UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

A Critical Recommendation to The University of British Colombia's Green Building Action Plan (GBAP), for Implementing Standardised Human Factor Policy and Metrics in the Emergent Component of Health and Well-being for Institutional Buildings

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Abstract

Through the appropriation of current guidelines, policies and case studies to the unique University of British Colombia context, this paper recommends metrics and policy to the Green Building Action Plan's emerging component 'Health & Wellbeing' and it's sub-components (thermal comfort, sound, materials, community and mind) to aid further development. These recommendations will encourage the social pedagogy and measurability of health & wellbeing as a major contributor to the overall productivity of communities, and in doing so, raise awareness of subsequent outcomes for institutional buildings in the green building landscape.

Contents

1.0 Health & Wellbeing

1.1 Built Environment

With an exponential growth in adoption, over 3.6 billion square feet of certified green buildings reported by Leadership in Energy and Environmental Design (LEED)[1], the importance of guiding the green industry with frameworks that translate into positive outcomes for the human factor is more important than ever. Green building; 'the planning, design, construction, and operations of buildings with several central, foremost considerations: energy use, water use, indoor environmental quality, material section and the building's effects on its site'[2]. Typically, green building design has responded to the environment through reductions in energy and water usage whilst minimising impacts to the immediate site both visually and physically.

This long-standing view of green building and sustainability stems from a regressive trend of carbon emissions from residential and commercial buildings[3], whilst being objectively measurable, hence has mostly overshadowed less recognised impacts on human health such as the indoor environment quality (light, sound, thermal comfort) and exposure to harmful toxins (materials)[4]. As the average person (North American adult) spends upward of 90% of the day indoors[5], a critical concern for the health and wellbeing of the average population[6] is raised with strong opportunity of reactive policy implementation.

2.0 Current Green Building Policy, Guidelines & Standards

The frontline of policy, code, guidelines, standards and accreditations as part of the implementation of green building practices is seemingly bottomless, however only few initiatives successfully support the appropriation of the built environment to include measures for health & wellbeing. The health of building occupants is relevant to both private spaces and the public realm and too should be considered. When assessing emergent components of the green building model it is important to deconstruct each initiative to discuss and compare focus areas and the subsequent successes.

WELL Building Standard

Launched in 2014 by the International WELL Building Institute following 6 years of research and development, the WELL Building Standard (WELL) evaluates and measures buildings according to features that support and advance occupant health and wellness[7]. Unlike other large scale green building accreditations, WELL focuses solely on the people in the building; health & wellbeing. Although comprehensive and targeted, v1 of the standard was optimised for commercial and institutional office buildings. Recently WELL released v2 of the standard whereby an auxiliary scoring matrix was released for multifamily residential projects; WELL and Multifamily Residential Core[8].

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[1] U.S. Green Building Council, Green Building Facts (2015), http:// www.usgbc.org/articles/green-building-facts
[2] Kriss J, What is green building?, US Green Building Council (2014)
[3] Department of Energy, Energy Information Administration, US energy-related carbon dioxide emissions (2014)
[4] Joseph G Allen, Green Buildings and Health, Global Environmental Health And Sustainability (2015)
[5] American Institute of Architects, Practicing architecture: design and health (2016)
[6] Committee on the Effect of Climate Change on Indoor Air Quality and Public Health, Climate Change, the Indoor Environment, and Health (2011)
[7] International WELL Building Institute, The WELL Building Standard: Version 1.0. (2015)
[8] International WELL Building Institute, The WELL Building Standard: Version 2.0. (2018)

WELL Building Standard v2[9]

Applicability Scoring Outline*

Thermal Comfort

- Thermal Performance
- Enhanced Thermal Performance
- Thermal Zoning
- Individual Thermal Control
- Radiant Thermal Comfort
- Thermal Comfort Monitoring
- Humidity Control

Community

- Health and Wellness Awareness
- Integrative Design
- Occupant Survey
- Enhanced Occupant Survey
- Health Services and Benefits
- Health Promotion
- Community Immunity
- New Parent Support
- New Mother Support
- Family Support
- Civic Engagement
- Organizational Transparency
- Accessibility and Universal Design
- Bathroom Accommodations
- Emergency Preparedness
- Community Access and Engagement

Sound

- Sound Mapping
- Maximum Noise Levels
- Sound Barriers
- Sound Absorption
- Sound Masking

Materials

- Fundamental Material Precautions
- Hazardous Material Abatement
- Outdoor Structures
- Waste Management
- In-Place Management
- Site Remediation
- Pesticide Use
- Hazardous Material Reduction
- Cleaning Products and Protocol
- Volatile Compound Reduction
- Long-Term Emission Control
- Short-Term Emission Control
- Enhanced Material Precaution
- Material Transparency

Mind

- Mental Health Promotion
- Access to Nature
- Mental Health Support
- Mental Health Education 2
- Stress Support
- Restorative Opportunities
- Restorative Spaces
- Restorative Programming
- Enhanced Access to Nature
- Focus Support
- Sleep Support
- Business Travel
- Tobacco Prevention and Cessation
- Substance Use Education and Services
- Opioid Emergency Response Plan

*Focus areas listed are limited to Thermal Comfort, Materials, Community, Mind, Sound (see full matrix - Appendix 3).

Fitwel

A certification system for optimising buildings to support health developed by the Centers for Disease Control and Prevention and General Services Administration and administered by the Center for Active Design. Alike the WELL Building Standard, Fitwel has a specific focus on occupant health & wellbeing in both occupational and residential buildings and does so through seven Health Impact Categories: Impacting Community Health, Reducing Morbidity & Absenteeism, Supporting Social Equity for Vulnerable Populations, Instilling Feelings of Wellbeing, Providing Healthy Food Options, Promoting Occupant Safety, and Increasing Physical Activity[10].

