged population is 107\%, and the number in Canada is 102\%.\textsuperscript{8} Similarly, 99\% of the Swiss population, and 97\% of the Canadian population is literate.

3.7.3 Diversity Through Languages

Cultural diversity in both countries is evidenced by the variety of first languages spoken. There are 4 official languages in Switzerland: Swiss-German, French, Italian, and Romansch, which is a Latin-based language. By far the most common is Swiss-German, since it is the mother tongue of nearly two-thirds (i.e. 63.7\%) of the population. The first languages of the remaining population can be broken down as follows: 19.2\% speak French, 7.6\% Italian, 0.6\% Romansch, and 8.9\% speak in a foreign language.

In Canada, the two official languages are also unevenly represented: English, the predominant language, is the first language for 60.1\% of the population, while French is the first language for 23.6\%. Aboriginal languages were reported as the mother tongue by only 0.7\%, whereas the remaining 15.6\% of the people have a foreign language as their first language.

When focus is shifted to the two case-study regions, there is however a slight difference between them. Basel-Landschaft, the canton in which the Tenum building is located, is linguistically less diverse than Switzerland on the whole, since most people's first language is Swiss-German (see Table 3.4). However, the GVRD, in which the C.K. Choi building is located,  

\textsuperscript{7}1992 statistics. http://www.admin.ch/bfs/stat_int/eint_can.htm
is above the national average in its linguistic diversity (see Table 3.5). The Tenum building is located in a more culturally coherent region, relative to the C.K. Choi building, but this does not seem to be an important factor in the survey findings.

<table>
<thead>
<tr>
<th>TABLE 3.4</th>
<th>A Breakdown of the First Languages Spoken in Switzerland</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOTHER TONGUE</td>
<td>%</td>
</tr>
<tr>
<td>Swiss-German</td>
<td>86.1</td>
</tr>
<tr>
<td>French</td>
<td>1.7</td>
</tr>
<tr>
<td>Italian</td>
<td>4.6</td>
</tr>
<tr>
<td>Romanch</td>
<td>0.1</td>
</tr>
<tr>
<td>English</td>
<td>0.9</td>
</tr>
<tr>
<td>Dutch</td>
<td>0.2</td>
</tr>
<tr>
<td>Greek</td>
<td>0.0</td>
</tr>
<tr>
<td>Other</td>
<td>6.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 3.5</th>
<th>A Breakdown of the First Languages Spoken in Canada</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOTHER TONGUE</td>
<td>%</td>
</tr>
<tr>
<td>English</td>
<td>63.6</td>
</tr>
<tr>
<td>French</td>
<td>1.3</td>
</tr>
<tr>
<td>Chinese</td>
<td>13.0</td>
</tr>
<tr>
<td>Punjabi</td>
<td>3.7</td>
</tr>
<tr>
<td>German</td>
<td>1.9</td>
</tr>
<tr>
<td>Tagalog (Filipino)</td>
<td>1.3</td>
</tr>
</tbody>
</table>

3.7.4 The Cost of Living

Although the cost of living is much higher in Switzerland, so too is the average annual income. When the income for men and women is compared as a ratio, and household expenditure figures are compared as percentages, then the financial situation facing Swiss and Canadians is much more comparable.

In 1996, women working full-time in Switzerland earned SFr.50,690 and men earned SFr.70,200, yielding an income gender ratio of 100:138, respectively. The average earning for women in Canada was $20,902 and for men $32,248, a ratio of 100:154.

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8 http://www.census.gov/ipc/www/idbsum.html
9 Greater Vancouver Key Facts: A Statistical Profile of Greater Vancouver, Canada. Strategic Planning Department, Greater Vancouver Regional District, September 1998, p. 15
Table 3.6 shows the amount of money the average Swiss and Canadian household spends annually on such items as food, shelter, health care, etc. When looking at the expenditures as a percentage of the total selected expenditure, it becomes apparent that Canadian and Swiss households spend a similar percentage on food, furnishings, clothing, and their education and recreation. Canadians do, however, spend more on shelter and household operations, which is likely due to the fact that far more of them own their own houses. The most significant spending difference pertains to health care. Relative to the other selected expenditures, the Swiss spend 5 times as much on health care as Canadians do. This difference can be attributed to extremely high health care costs, and the fact that the Swiss government does not subsidize them.

3.8 FUNDAMENTAL DIFFERENCES BETWEEN THE SWISS AND CANADIAN CHARACTERISTICS

So far, reasons have been offered to help explain why the findings from the two surveys are comparable. Although the two select group of respondents, the philosophy behind each case-study building, and the intent of the client groups are all fairly similar, the Swiss and Canadian general public’s attitude and behaviour towards the environment, including the state of the environment itself, are quite different. The limitations of the survey findings must therefore be recognized, and the ensuing guideline recommendations taken in context.

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10 There are limitations to the comparability of the figures in Table 2.3. First of all, the data came from two different sources: the Swiss Statistical Office and Statistics Canada. Second, the information was collected in different years. Finally, the headings under which the information was provided were not fully compatible (for instance Swiss cleaning costs vs. Canadian personal care costs, or Swiss alcoholic and non-alcoholic beverages vs. Canadian alcoholic beverages). Hence, Table 2.3 indicates general expenditure trends.

11 Total selected expenditure refers to the total expenditures on selected items (see 1st and last columns in Table 2.3) and does not constitute the total household expenditure. The total household expenditure in Switzerland is SFr.72,849 and in Canada it is $49,068. The spending categories for each country’s total household expenditures were not directly comparable, thus the categories needed to be calibrated.
### TABLE 3.6  A Comparison of Household Expenditures

<table>
<thead>
<tr>
<th>Selected Expenditure Detail</th>
<th>SWITZERLAND (1994)</th>
<th>CANADA (1996)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expenditure as a percentage of total selected expenditures</td>
<td>Annual household expenditure on selected items in SFr.</td>
<td>Expenditure as a percentage of total selected expenditures</td>
</tr>
<tr>
<td>Food</td>
<td>20.5 %</td>
<td>12,915 *</td>
</tr>
<tr>
<td>Rent and small maintenance</td>
<td>18.0 %</td>
<td>11,327</td>
</tr>
<tr>
<td>Heating and lighting</td>
<td>4.8 %</td>
<td>3,010</td>
</tr>
<tr>
<td>Furnishings</td>
<td>3.5 %</td>
<td>2,206</td>
</tr>
<tr>
<td>Clothing</td>
<td>4.6 %</td>
<td>2,868</td>
</tr>
<tr>
<td>Transportation</td>
<td>13.1 %</td>
<td>8,237</td>
</tr>
<tr>
<td>Health care</td>
<td>15.9 %</td>
<td>10,004</td>
</tr>
<tr>
<td>Cleaning</td>
<td>0.8 %</td>
<td>517</td>
</tr>
<tr>
<td>Education and recreation</td>
<td>11.1 %</td>
<td>6,992</td>
</tr>
<tr>
<td>Alcoholic drinks, tobacco, tea, coffee etc.</td>
<td>7.7 %</td>
<td>4,910</td>
</tr>
<tr>
<td>Total expenditure on the above listed items</td>
<td>100 %</td>
<td>SFr. 62,986 per household per year</td>
</tr>
</tbody>
</table>

* 1 Swiss Franc (SFr.) is approximately 1 Canadian Dollar ($)  

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13 [http://www.statcan.ca:80/english/Pgdb/People/Families/famil16a.htm](http://www.statcan.ca:80/english/Pgdb/People/Families/famil16a.htm)
3.8.1 Transportation

Canadians on average spend more money on transportation than the Swiss do (see Table 3.6). This may in part be due to the fact that they rely more heavily on their car – a fairly expensive mode of transportation – to commute to and from work. Although the number of Canadians owning cars is only slightly more (i.e. 488 cars per 1000 inhabitants vs. 450), the Swiss are more likely to make use of alternative transportation (likely due to shorter travel distances, more extensive transit networks, and higher fuel costs (i.e. 1.02 US$/l vs. 0.41 US$/l 1995 prices)) when travelling to work. The figures in Table 3.7 illustrate that the average Swiss commute is less taxing on the environment.