[9] International WELL Building Institute, WELL Building Standard v2 (2019)
[10] Fitwel: https://fitwel.org/standard

Fitwel Worksheet[11]

Workplace Scorecard*

Location
- Walkability
- Proximity to Transit

Stairs
- Accessible Stair
- Stair Location
- Stair Visibility
- Stair Design
- Stair Safety

Indoor Environments
- Tobacco-Free Building
- Asbestos-Free Building
- Indoor Air Quality (IAQ)
- Policy Indoor Air Quality (IAQ)
- Policy: Pollutants Indoor Air Quality (IAQ)
- Policy: Moisture Lead-Safe Property
- Integrated Pest Management
- Exterior Acoustic Comfort
- Interior Acoustic Comfort

Shared Spaces
- Operable Windows in Common Spaces
- Views from Common Spaces
- Exercise Room
- Kitchen Facilities

Water Supply
- Water Supplies and Water Bottle Refilling Stations

Vending Machines, Micro Markets, And Corner
- Healthy Vending Machines and Micro Markets
- Healthy Bodegas and Corner Stores

Emergency Procedures
- Emergency Equipment Database
- Automated External Defibrillator (AED)

Building Access
- Pedestrian Routes
- Short-Term Bicycle Parking
- Long-Term Bicycle Parking
- Bike Share Access
- Safe Street Infrastructure
- Transit Stops
- Sidewalk Amenities

Outdoor Spaces
- Walking Trails
- Bike Paths
- Outdoor Fitness Equipment
- Playgrounds
- Restorative Garden
- Proximity to Open Space
- Outdoor Space Amenities
- Farmers Market
- Fruit and Vegetable Garden
- Tobacco-Free Outdoor Spaces

Entrances and Ground Floor
- Tobacco-Free Property Signage
- Pedestrian Entrance
- Exterior and Pedestrian/Bike Route Lighting
- Local Amenities Advertising Entryway Systems

Dwellings
- Views from Dwelling
- Units Blackout Shades in Bedrooms
- Operable Windows in Dwelling Units
- Mould-Resistant Materials

Grocery Stores and Prepared Food Retail
- Healthy Grocery Stores
- Healthy Restaurants
- Healthy Prepared Food

*Checklist not complete (see full scorecard - Appendix 4).

[11] Fitwel, Worksheet for Workplace and Multifamily Residential (2018)

Living Building Challenge

Created by the International Living Future Institute in 2006[12], the Living Building Challenge (LBC) is a certification program focusing on health implications of the built environment. In it's third iteration (3.0), the LBC is now applicable to institutional buildings of all types and offers three levels of certification: Living Certification, Petal Certification and Net Zero Energy Certification. So far, 192 projects have been approved covering an area over 5 million square feet. The LBC uses the New Urbanism Transect model[13] to further categorise rural and urban classifications. All measures are somewhat objective in nature however relate to a more wholesome measurement of health rather than specifics of systems directly influencing the human health.

Living Building Challenge 3.0[14] Scorecard*	
Place ▯ Limits to Growth ▯ Urban Agriculture ▯ Habitat Exchange ▯ Human-Powered Living Water ▯ Net Positive Water Energy ▯ Net Positive Energy Health & Happiness ▯ Civilized Environment ▯ Healthy Interior Environment ▯ Biophilic Environment	Materials ▯ Red List ▯ Embodied Carbon Footprint ▯ Responsible Industry ▯ Living Economy Sourcing ▯ Net Positive Waste Equity ▯ Human Scale + Humane Places ▯ Universal Access to Nature + Place ▯ Equitable Investment ▯ JUST Organizations Beauty ▯ Beauty + Spirit ▯ Inspiration + Education

*See summary matrix - Appendix 5.

[12] International Living Future Institute, Living Building Challenge (2015)
[13] The Center for Applied Transect Studies: https://transect.org/
[14] International Living Future Institute, Living Building Challenge Standard 3.0 (2018)

3.0 Green Building Action Plan (UBC)

3.1 Background

As a global leader in built environment sustainability, the University of British Colombia (UBC) has transformed campuses into research, development and demonstration sites for sustainable behaviour, infrastructure and community. The UBC Strategic Plan 2018-2028 encapsulates the universities attitude toward building a campus and community responding to changing expectations, from the acute classroom environment, to the global landscape. In conjunction with broader notes from the Strategic Plan, UBC has implemented the Vancouver Campus Plan, Climate Action Plan and the Zero Waste Action Plan whilst generating annual Sustainability Reports. Amongst numerous other sustainability initiatives and guided by the Okanagan Charter, a firm stance has been taken toward the health and wellbeing through the UBC Wellbeing initiative, and more specifically to the built environment: promoting of physical activity; enabling social connections; improving productivity, learning and overall health; reducing financial stress of housing and transportation costs; fostering equity by creating a barrier-free campus[15].

In late 2018, UBC published a set of university-wide guidelines, the Green Building Action Plan (GBAP), in an attempt to create a built environment producing net positive contributions to human and natural systems by 2035. This publication serves as an auxiliary to UBC's well established Vancouver campus 20-Year Sustainability Strategy (20-YSS) (2014) in an attempt to develop more definite goals and language for the built environment.

> *The scope of the Green Building Action Plan covers institutional buildings on academic lands and residential and mixed-use buildings in neighbourhoods at the Vancouver campus. Currently, on this campus, UBC owns and operates over 342 institutional buildings, and its residential neighbourhoods house over 12,000 people in 73 multi-unit residential and mixed-use buildings.*[16]

The GBAP, informed by the Campus Plan and Climate Action Plan, supports the Strategic Plan 2018-2028 and all future iterations though the following vision, a 'physical campus will exhibit Campus as a Living Lab demonstration projects firmly tied to teaching, learning, and research, with an increased potential to lead to broader market transformation', 'a net positive campus for human and natural systems', 'pay dividends in the long-term with lower energy bills, avoided control and damage costs of the environmental impacts of inaction, and reduced health costs', and a 'process that incorporates learning and experience between projects, will be established to advance performance targets and try new ideas, reinforcing an adaptive long term approach to operational planning'[17]. The guidelines are intended to utilise the Residential Environmental Assessment Program (REAP) green building rating system for residential buildings and the UBC Technical Guidelines for institutional projects as a means of achieving standardisation and consistency. As set out by the UBC 20-Year Sustainability Strategy, all new builds and major

[15] UBC Wellbeing: https://wellbeing.ubc.ca/built-natural-environments
[16] Green Building Action Plan, University of British Colombia (2018)
[17] Ibid, Green Building Action Plan

renovations should meet minimum REAP Gold certification[18] which is supported by GBAP. It is important to distinguish and acknowledge the need for a framework that encompasses both new builds and retro-fitting as 'there are currently few policies, strategies or programs to guide the retrofitting of buildings within the UBC neighbourhoods'[19].

3.2 Health & Wellbeing Component

The release of this cornerstone sustainability publication is premature to its complete development in an attempt to generate momentum, awareness and to allow an opportunity for emerging components to refine through new data. Although intentional, the early release of this document presents emerging components, such as Health & Wellbeing, as grossly under-developed, unspecific and without metrics. Whilst it is encouraging that such significant human factors are considered along-side more traditional components of green building practice, the infancy of this emergent component is none-the-less concerning amongst a global policy landscape abundant with effective precedent.

Although underdeveloped, the GBAP does provide some great indication of intended trajectory through the inclusion of a Five-Year Implementation Plan encompassing short-term priority actions:

GBAP Health & Wellbeing: Five-Year Implementation Plan[20] Short-Term Priority Actions
Review research and best practices for physical, mental and social health and wellbeing in buildings
Develop health and wellbeing guiding principles for building design that promote physical, mental and social wellbeing: *Incorporating social or contemplative space* *Designing spaces that allow inclusion* *Incorporating universal design principles* *Promoting ease of use* *Incorporating ergonomic principles* *Developing daylighting requirements* *Considering acoustic requirements*
Identify metrics for health and wellbeing and develop targets and performance measures: *Temperature* *Indoor air quality* *Daylight levels*

[18] UBC Sustainability, 20-Year Sustainability Strategy, University British Colombia (2014)
[19] Ibid, Green Building Action Plan
[20] Ibid, Green Building Action Plan

Acoustic levels

Views to exterior

Number of indoor plants

Healthy working postures

Develop a strategy for all projects to include considerations of ergonomics, universal access requirements, and how users of different sizes and abilities will interact with the environment

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Test the WELL Building Standard against existing buildings (e.g., Earth Sciences Building) in a pilot study and identify WELL Building Standard credits and best practices that are aligned with UBC priorities.

Coordinate with UBC's Wellbeing Strategy in collaboration with UBC Wellbeing to guide how building and landscape design can nurture physical, mental and social dimensions of health and wellbeing.

Incorporate health and wellbeing strategies into policies and design briefs for building and landscape projects.

Establish relationships with off-campus partners to advance the connection between research and practice for health and wellbeing in buildings.

In light of the above plan, and in alignment with following best practice amongst existing policy and guidelines, the following sub-components of Health & Wellbeing are to analysed with regard to policy and metrics at UBC.

3.2.1 Thermal Comfort

Passive and Active: An applicable discussion on two thermal comfort models

The component firstly reviews relevant guidelines and standards regarding thermal comfort models, including the Well Standard and ASHRAE 55. Then, it critically analyses the climatic context of UBC and discusses the possible application for the most prevailing thermal comfort model, PMV/PPD model and Adaptive comfort model in UBC. The primary purpose is, based on the Green Building Action Plan (GBAP) health and wellbeing component, to identify recommendations for policy improvements that support thermal comfort under health and wellbeing category.

PMV/PPD Model VS Adaptive Comfort Model

Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation. The human body can be viewed as a heat engine where food is the input energy. The human body will generate excess heat into the environment, so the body can continue to operate. The heat transfer is proportional to temperature difference.

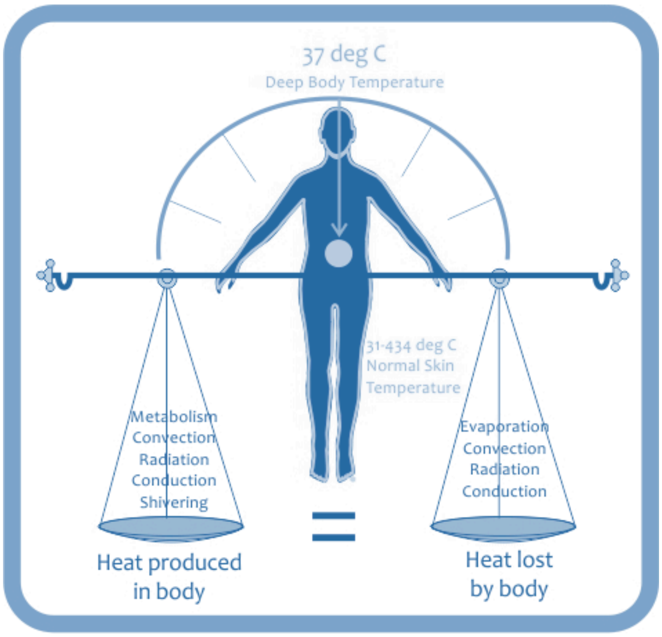


Figure.1 The first law of thermal dynamics, courtesy of NEZB

For WELL standard, there are two pathways to follow, either adopting the PMV model for mechanically ventilated spaces or using adaptive comfort mode for naturally ventilated spaces.

Choose between the following:

1

Mechanically ventilated spaces:

The following requirements are met:

a. During all standard occupied hours of the year, all regularly occupied spaces achieve thermal conditions representing Predicted Mean Vote (PMV) levels within +/- 0.5; PPD ≤ 10% (as per ASHRAE 55-2013, ISO 7730:2005 or EN 15251:2007).[1,33,34]

2

Naturally ventilated spaces:

During all standard occupied hours of the year, all regularly occupied spaces achieve one of the following thermal conditions:

a. 90% acceptability limit (as per ASHRAE 55-2013).[1]

b. Class I acceptability limit (as per EN 15251:2007).[34]

Figure.2 Two pathways for thermal comfort evaluation, courtesy of WELL

The Predicted Mean Vote (PMV) model stands among the most recognized thermal comfort models. It was developed using principles of heat balance and experimental data collected in a controlled climate chamber under steady state conditions. The model was developed by Povl Ole Fanger of Denmark in the 1970s. It is based on a physiological heat balance in the human body, and attempts to predict the average vote of a large group of people on the a seven-point thermal sensation scale where: +3 = hot, +2 = warm, +1 = slightly warm, 0 = neutral, -1 = slightly cool, -2 = cool, -3 = cold. This heat balance depends on many factors. These physiological heat flows are modelled using a combination of the following variables: Air temperature, Humidity, Air velocity, Radiant temperature, Clothing, Activity level / Metabolism of the person.

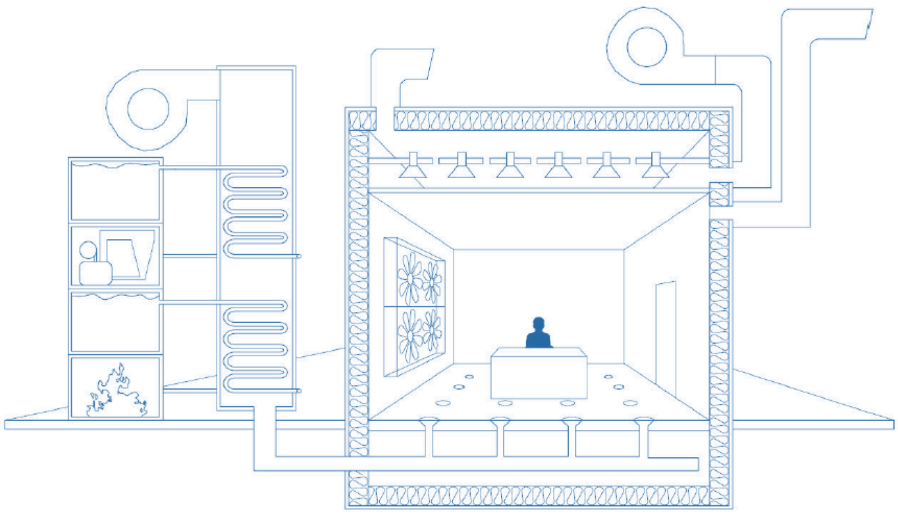
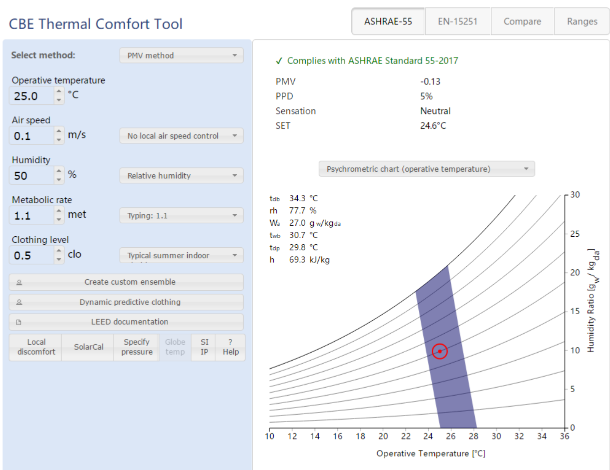