<table>
<thead>
<tr>
<th>TABLE 3.7 Principal Method of Travel to Work in Switzerland and in Canada</th>
</tr>
</thead>
<tbody>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Public transit</td>
</tr>
<tr>
<td>Car</td>
</tr>
<tr>
<td>Walk</td>
</tr>
<tr>
<td>Other (bicycle, motorcycle, taxi, etc.)</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

3.8.2 The Political Context

Relative to Canadians, it is easier for the average Swiss citizen to offer his/her input to the political process. More so than in Canada, current Swiss environmental laws are a direct reflection of the mass public's beliefs.

The voices of Canadians can on average be heard every four years, when the members of Parliament are elected. The democracy in Canada is not direct, since politicians representing the public, vote on civil issues on its behalf. Interest groups often act as a "middleman" between
the government and the people. Their success depends on strong financial support, organizational cohesiveness, prestige, and overall aims that are in keeping with the prevailing values of the society in which they operate (Van Loon & Whittington 1987:426). Hence, for the average Canadian to voice his/her opinion on political issues requires some lobbying, either directly at the politicians, or as part of an interest group.

The role of the Swiss political system in bringing about that population's ecological awareness is significant. As members of an active democracy, Swiss citizens are entitled to initiate referendums and legislation, which form the core of the political process in Switzerland. As a result, private citizens often initiate the move to more stringent environmental laws. In turn, accepted environmental proposals are brought to the attention of the general public, while those environmental laws that are eventually passed reflect the support of the voting citizens (Europa Publications limited, 1998:3223).

To illustrate how the resolve of the citizens has shaped environmental laws in Switzerland, Table 3.8 provides a sample list of issues the Swiss voted on:

<table>
<thead>
<tr>
<th>DATE</th>
<th>INITIATIVE FOR:</th>
<th>% OF &quot;YES&quot; VOTES</th>
<th>% OF &quot;NO&quot; VOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 1978</td>
<td>Animal Protection Act</td>
<td>81.7</td>
<td>18.3</td>
</tr>
<tr>
<td>Sept. 1984</td>
<td>A safe, economical and environment-friendly energy supply. (Although this was not passed, many voters supported this initiative).</td>
<td>45.8</td>
<td>54.2</td>
</tr>
<tr>
<td>Nov. 1989</td>
<td>Increasing the speed on the Autobahn from 120 km/hr to 130 km/hr (which would increase fuel consumption).</td>
<td>38.0</td>
<td>62.0</td>
</tr>
<tr>
<td>May 1992</td>
<td>Water Protection Act</td>
<td>66.1</td>
<td>33.9</td>
</tr>
<tr>
<td>March 1993</td>
<td>Raising the fuel tax.</td>
<td>54.5</td>
<td>45.5</td>
</tr>
<tr>
<td>Feb. 1994</td>
<td>The introduction of a performance or user dependent tax for cars.</td>
<td>67.1</td>
<td>32.9</td>
</tr>
<tr>
<td>Feb. 1994</td>
<td>Protection of the Alp regions from transit traffic.</td>
<td>51.9</td>
<td>48.1</td>
</tr>
<tr>
<td>Feb. 1994</td>
<td>More rigorous emission standards for the Aviation Act</td>
<td>61.1</td>
<td>38.9</td>
</tr>
</tbody>
</table>
3.8.3 Size

The size of a nation, and its reserve of undeveloped land can influence the attitude people have on environmental problems. Switzerland is a very small country. With an area of 41,284 km$^2$, it measures a mere 220 km at its greatest extent from north to south, while the east-west axis is 348 km.\textsuperscript{14} By contrast Canada covers 9,970,610 km$^2$ and is about 241 times greater than Switzerland. BC alone (947,800 km$^2$) is 23 times greater.

Switzerland's population density is similar to that of its surrounding European neighbors, approximately 175 people per square kilometer.\textsuperscript{15} Since most of Canada has an inhospitable landscape and climate, its overall population density is considerably lower. In the 1996 census, the population density was a only 3.0 people per square kilometer, with a population density in BC of 4.1 per square kilometer. In relative terms, Canada's landscape has a much greater capacity to absorb human influenced environmental damage. In Switzerland where environmental problems are more concentrated the need to take action is generally perceived as being greater.

3.8.4 An Account of Energy Consumption

A comparison of the various fuels consumed per capita (see Table 3.8) shows that in all instances except for nuclear energy, the Swiss consume significantly less per capita than the Canadians.

<table>
<thead>
<tr>
<th>TABLE 3.9</th>
<th>Primary Energy Consumption by Fuel per Capita</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SWITZERLAND</td>
</tr>
<tr>
<td></td>
<td>Year</td>
</tr>
<tr>
<td>Oil</td>
<td>1993</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>1996</td>
</tr>
<tr>
<td>Coal</td>
<td>1996</td>
</tr>
<tr>
<td>Hydroelectricity</td>
<td>1996</td>
</tr>
<tr>
<td>Nuclear Energy</td>
<td>1996</td>
</tr>
<tr>
<td>Total Consumption of Primary Energy</td>
<td>3.28</td>
</tr>
</tbody>
</table>

\textsuperscript{14} The Environment in Switzerland 1997 – Facts, Figures, Perspectives. The Swiss Federal Statistical Office (SFSO) and the Swiss Agency for the Environment, Forests and Landscape (SAEFL), Bern, 1997

\textsuperscript{15} http://www.odci.gov/cia/publications/nsolo/factbook/sz.htm#People
Just as consumption levels are lower in Switzerland, so too are emission levels and waste production (see Table 3.9).

<table>
<thead>
<tr>
<th>STATISTIC</th>
<th>YEAR</th>
<th>SWITZERLAND</th>
<th>CANADA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions of sulphur oxides, SO$_2$, kg per person</td>
<td>1991</td>
<td>9</td>
<td>122</td>
</tr>
<tr>
<td>Emission of nitrogen oxides, NO$_2$, kg per person</td>
<td>1991</td>
<td>26</td>
<td>N/A</td>
</tr>
<tr>
<td>Emission of volatile organic compounds, Kg HC per person</td>
<td>1990</td>
<td>43.7</td>
<td>96.0</td>
</tr>
<tr>
<td>Emissions of carbon dioxide, CO$_2$, tonnes per person</td>
<td>1992</td>
<td>6.2</td>
<td>16.1</td>
</tr>
<tr>
<td>Municipal waste, kg per person</td>
<td>1990</td>
<td>441</td>
<td>601</td>
</tr>
<tr>
<td>Recovery rates, %:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper and cardboard</td>
<td>1990</td>
<td>49.4</td>
<td>20.0</td>
</tr>
<tr>
<td>Glass</td>
<td>1990</td>
<td>64.7</td>
<td>N/A</td>
</tr>
</tbody>
</table>

3.8.5 Industry

Apart from the different attitudes of the Swiss and Canadian citizens, the nature of industry affects the overall energy consumption in each country. Canada is endowed with large amounts of natural resources (minerals, forest, water, etc.), and a great number of jobs involve the harvesting of these resources. The Canadian industry consists mainly of the primary processing of resource-based materials: petroleum products, heating oil, paper products, wood products, various metals and alloys, synthetic rubber, passenger cars, and cement are some of the principal productions (Turner, 1998:313).

Switzerland on the other hand, has few natural assets, and the employment sector is mostly comprised of secondary processing and manufacturing type of work. It follows that food producing industries, the manufacture of textiles, clothing and footwear, chemicals and pharmaceutical products, the production of machinery (including electrical machinery and scientific and optical instruments), and watch and clock making are the most important (Turner, 1998:1335).
Canada's strong dependence on resource-based industry and Switzerland's focus on a manufacturing-based industry, is reflected in the commercial energy production statistics (see Table 3.10).

<table>
<thead>
<tr>
<th>TABLE 3.11 Production of Commercial Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>(United Nations, 1997:620,621,636 &amp; 637)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>SWITZERLAND</th>
<th>CANADA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production in Tons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>of Coal Equivalent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solids</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Liquids</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Gas</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Electricity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12,844</td>
<td>13,605</td>
</tr>
<tr>
<td>Total Primary Energy Production in Kilograms of Coal Equivalent per Capita</td>
<td>1,819</td>
<td>1,927</td>
</tr>
</tbody>
</table>

The resource-based industry leads to an energy consumption and CO₂ production that is greater per capita in Canada than in Switzerland.

3.8.6 A Last Note on the Findings

Overall, while standards of living are fairly similar in both countries, the behaviour of Canadians is far more taxing on the environment, since they consume and produce energy at a much greater rate. Even though there are significant cultural differences, in terms of attitudes and behaviour affecting the environment, the two sets of survey responses were fairly similar. It must be remembered that the respondents are a very small, select group of individuals, and are clearly not representative of all Swiss and Canadians working in environmentally responsive office buildings.

16 In the Statistical Yearbook the figures provided are for Switzerland and Liechtenstein combined. Given the population figures that the book provided, calculations were made to isolate the data for Switzerland.
4. ENVIRONMENTAL DESIGN GUIDELINES

To offer constructive direction for environmentally responsive building design, a number of environmental design guidelines have been established over the past five years. Most guidelines, however, fail to make explicit that the success of their recommendations ultimately hinges on the building users. Often designers envision that users will adapt their behaviour to suit the building and its intended operation, in practice however, this is unlikely. Rather, user behaviour and satisfaction have a significant bearing on the energy and resource efficiency of a building over its life.

This last chapter is divided into three parts. The first part introduces the recommendations outlined in *An Architect’s Guide for Sustainable Design of Office Buildings* (Cole & Auger, 1996). Any issues pertaining to the thermal quality, ventilation, and lighting are covered, since the purpose is to focus on aspects of a building that have a considerable component of user involvement.

The second part of this chapter focuses primarily on information derived from the questionnaires and research literature that relates to:

1. The nature of user behaviour pertaining to the regulation of building systems;
2. The perceived control occupants have over their environment, and how this affects satisfaction, productivity and energy efficiency;
3. The most effective balance, in terms of user satisfaction and energy efficiency, between manual control and automated systems.

Based on this analysis, the last part of this chapter examines the ways in which the outlined design recommendations can be reframed to make designers aware of user behaviour. In particular, recommendations in Tables 4.1 to 4.5 are refined, or new ones are added to make the *Architect’s Guide* more “user inclusive”.

PART I THE GUIDELINE RECOMMENDATIONS

4.1 THE OBJECTIVES OF THE GUIDELINES

The Real Property Branch of Public Works and Government Services Canada sponsored the creation of the *Architect’s Guide*. It has committed to following high standards of environmentally responsible design for the buildings it owns or leases, and thus has specific demands of its designers:

<table>
<thead>
<tr>
<th>TABLE 4.1 Design Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>The environmental agenda will require architects and other design professionals to:</td>
</tr>
<tr>
<td>1. Understand the emerging environmental agenda and develop the appropriate knowledge and skills to be able to respond accordingly on all design projects;</td>
</tr>
<tr>
<td>2. Challenge existing design norms and reassess each design project on its own merits;</td>
</tr>
<tr>
<td>3. Be open and receptive to emerging environmental ideas and be willing to re-evaluate best practices;</td>
</tr>
<tr>
<td>4. Establish a coordinated team approach to design in which every member of the design team is, at some level, aware of and can make timely contributions to all the significant design issues;</td>
</tr>
<tr>
<td>5. Look creatively at re-using existing buildings, materials and components in conjunction with a host of new materials that will become available as the building industry examines innovative ways of turning wastes into resources;</td>
</tr>
<tr>
<td>6. Develop new skills, knowledge, and attitudes to support renovation work and to learn to be more curators of the built environment rather than creators;</td>
</tr>
<tr>
<td>7. Examine the cost effectiveness of environmental strategies within a comprehensive analysis of total renovation costs and not simply evaluate them on the basis of the incremental cost-benefit of the strategy alone.</td>
</tr>
</tbody>
</table>
As well as prescribing the design process, the Real Property Branch has provided architects with a broad set of environmental design recommendations. The *Architect's Guide* primarily addresses the following issues:

...[The] improvement of indoor environmental quality, the effective use of site resources, the reduction in the use of energy, water and materials, the reduction of solid wastes, and the utilisation of environmentally responsible building materials (Cole & Auger, 1996:V).

The greater portion of the *Architect's Guide* is directed at environmental issues associated with the construction of a building, and not its operation and maintenance (this is typical of environmental design guidelines). Since this thesis focuses on the users of environmentally responsive buildings, review of the guidelines will mostly pertain to chapter 2 “Health and Well-Being” and certain elements in chapter 4 on “Energy Use”.

The scope of Chapter 2 revolves around the fundamentals of occupant health and comfort. In order to enhance indoor environmental quality, the guidelines offer direction for architects to:

- Provide comfortable and healthy work conditions which satisfy the maximum number of building occupants;
- Provide these conditions within an acceptable energy and cost framework;
- Ensure that such conditions can be operationally maintained.

In the “Energy Use” chapter various design strategies and specifications that will lead to reduced embodied energy use are presented. Although a building’s design has a marked effect on its energy efficiency, it is the building operator and occupants who ultimately determine the amount of energy used. Since the building user is implicit within the various guidelines, the pertinent ideas from this thesis will be incorporated into the discussion of the guidelines.