Figure.3 The diagram of PMV model analysis, courtesy of Chris Mackey

The Predicted Mean Vote (PMV) model is the only model recognized as valid for air-conditioned buildings. It is imperfect, but still the default for the HVAC industry. Criticism of the PMV model led to the development of the Adaptive Comfort model. These criticisms included a lack of correlation between reported occupant preferences and the conditions described as comfortable by the PMV model. In 1997, De Dear and his team of researchers in Sydney started asking which variables are good indications of comfort? It turned out that PMV models were very poor indications of whether occupants would feel comfortable in naturally-ventilated buildings



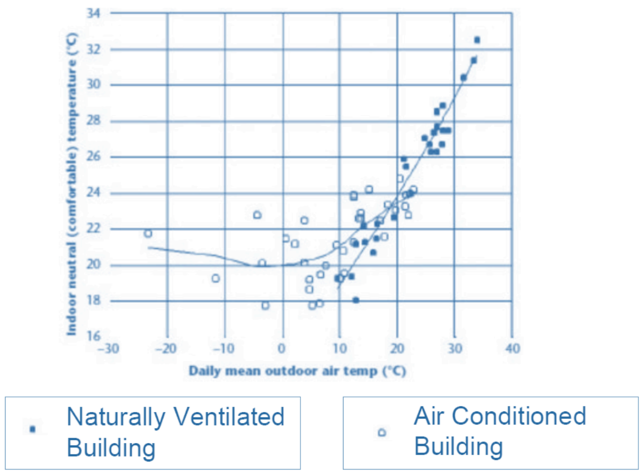


Figure.4 The diagram of PMV model. courtesy of CBE
Figure.5 de Dear, R. et al . (1997) Developing an adaptive model of thermal comfort and preference

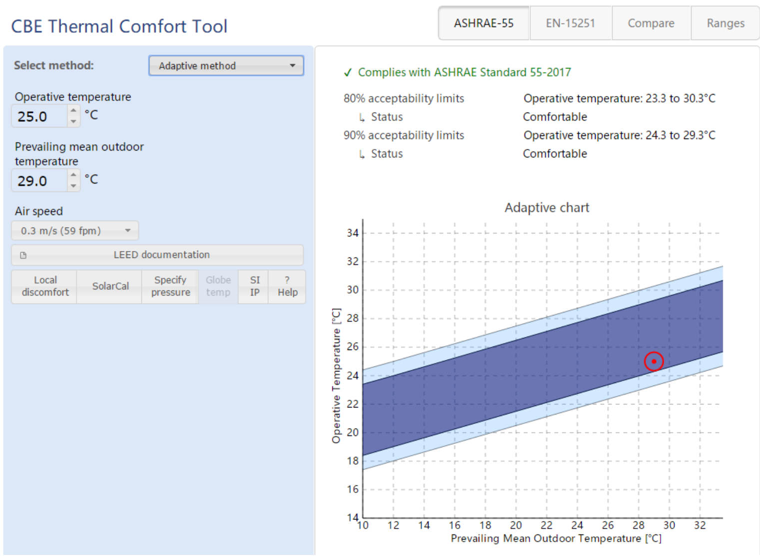


Figure.6 The diagram of Adaptive comfort model. courtesy of CBE

Adaptive Comfort models attempt to address a wider range of factors that affect human comfort. The adaptive model, on the other hand, was developed based on hundreds of field studies with the idea that occupants dynamically interact with their environment. Occupants control their thermal environment using clothing, operable windows, fans, personal heaters, and sun shades.

ASHRAE introduces a system of two parallel comfort models for the United States, whereby PMV is to be used for buildings which are mechanically conditioned, and Adaptive Comfort is to be used for buildings which are naturally ventilated. ASHRAE 55 contains both.

However here comes the enquiry, what if there is a place transitioning between natural summer ventilation and winter heating, such as Vancouver? Although ASHRAE 55 answers that there is no provision for mixed-mode buildings, so these default to PMV. Should we adopt the PMV model for thermal comfort evaluation as most of the time in summer, people are naturally ventilated in Vancouver?

Application in UBC climate context

Surrounded by forest on three sides and ocean on the fourth, UBC Vancouver campus locates at the west peninsula of Vancouver with an institutional and residential type of building environment, where the grid of campus is around 28° east of south. According to the typical annual climate database for Vancouver (1980), the annual temperature fluctuates from 2 °C to 23°C with a maximum 8°C difference in daily temperature. It is rarely going below -4°C or above 26°C. The warm season in Vancouver usually starts from June 15th to September 11th with an average daily temperature above 19°C. The hottest day is around August 1st ranging from 15°C to 23°C. While the cool season generally begins from the 13th of November to the 5th of next March, with an average daily high temperature below 9°C. The coldest day of the year is 2nd of January ranging from 2°C to 6°C。

However, as we all know and feel, the climate in Vancouver has changed and is changing, especially in summer. If we plot out the real temperature data of the year 1980 and 2017, the summer overheating is becoming an issue for the residents, as the hours exceed 25c is 49(2017) hours rather than 6(1980)