### 4.2 IMPROVING THERMAL QUALITY

The *Architect’s Guide*, defines thermal quality as, “the absence of discomfort caused by temperature, humidity and air movement conditions that are inappropriate to the task at hand” (Cole & Auger, 1996:17). It suggests that the degree to which temperature and humidity levels
are monitored for comfort, is proportional to the energy consumed. The *Guide* offers several recommendations for enhancing control of the thermal quality in a building:

TABLE 4.2 Improved Control of the Thermal Environment Can be Achieved by:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Providing heating and cooling devices in close proximity to occupants;</td>
</tr>
<tr>
<td>2.</td>
<td>Where general space heating and cooling is provided, considering the effect of partitioning and space planning to ensure even heating and cooling control throughout the interior of occupied spaces;</td>
</tr>
<tr>
<td>3.</td>
<td>Providing for some flexibility, or ability to control local thermal conditions based on specific occupant requirements, while still maintaining reasonable limits overall;</td>
</tr>
<tr>
<td>4.</td>
<td>Designing zones that are as small as is practical;</td>
</tr>
<tr>
<td>5.</td>
<td>Providing controls which correspond to interior partitioning;</td>
</tr>
<tr>
<td>6.</td>
<td>Providing controls which are readily accessible from the space to which they are connected and are easily comprehensible to occupants will encourage their use;</td>
</tr>
<tr>
<td>7.</td>
<td>Planning for the careful admission of direct sunlight into the building interior using effective solar control devices on windows;</td>
</tr>
<tr>
<td>8.</td>
<td>Using thermal mass inherent in the building to regulate temperature variations.</td>
</tr>
</tbody>
</table>

### 4.3 VENTILATION EFFECTIVENESS

The *Guide*’s discussion on ventilation effectiveness is quite brief. To recapitulate the section, ventilation systems should be designed to provide the minimum specified number of air changes per hour for the building type and occupancy, and deliver the air directly to the occupants, without compromising the thermal environment. As the *Guide* states, the amount of supply air reaching the breathing zone depends on the following:

- Path by which supply air moves through an occupied space and reaches an exhaust or return;
- Directness of delivery of ventilation air to the occupants, i.e. diffuser type and location;
- Placement of obstructions to air movement such as partitions and acoustics barriers.

Three recommendations for enhancing ventilation are offered:
TABLE 4.3 Ventilation Effectiveness Can be Improved by:

1. Analyzing the impact of air supply and return locations on airflow in typical and unique spaces in order to eliminate short-circuiting and dead air zones;
2. Using the most appropriate diffusers and velocities for a given space;
3. Where possible, locating return-air opening no more than 3m from any typical copy machine to provide dilution of emissions, or dedicated exhaust.

Natural window ventilation is mentioned in chapter 4, but not included specifically in any of the design recommendations (Cole & Auger, 1996:59):

"Operable windows provide the opportunity for natural ventilation when outside conditions permit. To minimize conflict with energy efficiency, sensors can be linked to the HVAC system so that the terminal serving the zone will adjust accordingly when the window is opened during the heating or cooling season."

4.4 LIGHTING CONTROL

There are two aspects of lighting quality to which this thesis can offer direction. First to be addressed is the lighting control. Although introduced in the “Health and Well-Being” chapter, lighting control is more thoroughly discussed in the “Energy Use” chapter. The Guide provides the following recommendations for minimizing the use of electric lighting during the times when there is sufficient daylighting:

TABLE 4.4 The Quality of the Lighting Control Can be Improved by:

1. Providing a mixed approach to lighting control which combines local, manual switching to meet the needs of the users and automatic ‘fail-safe’ features such as occupancy sensors etc., to reduce wasted lighting energy;
2. Providing manual switching to users in all rooms;
3. Providing separate switching in all daylit zones;
4. Using a controlled stepped lighting strategy, e.g., using three tube luminaires wired for two switches allows four lighting settings: off, one tube, two tubes or three tubes;
5. Using photocell controlled dimming ballasts to adjust output of fixtures in response to daylight;
6. Scheduling each area on its own, with override, (often by pressing a number on the phone which signals the computer to switch lights) can reduce demand on the lighting system;
7. Specifying time switches and other systems for turning off lights on a particular floor or the entire building.
4.5  NATURAL LIGHTING

The second lighting issue of relevance is the use of natural lighting. Not only will carefully admitted natural light significantly improve the workspace quality, but the energy savings as well. The *Guide* has several interior design recommendations for optimizing daylighting:

<table>
<thead>
<tr>
<th>TABLE 4.5</th>
<th>Improved Daylighting Can be Achieved by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Planning the interior organization to maximize for the potential benefits of daylighting from existing window configuration;</td>
</tr>
<tr>
<td>2.</td>
<td>Recommending that the internal planning of partitions be organized to enhance the benefits of daylight;</td>
</tr>
<tr>
<td>3.</td>
<td>Selecting internal reflectances which maximize the reflection of daylighting deeper into the building interior;</td>
</tr>
<tr>
<td>4.</td>
<td>Examining the potential benefits and adverse effects of admitting sunlighting into the work-place;</td>
</tr>
<tr>
<td>5.</td>
<td>Planning the interior to provide the greatest possible visual access to the exterior.</td>
</tr>
</tbody>
</table>

PART II  DISCUSSION OF USER BEHAVIOUR

4.6  COMPARING CELLULAR OFFICES TO AN OPEN-PLAN

Decisions architects make while designing the floor layout can considerably influence the perception the users will have of their office environment and its controls. There are two related situations in which an occupant will find him/herself: in an individual or shared space, and in a window or core location. With regards to the case-study office buildings, those working in individual offices occupy owned spaces, while the respondents working in an open-plan office occupy a shared space. It is frequently those in individual offices that have a directness to a window, while many individuals working in a large communal space are remote.

In a cellular office space there is a one-to-one relationship between the individual and the various control devices: the window, blinds, radiator valve and light switches. An occupant of a
personal office will regard the space as his/her own. Along with a sense of ownership comes a desire to personally make decisions about the status of thermal quality, ventilation and lighting.

An open-plan layout has many implications for users. A person in a shared space may regard their work area as theirs, but not in the same sense as the cellular office user. Sharing a space with others means sharing controls for the environmental systems. As Figure 4.1 clearly shows, a decreased sense of control is directly proportional to the number of occupants sharing a room. Reaching consensus on room temperature, window opening, blind position and the lights can be uncomfortable in a group setting. The actions of one person have the potential of affecting the condition of the entire area and all co-workers. For example, the opening of a single window may cause conflict — either because of differences people have in comfort needs, or because someone else’s work area may physically inhibit operation or require intrusion of that space.

The location of one’s work station will either enhance or lessen the sense of control a person has over the building systems. Those individuals working next to a window automatically have access to more controls, such as the blinds, radiator valves, and the window itself. Even when the actual control the window area provides is insignificant, it is still perceived as significant by the other occupants. Those individuals who work away from the windows usually report a higher degree of dissatisfaction and discomfort than those working along the perimeter do.

The greater the depth of the floor plan, and the greater the proportion of people remote from windows, the more energy-intensive the building becomes -- for reasons other than increased use of artificial lighting and conditioning. It is a paradox that deeper spaces, rather than becoming more energy efficient, become more dependent on engineering services, in an effort to provide user satisfaction: “To minimize the need for change, systems lapse into ‘default’ states which minimise conflict and inconvenience but are not optimal” (Ruyssevelt et al. 1998).
In other words in a large shared space systems often tend to operate inefficiently, be left on unnecessarily, or they need to be on when there are only a few occupants present.

![Graph showing perceived control versus room size](image)

**Figure 4.1 Perceived Control versus Room Size**

*(Bordass & Leaman 1994)*

### 4.7 REACTING VERSUS “PRO-ACTING”

With the given set constraints, designers aim to optimize all aspects of their design. Building users, however, hardly ever optimize – especially those in an open-plan situation. Instead of basing their actions on anticipated events (such as opening the C.K. Choi’s ventilation channels for night cooling), occupants tend to develop coping strategies once they face uncomfortable conditions: “They are likely to make the decision to use the switch or control only after the event has prompted them to do so (rather than in advance of it), and will often wait quite a long time until taking action (when they reach a ‘crisis of discomfort’)” (Leaman, 1999).