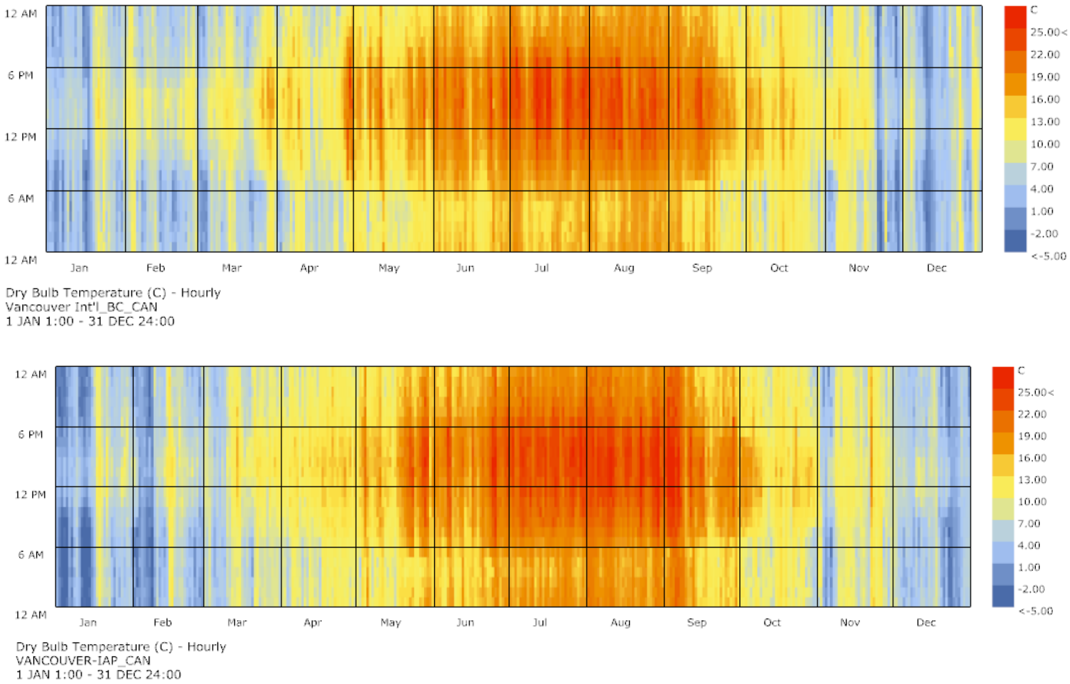


Figure.7 Vancouver temperature 1980 VS 2017, courtesy of Haobo Liu

As a large number of buildings on campus do not have a cooling system, these 49 hours become a real issue even though we count the fact that domestic temperature is even higher than outdoor air temperature because of the heat aggregation.

Figure.8 A large number of buildings on campus do not have cooling system

Someone may say, we could install a cooling system and adopt the PMV model to simply and quickly solve the problem. However. This strategy accelerates global warming and creates a dead loop to intensify the cooling demand through the associated production, installation and maintenance of the cooling system, although electricity in Vancouver is from hydropower.

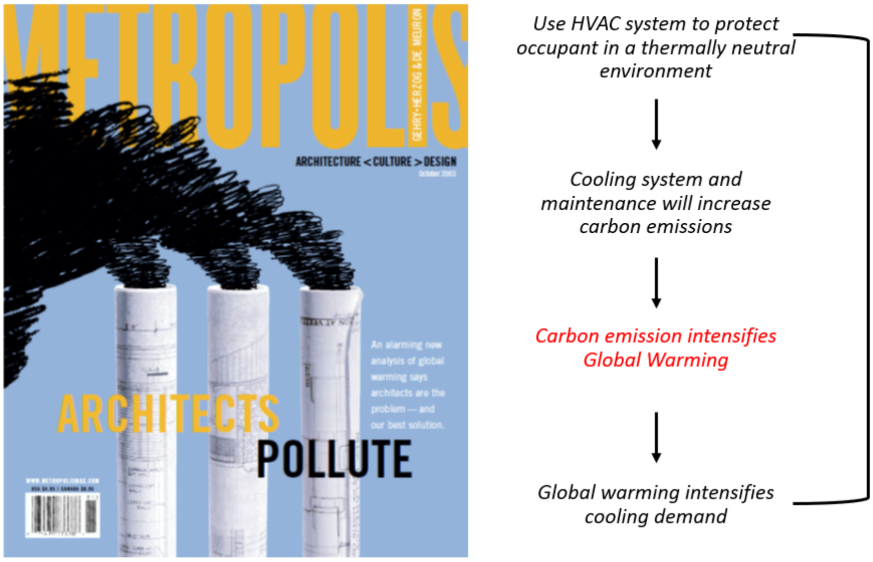


Figure.9 Dead loop of using mechanical cooling system

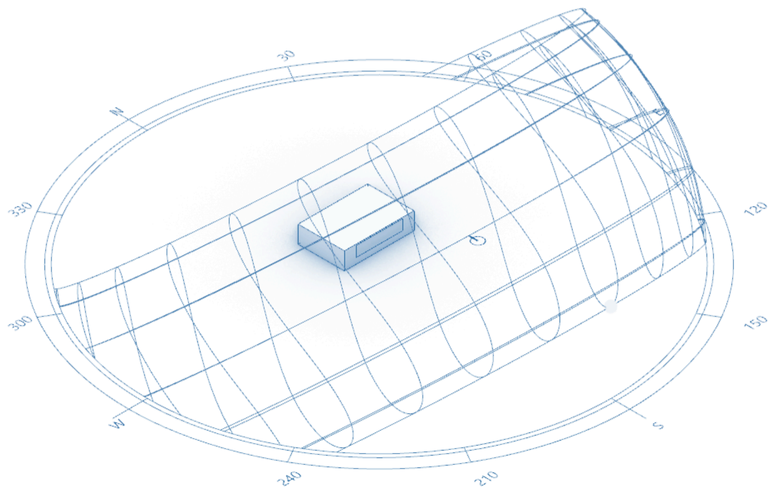


Figure.10 A test case scenario, courtesy of Haobo Liu

Let us assume, what if we apply some passive strategies to mitigate the overheating problem, and ensure the indoor thermal comfort during the heating period through the test of adaptive comfort model.

Firstly, a base case is set up under the scenario that outdoor dry bulb temperature is 24c and the indoor temperature is 26c, the surface of the room is as high as 39c because of the solar radiation. The wind speed is not taken into account.

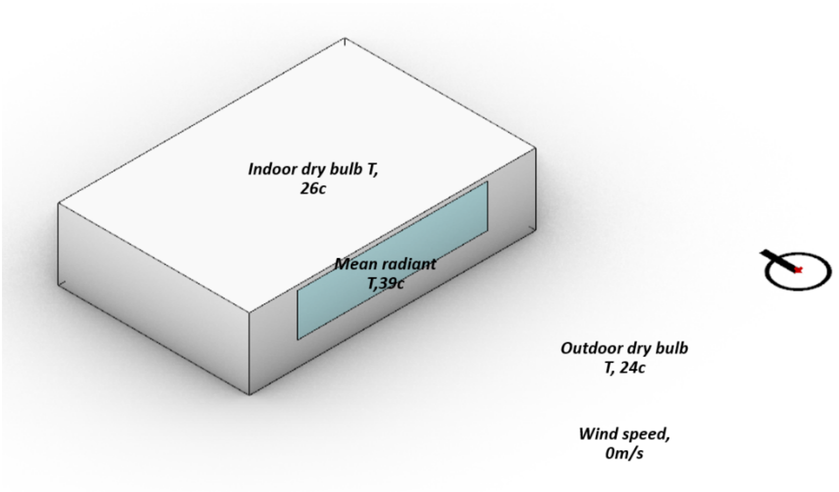


Figure.11 1st case scenario with temperature settings, courtesy of Haobo Liu

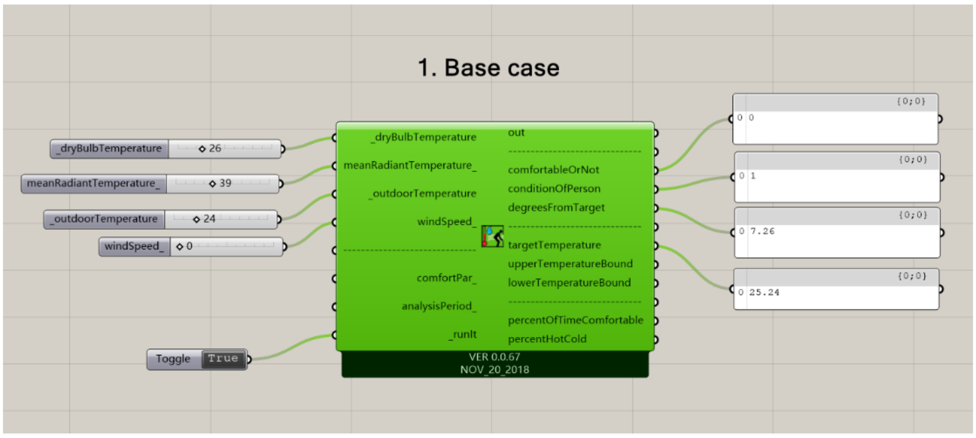


Figure.12 Adaptive comfort model showing the result, courtesy of Haobo Liu

As we could see, though the adaptive comfort model, we could predict that the thermal condition is too hot to live, and the operative temperature is 7.26c higher than the comfort target. The operative T= (indoor T + radiant T)/2

Figure.13 UBC campus

However, give the coastal context of UBC campus, we could make use of the natural wind from the ocean, which cools down the radiant temperature to 35c and decrease the target difference to 5.26c

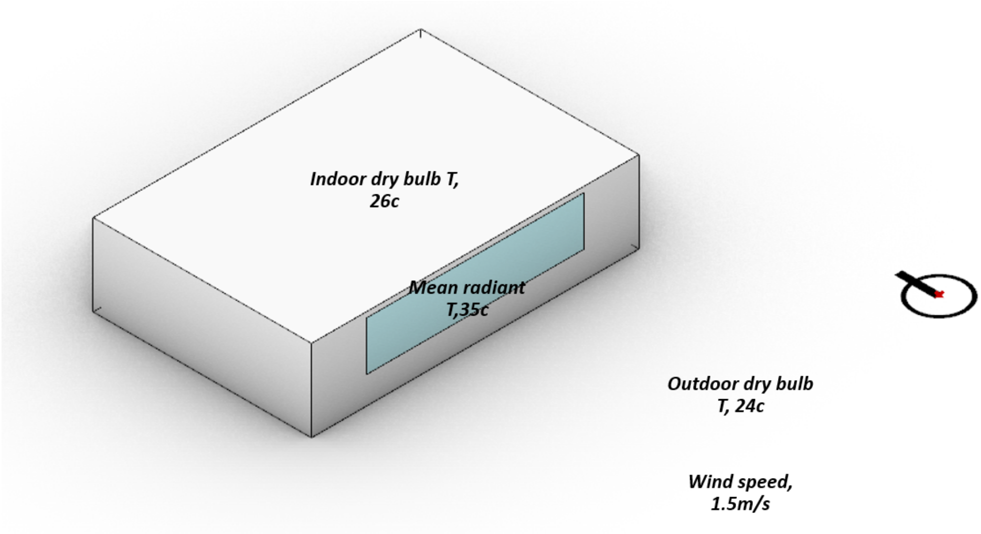


Figure.14 2nd case scenario with temperature settings, courtesy of Haobo Liu

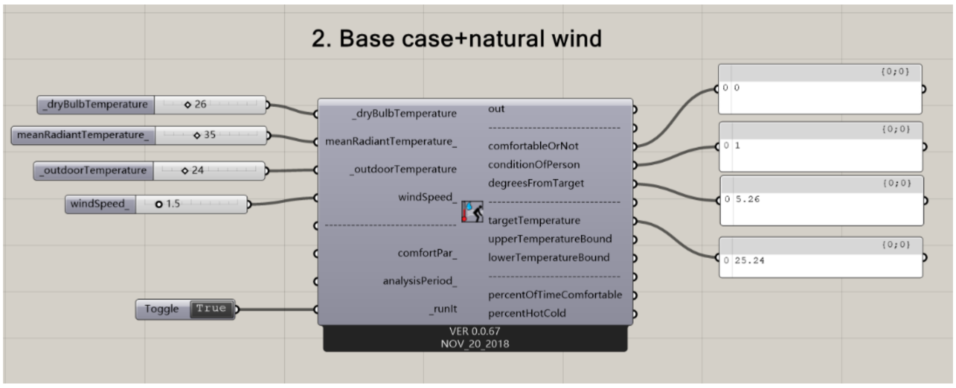


Figure.15 Adaptive comfort model showing the result, courtesy of Haobo Liu

Inspired by a friend, who protected herself from the hot summer last year through only a fan, we suggest installing some handy fans in the room to accelerate the ventilation rate. Through this step, the indoor air temperature is brought down to 25c, and the target difference goes down to 4.76c. However, the adaptive comfort model shows that the occupant still feels hot.