This tendency for occupants to react as opposed to “pro-act” has negative consequences for energy conservation. People tend to over-compensate in their attempt to find a “neutral” comfort level. They will also often use the easiest, quickest or most convenient strategy to
modify their environment, rather than the one (or several) which is most appropriate or energy conserving. This point is vindicated by the behaviour of the C.K. Choi occupants: when the thermal conditions are excessive in the winter most of them open a window, instead of (or after) turning down the heating system. People's desire for immediate and recognizable results may explain in part why, "occupants often prefer naturally ventilated buildings over air-conditioned ones, sometimes even when measured conditions in the latter are better" (Bordass & Leaman, 1993).

4.8 USER CONTROL OVER THE OFFICE ENVIRONMENT

Given that people only make changes to their environment when experiencing noticeable discomfort, perceiving a lack of useable controls in that situation can frustrate the user. The amount of control an occupant perceives is fundamental to the success of a building: "From a user's perspective, perception of personal control is the single most important factor underlying comfort" (Leaman, 1999). As Bordass and Leaman illustrate in Figure 4.2, the user's ability to avoid discomfort by controlling the heating, ventilation, and lighting can lead to increased productivity. It is important to note that the controls that have the greatest influence on productivity are those that govern heating.

![Image of Figure 4.2: Productivity versus Degree of Control](image)

**FIGURE 4.2** Productivity versus Degree of Control  
(Bordass & Leaman, 1993)
Control is not simply about light switches, or opening windows, or adjusting chairs – the things that provide individuals with personal comfort. It is also about how people can “adjust their environment in relationship to the requirements of their work tasks and the relative needs of people around them in working groups” (Leaman, 1992). The obvious reason why people want more control is to improve environmental conditions for themselves; “It is less obvious that users often use coping strategies where they try to make things less uncomfortable or less dysfunctional” (Leaman, 1999).

According to Bordass and Leaman, there are three factors that influence the amount of perceived control a user has over building interfaces (Bordass & Leaman, 1997:192):

1. Clearly, the actual control a person has affects their perceived control. In an open-plan office, this depends not only on the design and location of the control features, but also on the group dynamics the workers have. In the Tenum building for instance, where a number of different firms work in one open area, it is likely more difficult for the occupants to agree on a control setting, than where there is only one firm working in an open sector.

2. Perceived control depends on the fine-tuning capabilities the occupants have, of which there are four components:
   a. The opportunity to adjust the controls is an important aspect of fine-tuning their environment;
   b. When the atmosphere is uncomfortable, the possibility of moving to a more suitable environment also empowers a person;
   c. The chance for occupants to make ergonomic adjustments (such as posture, clothing, etc.);
   d. The ability to make “trade-off decisions” between two different outcomes (i.e. noise vs. ventilation) gives them a sense of being able to make fine-scaled adjustments.

3. Whether provided by the building design or facilitated by the management, the greater the speed of the response to users’ demands, the greater they perceive the effectiveness of the control. This idea is quite powerful. Even when the response is not entirely effective, if it is rapid and sympathetic, then user satisfaction is sustained.

The importance of control, perceived or real, is emphasized by the behaviour of those who perceive poor control over building features. Occupants attempt to compensate for discomfort in a number of ways (Leaman, 1992) – none of which are typically advocated by designers:

1. They adapt their office environment to their advantage, yet not necessarily to the advantage of the building design (such as the Häring firm that disapproved of the Tenum’s flexible lighting and installed the conventional, more energy consumptive lighting).
2. In some offices, the occupants may play “power games”. In particular those with status or seniority may appropriate the window seat (though this situation is not evident amongst the Tenum respondent group).

3. Occupants search for technical “fixes”. For instance, one C.K. Choi respondent brought an electric heater to overcome the perceived low winter room temperatures.

4. When poor control results in discomfort, people often find unusual solutions (likely temporary). To reduce solar heat gain on the southeast side, Tenum occupants taped thin cardboard over the clerestory windows -- this reduces overheating, but also daylighting.

4.9 INTEGRATING AUTOMATED SYSTEMS AND MANUAL CONTROL

Many designers believe that, given the unpredictable or unreliable behaviour of occupants, environmentally responsive buildings are most effective when comfort provisions stem from fully automated systems. This approach is not as effective in practice, as it is in theory. First, advances in technology provide increasing options that can challenge designers, clients, system managers, as well as the users. Second, a high dependence on technology (or the management that operates the technology) leaves occupants feeling powerless to adjust their environment, and thus frequently dissatisfied. This last point is elaborated on in the following quote:

*There is ... evidence from studies in office buildings, that thermal comfort is, in part, related to the extent of control users have over their environment and that reducing control options produces a progressively narrower comfort band requiring tighter and tighter engineering (and more energy) to maintain. If only engineering solutions are sought, there is a danger of setting up a vicious circle in which more engineering simply leads to more engineering (Bell, Lowe & Roberts, 1996:103).*

Other designers intentionally minimize the use of mechanical systems, choosing to rely heavily on passive strategies. They plan for a range of well-being by specifying the natural conditioning of a facility. This type of building demands a high degree of user involvement to meet its energy efficiency. It has controls which users must turn on, and remember to turn off. However, too much control may diminish comfort and energy efficiency, rather than strengthening them. Unintended results can occur if there are unforeseen conflicts between control devices, when the controls have been “included gratuitously”, or when all of them become difficult to manage.
or maintain (Bordass & Leaman 1994). Given that people's behaviour can make either approach fallible and increase energy use, it should be the user behaviour that dictates which aspects of the two approaches are incorporated into a building. It is essential to present people with enough interfaces for them to perceive sufficient control over their environment. However, it is also important to recognize that occupants often postpone taking action until they experience their "crisis of discomfort", yet for lack of interest, ignorance or forgetfulness, do not tend to return the system to a neutral state once the "crisis" is over – at least not until the next crisis is reached. Hence, environmental technology is most effective when it recognizes and accounts for the shortcomings of human behaviour. Whereas the occupants enjoy activating systems, automated sensors can be useful in decreasing or shutting systems off.

This concept has been implemented in the C.K. Choi's lighting strategy in three different ways:

1. Technology has been used to reduce the Choi's electric load by automatically adjusting the lighting output in response to the available daylight. The success of this strategy lies in its subtlety: as long as the automatic adjustments are not perceived, the occupants will not object to them. If the control technology is not refined enough to be imperceptible, then if user satisfaction is to be ensured a manual override is essential.

2. The Building Management System shuts some of the corridor lights (which cannot be regulated by the users) off for the night. As long as the shut-off time long succeeds the vacating of the building it does not interfere with the users. Problems only arise when occupants have unusual work schedules and are in the building when the shut-off occurs.

3. Electricity use is curbed using occupancy sensors to shut the light off when no one is in the room. Perhaps the term "absence sensors" would more appropriately describe their purpose. There is an important distinction between a sensor that turns the light on when detecting the presence of an occupant, and one that turns the light off after an occupant has left the area and no longer requires its services. With the first type of device, the occupant becomes consciously aware of the fact that they are being monitored. With the latter device, technology remains in the background, and is less likely to be perceived by the user as invasive.