Figure.15 Active fans

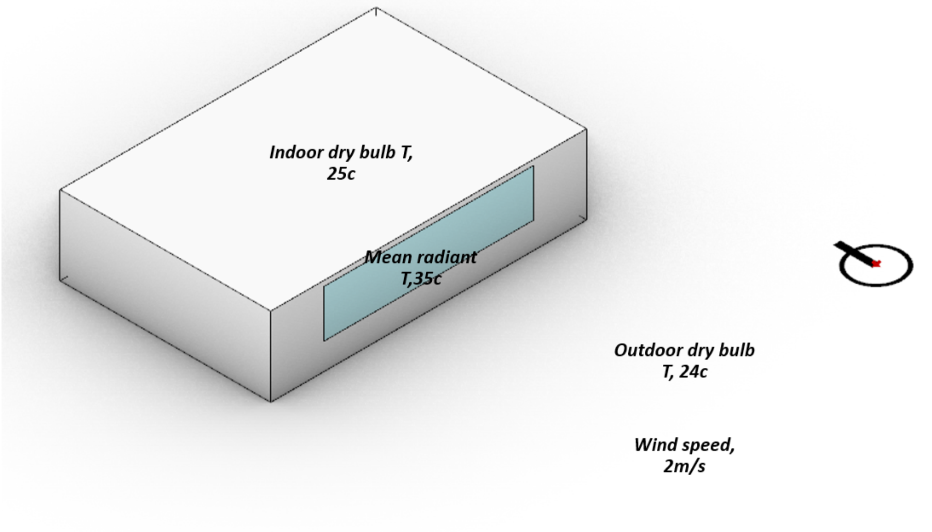


Figure.16 3rd case scenario with temperature settings, courtesy of Haobo Liu

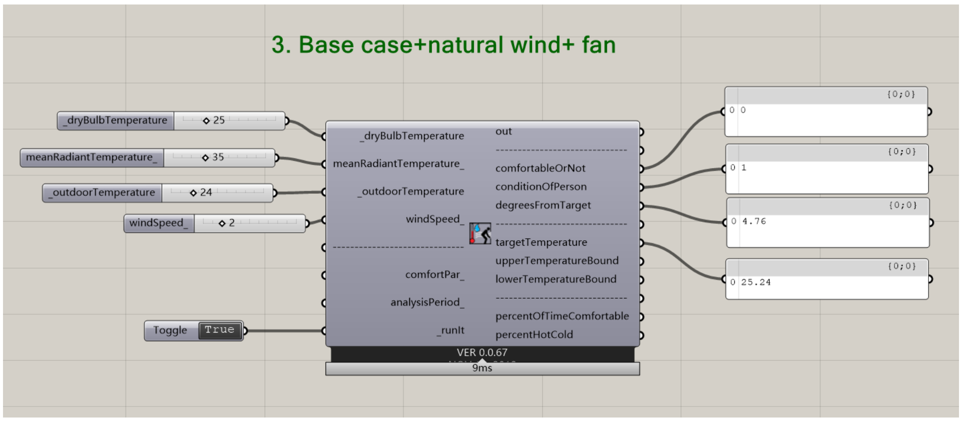


Figure.17 Adaptive comfort model showing the result, courtesy of Haobo Liu

The last strategy, installing the exterior shade, which could block out the sun and prevent solar radiation hitting on the window surface, helps bring down the radiant temperature of the room to the air temperature.

Horizontal overhang *Vertical fin* *L shape* *U shape*

Figure.18 Exterior shades

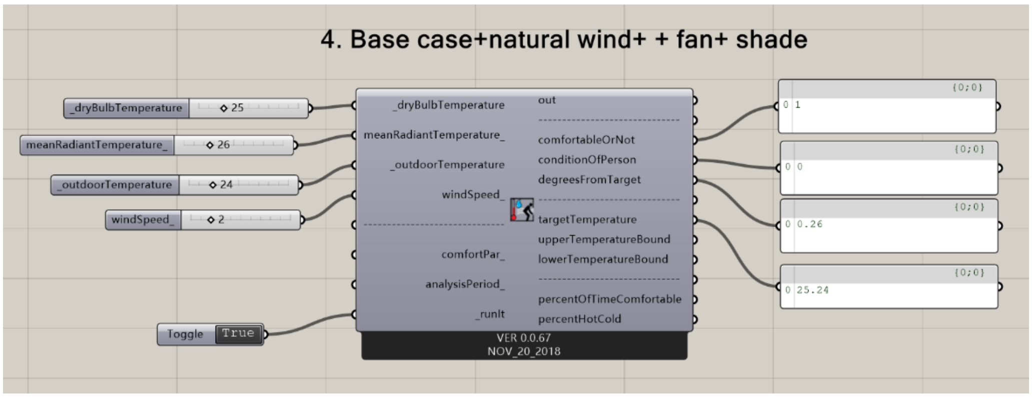


Figure.19 4th case scenario with temperature settings, courtesy of Haobo Liu

This step, cut the target temperature difference to only 0.26c, finally makes the occupant comfortable.

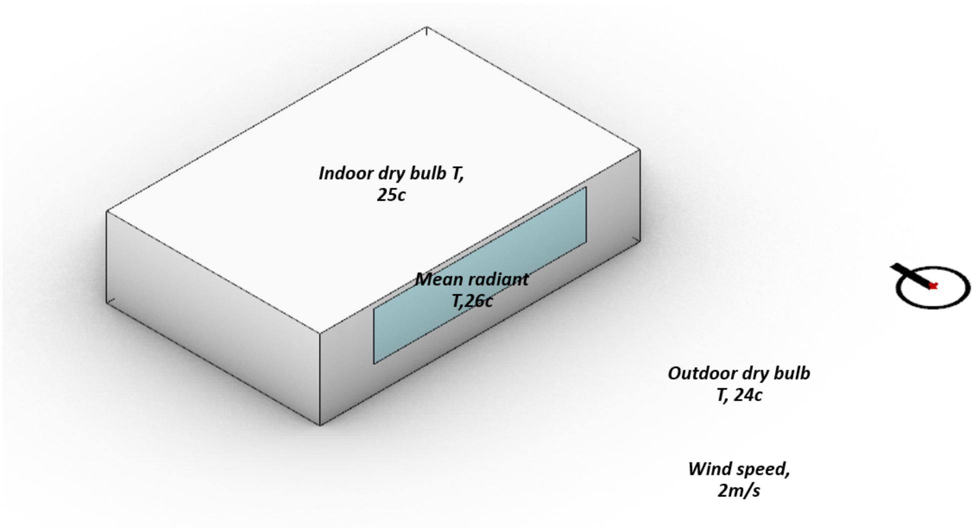


Figure.20 Adaptive comfort model showing the result, courtesy of Haobo Liu

Recommendation for the policy

In conclusion, here are some recommendations to the future UBC regulatory guidelines.

Firstly, we could divide the whole year into two seasons. For the heating season, the PMV model is adopted to maintain thermal comfort.

Secondly, for the cooling seasons, we could use the adaptive comfort model to calculate the thermal comfort and push the building to be naturally ventilated for low dense building types such as residential building and office.

Thirdly, for future study, regarding the climate adaptation, we still need to pay attention to the future temperature rising and test the thermal comfort using the future climate data.

3.2.2 Sound

Focus on Both Sending and Receiving

When we are targeting the health and well-being during institutional building design, sound is one of the critical factors that we have to consider. Although there are various types of spaces in an institutional building, typically it is common that we should try to make the speech clearer and block the noise through identification and mitigation of acoustical parameters.