If technology is to remain subtle, it must include a manual override. In the Choi offices the occupants are free to turn the lights on and off, yet if they happen to forget the latter, the automated system is there do it for them. Although use of the "absence sensors" in the C.K. Choi is effective, they are predominantly installed in "owned" spaces (there are also sensors in
the "shared" washrooms). In the open-plan areas, where there is a greater need for them since the sense of occupant responsibility is less, there are no sensors.

It is difficult to optimally integrate heating technology and user control for thermal conditioning of building interiors. In some office buildings the temperature is pre-determined by an automated system which cannot be accessed by the users. In other offices the temperature is completely regulated by the users. Although user satisfaction is typically much higher in these circumstances, energy is often needlessly wasted. This point is demonstrated in both the C.K. Choi and Tenum office building where the users adjust the heating output with a radiator valve, but many do not reduce it when they leave for long periods of time or for the day. This problem is particularly prominent in the shared spaces, where the sense of responsibility people have for that space is relatively low. "Absence sensors" are not an appropriate solution to this problem for a number of reasons:

1. The heating is not simply in an ON or OFF state like the lighting system (i.e. it influences the temperature range);
2. The response time of increasing or decreasing the heating is much greater;
3. Fluctuations in temperature (which would arise when a person is in and out of the office frequently) are more problematic.

For these reasons, technology can at best schedule a heating reduction during the evening when the building is vacated (as is the case in both case-study buildings). This, however, is not the most efficient solution, since a considerable amount of time often passes between the moment the last person leaves the building, and the moment the Building Management System is scheduled to decrease the heating. A manual override would not only provide control to those occupants whose work schedules may be unpredictable, but it would mean that the system could easily be reduced or shut down much earlier. Buildings typically have the heating system needlessly condition the entire building until late in the evening to increase the chances that the building is vacant by the time the heating is automatically shut off. However, it could be
shut off when the majority of occupants leave for the day, and allow any individuals still in the building after that time to regulate the heating for a much smaller zone.

PART III RECOMMENDATIONS FOR THE GUIDELINES

4.10 RE-EXAMINING THE DESIGN RESPONSIBILITIES

If designers using the Architect's Guide are to become more aware that occupant behaviour can significantly affect the building's energy efficiency, then this point must be made explicit at the outset. The design responsibilities outlined by the Real Property Branch focus on a design process that promotes the exploration of environmental issues, a good rapport with all consultants, use of environmentally responsive building materials, among other financial and skill related themes – it does not acknowledge the significance of the users-to-be. To make the list of design responsibilities in Table 4.1 more complete, the following points are offered:

- Identify the different categories of occupants (permanent users, part-time users, maintenance staff, etc.), their work environment, and their likely requirements and behaviour.
- Understand that people's perceived control over their environment is closely linked to their comfort and productivity, as well as the building's energy efficiency. Hence, specify strategies and systems that provide users with adequate control, are simple to manage and use, and provide feedback on their performance.
- Provide the owner, systems management, and especially the occupants with information on how to understand and properly use the skills required to operate the building and its services effectively.

4.11 RECOMMENDATIONS FOR THERMAL QUALITY

Since control over thermal conditions is typically more important than any other aspect of user control, it is encouraging that in the Architect's Guide there is considerable emphasis given to improving thermal control. The Guide (Table 4.2) suggests a number of commendable design strategies: close proximity to heating and cooling devices; flexible user control that does not
compromise the overall condition; and readily accessible and comprehensible controls. To add to these suggestions, the actual and perceived thermal control can be improved by:

- Designing a shallow-depth floor plan that brings the occupants in closer proximity to the control features, particularly when the heat distribution and controls are to be located along the perimeter.
- Providing heating and cooling systems that respond to user induced change rapidly.
- Providing manual override specifically for those occupants who work unusual hours, if a Building Management System is to be used to reduce the heating or cooling at nights.

4.12 RECOMMENDATIONS FOR VENTILATION

The Architect’s Guide provides advice for effective ventilation that strictly applies to a central, automatic system. Natural ventilation is not emphasized, despite its potential benefits. From a user’s perspective, control over ventilation is next in importance to control over heating. User satisfaction tends to be greater in buildings that provide natural ventilation, rather than mechanical conditioning. Naturally-ventilated offices have higher user tolerance (because they usually offer more user control) and more rapid response, even though the control systems only tend to alter conditions marginally. Air-conditioned buildings have lower user tolerance and slower response rates, and often run for longer periods of time either inside or outside the comfort zone, albeit the automated conditioning system has a larger effect on the overall conditions (Bordass & Leaman 1994). Since natural ventilation affects not only energy consumption, but also user comfort and satisfaction, it should be explicitly included in the Guide recommendations. If the title in Table 4.3 is reworded to include the idea of user control, then the following suggestions can be added.

Ventilation effectiveness and control can be improved by:

- Providing natural ventilation when the potential downsides, such as draughts and the admission of external noise and air pollution are not an issue, or can be overcome.
- Ensuring that there is no conflict, between the facilitation of natural ventilation and the use of other control features, such as the operation of internal and external shading devices.
4.13 RECOMMENDATIONS FOR LIGHTING

The recommendations for improving the quality of the lighting control (Table 4.4) are quite thorough in their reference to the user and integrating user controls with automated features. There are no significant new insights that the survey findings or research literature can add to the discussion. However, in conjunction with the first recommendation, which advocates the combination of manual switching with automatic ‘fail-safe’ features, the following point should be made explicit:

- Avoiding automatic switch-on that is easily noticeable by the user, and instead considering the less perceptible “absence-sensing” and photoelectric dimming to avoid waste.

Further, in order to accommodate those individuals who use the building during unusual hours, the last recommendation should be edited to read:

- Specifying time switches and other systems for turning off lights on a particular floor or the entire building, with manual overrides.

The techniques described in the Architect’s Guide to improve daylighting (Table 4.5) are also fairly complete, and do not require revisions. The survey findings and literature materials highlight the potential problem of increased energy use, rather than decreased use, resulting from the inappropriate admission of glare and sunlight; however, the guidelines take this potential conflict into consideration.

4.14 IDEAS FROM THE ANALYSIS OF THE 5 DIFFERENT PERSPECTIVES

The additions and alterations to the guidelines, and the manner in which they are phrased, are similar in style to the existing recommendations in that they are quite generic. They do not highlight any distinctions between the various needs or behaviours of different types of user groups. Although the findings from the five different perspectives of user groups are neither comprehensive, statistically significant, nor from the same cultures, they point to the need for designer awareness.
4.14.1 Designing for Part-Time Office Users
When designing an office building that is predominantly used by part-time workers, architects should be aware that this group of users is less likely to recognize the control devices available to them, and is therefore less likely to interact with them. As a consequence, the overall satisfaction with the building may potentially be lower for part-time users.

4.14.2 Designing for Office Owners
When a building is owner occupied, the owners tend to be fairly critical of the building's performance and the amount of control that they have over their environment. Yet even when such a building user has a financial stake in the building, it does not guarantee that his/her behaviour is more conducive to lower energy consumption. In other words, owners tend to notice the building features designers have supplied them with, but they may not necessarily make a conscious effort to use these features as they were ideally intended.

4.14.3 Acknowledging Short-Time Office Users
Although there is no indication that the behaviour of long-time building users is more appropriate, it is evident that the part-time users tend to have less of an understanding of the building features. This point is especially important for designers of buildings with a high foreseen turn-over rate. When a building is first opened, or when it is intended for short-term users, then raising the awareness users have of the design features becomes significant.

4.14.4 Looking at the Age of Office Users
Where age is concerned, the findings from the two respondent groups are inconclusive. It is thus not possible to tell from this study if a person's age is a significant indicator of energy saving behaviour.
4.14.5 Designing for Women in Offices

It seems that women are more inclined to increase the heating when they are cold, than men are. This does not appear to be due to a lack of awareness of available building features on their behalf. Although beyond the scope of this thesis, it is quite possible that women's threshold for a comfortable temperature setting is higher than men's.

4.14.6 Discussion on Including the Findings from the Various User Groups

"Design recommendations" for the various user groups are absent from the reframed guidelines in sections 4.11 through to 4.13, but have been included at the end of this chapter. They do not appear to be compatible with the style of the existing recommendations, since the Architect's Guide has been formulated to address generic office buildings with generic occupants. It seems that if environmentally responsive designers are to become more sensitive to the influences of user behaviour, they must also understand the behaviour and attitudes of various user groups more clearly. Hence, it would helpful for the Guide to include a separate section, which recognizes that within the groups of users there is considerable differentiation, and consequently provides various custom design approaches.

Having said that, the study’s findings on different user groups are not conclusive enough to offer an indication as to how a design can be customized to enhance the satisfaction and "environmental behaviour" of the different user groups. For instance, there is no further insight as to whether more education or a greater reliance on technology would help to increase the satisfaction of part-time and short-time users, and ultimately reduce energy consumption. Similarly, they do not offer any design strategies for encouraging women to use alternate ways of increasing their thermal comfort, without negatively impacting on their sense of control. However, the findings do point out that there are distinctions in the way different user groups interact with the building, perceive control over design interfaces, and compensate for adverse indoor conditions.
5. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

The philosophy behind a building, the way its design maximizes energy savings, the manner in which it is constructed, and its constituent materials are all important aspects covered in environmental building design guidelines. However, they are not the only determinants of an efficiently operated and maintained building. Careful planning and construction does not guarantee a building will be "sustainable", if the user behaviour has not been properly taken into account. As a tool that designers refer to for exemplary design practice, environmental design guidelines should set a high standard, and encompass all aspects of an ideal environmentally responsive building, including elements of user behaviour. Therefore, they should help designers aim for optimal building operation by outlining the means to designing an energy efficient systems, as well as detailing how different layouts, and strategies for control devices and implementing technology will influence the satisfaction and productivity of the building occupants. If environmentally responsive buildings are to be successful, it is critical that designers are made aware of the need to incorporate the notion of the user variable into their design process.

5.1 GENERAL CONCLUSIONS FROM THE RESEARCH

In the process of analyzing and reframing the recommendations in the Architect's Guide for Sustainable Design of Office Buildings, two relevant ideas manifested. First of all, an office building's floor
plan layout can strongly affect the satisfaction of the occupants, in terms of their control over the condition of the indoor environment. A design with a high proportion of users to control devices has clear benefits. In most environmentally responsive buildings, the majority of control interfaces are located by the windows. As such, individuals that sit next to a window tend to report a greater satisfaction with their ability to regulate thermal conditions, ventilation, and daylighting. This seems to be the case whether a user actually has greater control over the building features, or simply perceives it. By contrast, individuals who sit in a core location have a diminished sense of control over their environment, and are not as likely to interact with perimeter building features.

Due to the fact that the reluctance to freely take actions (such as heating, window opening, and regulating lights and blinds) is proportional to the number of people working in a shared office, the most ideal situation – at least form a user control perspective – is an individual office for occupants.

The second important point is that the extent to which technological systems are incorporated into a design, is best informed by the building user attitudes and behaviour. When the building is highly automated, users are left with a sense of powerlessness, which can undermine user satisfaction. Conversely, since people tend to react to a “crisis of discomfort”, rather than base their behaviour on anticipated events, a building that depends on responsible user behaviour, may end up with higher than anticipated energy consumption. Technology is applied most appropriately when it is able to minimize energy use without compromising the users’ sense of control. Technology that is imperceptible to occupants and that compliments user control is most effective. In other words, technology can be used to account for the users’ missed opportunities, by shutting unused systems off automatically; but to reduce conflict, users should be given manual overrides.
5.2 RECOMMENDATIONS FOR FURTHER RESEARCH

Due to the scope and scale of the research, there are clearly limitations on the generalizability of the findings. Many aspects, such as cultural differences and different user group perspectives could not be adequately explored. However, this research does mark some areas open to further research.

- The move away from an open-plan arrangement to singular offices with direct access to control interfaces has been strongly advocated. At the same time, there generally seems to be an increasing emphasis on the importance of designing buildings that are open and flexible, and capable of accommodating many different users and activities throughout the life of the building. Some clients and designers are moving away from the notion that buildings can simply be demolished when they become outdated or impractical, and be replaced by a new one. They are thinking about long-term use. Hence, the benefits that cellular offices and individual control bring to users must be weighed against the benefits of providing flexibility in a building that is expected to have a long life span.

- The concept of providing users with improved access to control devices, and the design layout which facilitates this has been studied in isolation. A logical next step would involve examining what is being advocated, in relation to the other factors such as construction costs, material use, and the overall energy performance of an environmentally responsive building design.

- Finally, as environmentally responsive buildings become more prevalent, the need to thoroughly understand how user behaviour affects energy consumption will become more important. What user satisfaction and access to control devices means to various user groups needs to be examined in much greater depth. As environmentally responsive buildings become more mainstream chances will increase that such buildings with very specific user groups, like women’s centres, daycares, senior centres, etc. will be built. If architects can clearly understand how the different user profiles affect user satisfaction and behaviour, they will be able to design a much more successful, energy efficient building.
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APPENDIX II

Below is the C.K. Choi questionnaire, of which the responses were analyzed and discussed in Chapter 3. With the exception of a few minor alterations, which were required to address the different building design, the Tenum questionnaire is essentially the same, but in German.

SECTION A

SOME GENERAL INFORMATION In order to help you get started, I'd like to ask you a few general background questions about the C.K. Choi building (the Institute of Asian research) in which you work/study.

1. What is your current roll within the C.K. Choi building? (Please mark with an 'X')
   - [ ] Student
   - [ ] Faculty
   - [ ] Visiting faculty
   - [ ] Other, please specify:

2. How long have you worked/studied in this building?

3. On average, how many hours a week do you use the building?
   - [ ] 1 – 10 hours
   - [ ] 11 – 20 hours
   - [ ] 21 – 30 hours
   - [ ] 31 – 40 hours
   - [ ] more than 40

4. On average, what time of day do you start to work/study in the building?

5. On average, what time do you finish your work/study in the building?

6. During what time of year do you work/study in the C.K. Choi building? (Please check off all times that apply to you.)
   - [ ] September - December
   - [ ] January - April
   - [ ] May - August

7. Please locate your work/study area with an 'X' on the following diagram.

   ![GENERAL FLOOR PLAN (GROUND FLOOR, 2ND FLOOR & 3RD FLOOR)](image)

8. Have you worked/studied in an office / university building prior to the C.K. Choi building?
   - [ ] yes
   - [ ] no

   If not, please proceed to Section B # 23. If you answered “yes” please go to Section B # 1.
SECTION B

YOUR ACCEPTANCE OF YOUR BUILDING In this section I'd like to understand the extent to which you accept the C.K. Choi building as one that is typical for your area.

Comparing the previous conventional office/university buildings you have worked/studied in, to the C.K. Choi building, which do you like better?  
(Please circle the number that most closely represents your view)

<table>
<thead>
<tr>
<th></th>
<th>C.K. Choi Building</th>
<th>Previous Office/University Building(s)</th>
<th>Same for both</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The outside appearance</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2.</td>
<td>The inside appearance</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3.</td>
<td>Acoustics and soundproofing</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4.</td>
<td>Amount of natural daylight available</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>5.</td>
<td>Quality of inside air</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>6.</td>
<td>Inside temperature</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>7.</td>
<td>The convenience of regulating electric lighting</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>8.</td>
<td>The convenience of regulating heating</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>9.</td>
<td>The convenience of regulating ventilation</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Similarly, comparing the previous conventional office/university buildings you have worked/studied in, to the C.K. Choi, which building environment more strongly encourages your...  
(Please circle the number that most closely represents your view)

<table>
<thead>
<tr>
<th></th>
<th>C.K. Choi Building</th>
<th>Previous Office/University Building(s)</th>
<th>Same for both</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.</td>
<td>Ability to work/study productively</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>11.</td>
<td>Ability to interact with other co-workers/students</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>12.</td>
<td>Overall enjoyment of the inside environment</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

13. When you think about it, in which building do you feel healthier?
(Please check off which of the following applies to you)

- [ ] C.K. Choi Building
- [ ] Previous Office/University Building(s)
- [ ] Same for both
What kinds of adjustments have you had to make upon moving from the previous conventional office/university building you worked/studied in, to the C.K. Choi building?

(Please circle the number that most closely represents your view)

<table>
<thead>
<tr>
<th></th>
<th>Difficult adjustment</th>
<th>Easy adjustment</th>
<th>No adjustment was needed</th>
<th>Does not apply to my situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.</td>
<td>Personally turning on/off electric lights</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>15.</td>
<td>Personally controlling the amount of natural daylight that reaches your work area</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>16.</td>
<td>Changing your expectations on feeling comfortable in the building’s temperature level</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>17.</td>
<td>Seeing few finishing materials (i.e. no carpet in some areas, exposed structures, no wall-paper, no trims, etc.)</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>18.</td>
<td>Having a presence of echoing sounds</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>19.</td>
<td>Getting used to the idea of composting toilets</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>20.</td>
<td>More frequently using the stairs instead of the elevator</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>21.</td>
<td>Working in an open, communal space</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>22.</td>
<td>Not having an air conditioner</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

In order to reveal your opinion towards the C.K. Choi building answer the following:

(Please circle the number that most closely represents your view)

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Don't know/uncertain</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.</td>
<td>Do you feel you have enough control over the ventilation?</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>24.</td>
<td>Is the inside temperature tolerable during the summer?</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>25.</td>
<td>Do you feel as though you receive enough fresh air during the wintertime?</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>26.</td>
<td>Are there any uncomfortable drafts in the building?</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>27.</td>
<td>In general, is the inside temperature appropriate during the winter?</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>28.</td>
<td>Do you feel you have enough freedom in regulating the inside temperature?</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>29.</td>
<td>Is the lighting arrangement flexible enough for the tasks you perform?</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>30.</td>
<td>During the day, is there usually enough daylight coming into your work area, to negate the use of electric lights?</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>31.</td>
<td>Would you consider having only cold water running from the washroom taps acceptable?</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>32.</td>
<td>Do you find the composting toilets to be acceptable?</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>33.</td>
<td>Do you use the venetian blinds to regulate the amount of sunlight entering your work area? (If not, go to Section C # 1)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>34.</td>
<td>When it is sunny, are the venetian blinds sufficient in providing a comfortable working atmosphere?</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>35.</td>
<td>Does glare from the outside often cause you to lower the blinds? If yes, does this force you to have the lights on during the day?</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
SECTION C

YOUR BEHAVIOUR IN THE BUILDING In this next section I want to learn how your behaviour affects the C.K. Choi building, and vice versa, how this building affects your behaviour.

1. During the winter, if you are too cold inside the building, how do you compensate for the low inside temperature?

2. During the winter, if you are too hot inside the building, how do you compensate for the high inside temperature?

To help me find out what your manner in the C.K. Choi building is like, I would like you to answer the following questions: (Please circle the number that most closely represents your view)

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Don’t know/uncertain</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Do you feel you could help save electricity if you had even more control over the electric lighting?</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4. Do you frequently use the venetian blinds to help block unwanted glare and/or prevent overheating due to direct sunlight?</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

7. On a daily basis, about how often do you use the elevator?

8. On a daily basis, about how often do you use the staircase?

SECTION D

YOUR UNDERSTANDING OF YOUR BUILDING This section will be used to investigate your understanding of the C.K. Choi building in which you work/study

1. How do you personally regulate the amount of fresh air you receive in the office? (Please check off which of the following applies to you)

☐ I open a window
☐ I don’t regulate the amount of fresh air (the natural ventilation in the building is sufficient)
☐ Other, please specify

2. What controls do you have available to manipulate the inside temperature?

3. Do you feel you have enough freedom in regulating the inside temperature? (Please check off which of the following applies to you)

☐ Yes ☐ no ☐ don’t care
SECTION E

YOU AND THE ENVIRONMENT  So far I have been concerned with the immediate environment of your building. Now I would like to ask you some questions about the broader environment you find yourself in.

What are your thoughts on the following environmental viewpoints?
(Please circle the number that most closely represents your view)

<table>
<thead>
<tr>
<th></th>
<th>Agree</th>
<th>Disagree</th>
<th>Uncertain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Science will be able to solve most environmental problems.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2. Plants and animals exist primarily to be used by people.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3. There are limits to growth beyond which our industrialized society cannot expand.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4. People have the right to modify the natural environment to suit their needs.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5. To protect the environment large corporations must reduce their demands on natural resources.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6. For the sake of the environment we are going to have to drastically reduce our level of consumption.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7. To maintain a healthy economy we will have to control industrial growth.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

How do you regard the following political outlooks?
(Please circle the number that most closely represents your view)

<table>
<thead>
<tr>
<th></th>
<th>Agree</th>
<th>Disagree</th>
<th>Uncertain</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. In the long run, I'll put my trust in the 'down-to-earth' thinking of ordinary people rather than in &quot;the theories of experts and intellectuals&quot;</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9. Most of the time you cannot trust the government to do what is right.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>10. One of the main problems in this country is that the people who control big corporate money still have things too much their own way.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

How do you consider the following social issues?
(Please circle the number that most closely represents your view)

<table>
<thead>
<tr>
<th></th>
<th>Important</th>
<th>Not very important</th>
<th>Undecided</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. How important is it for the government to try to even out differences in wealth?</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>12. How important is it for the government to force industry to bear the costs of stopping air and water pollution?</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>13. How important is it for the government to provide public housing for low-income earners?</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>14. How important is it for the government to increase welfare payments and programs?</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>15. How important is it for the government to increase taxes on business?</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
16. Have you participated in a local environmental group in the past? □ yes □ no
17. Do you currently participate in a local environmental group? □ yes □ no

Finally, in order to better understand the perspective from which you gave your responses, please fill in the following personal information. (Please mark appropriate response with an 'X')

18. What is your gender?  male □ female □

19. Which age range do you belong to?
   □ 18 – 29 □ 30 – 39 □ 40 – 49
   □ 50 – 59 □ 60 or older □

20. What is your highest level of education?
   □ Less than secondary □ Secondary grad
   □ Trade/technical □ Community college
   □ some university □ Undergraduate degree
   □ Graduate or professional degree.