Current Issues and Analysis

Constantly, we care about education which directs our future. But when we discuss how to improve its acoustical performance, typically we only pay attention to the effect of sending such as curriculums and teachers instead of receiving like students. The shocking fact is that many students leave their education every year having simply not heard one of four spoken words. The feelings of students are less concerned when it comes to the vital life skill of listening. This would not matter so much if every classroom is fit for purpose and every student enjoyed perfect reception of speech.

Unfortunately, that is not the case. The problem is speech to noise ratio. If the background noise is too loud, students simply are not able to hear what they are being taught. This effect could be even more severe for students with hearing impairment or learning in a second language. In addition, noise also creates stress. That is why teachers often prioritize vocal tiredness and classroom noise among their issues.

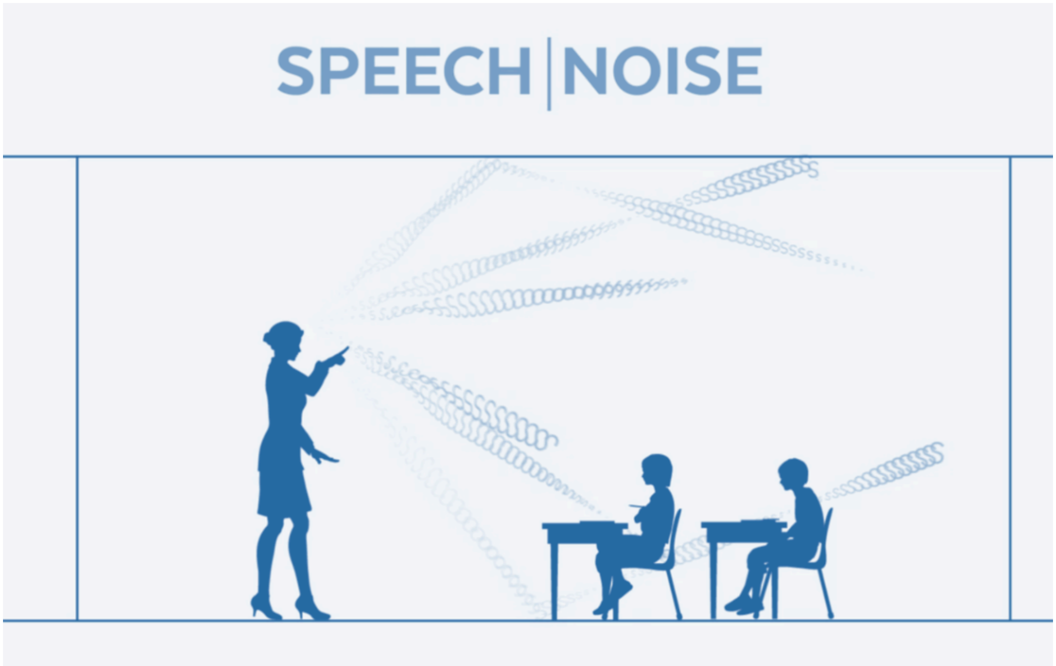


Figure.21 Speech to Noise ratio

Requirements review of acoustic performance in standards

Since the green building rating system, LEED as well as the healthy building rating system, WELL are widely applied to evaluate the building performance other than the quality of construction, they become more focusing on the importance of acoustical environment in occupied spaces. In their latest released versions, LEEDv4 and WELLv2, both of them have specific credits for optimized sound effects.

LEED v4:

Design classrooms and other core learning spaces to meet the Sound Transmission Class (STC) requirements of ANSI Standard S12.60, Acoustical Performance Criteria, Design Requirements and Guidelines for Schools, except windows, which must meet an STC rating of at least 35.

WELL v2:

This standard organized sound as a separate chapter so that it is more distinctive to describe the credits of acoustic performance across the spaces. It's intents are categorized by sound mapping, levels, barriers, absorption and masking, the specific requirements are adhered to ASHRAE.

ANSI S12.60

ANSI Standard S12.60 for Classroom Acoustics addresses the issues of both reverberation time and background noise and their effect on speech intelligibility by placing maximum permissible levels on each.

Under the standard, the maximum reverberation time in an unoccupied, furnished classroom with a volume under 10,000 cubic feet is 0.6 seconds, and 0.7 seconds for a classroom between 10,000 and 20,000 cubic feet. The maximum level of background noise allowed in the same classroom is 35 decibels (dBA).

The standard's acoustical performance criteria and design requirements apply during the design and construction of all new classrooms or learning spaces of small-to-moderate size, and, as far as is practical, to the design and reconstruction of renovated spaces.

ASHRAE Handbook HVAC 2017.

Chapter 48-Noise and Vibration Control:

Components of the mechanical system (e.g., fans, dampers, diffusers, duct junctions) all may produce sound by the nature of the airflow through and around them. As a result, almost all HVAC components must be considered. Because sound travels effectively in the same or opposite direction of airflow, downstream and upstream paths are often equally important.

This chapter provides basic sound and vibration principles and data needed by HVAC system designers.

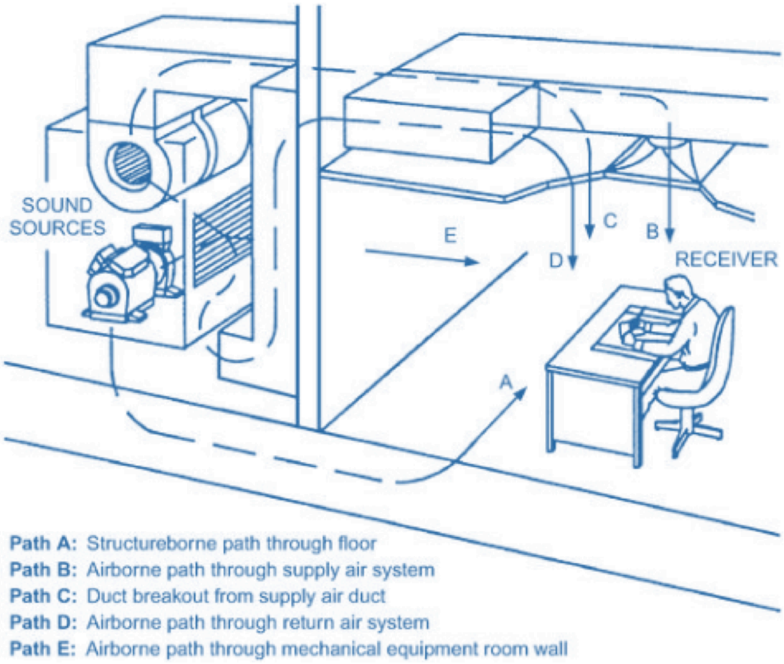


Figure.22 Typical Paths of Noise and Vibration Propagation

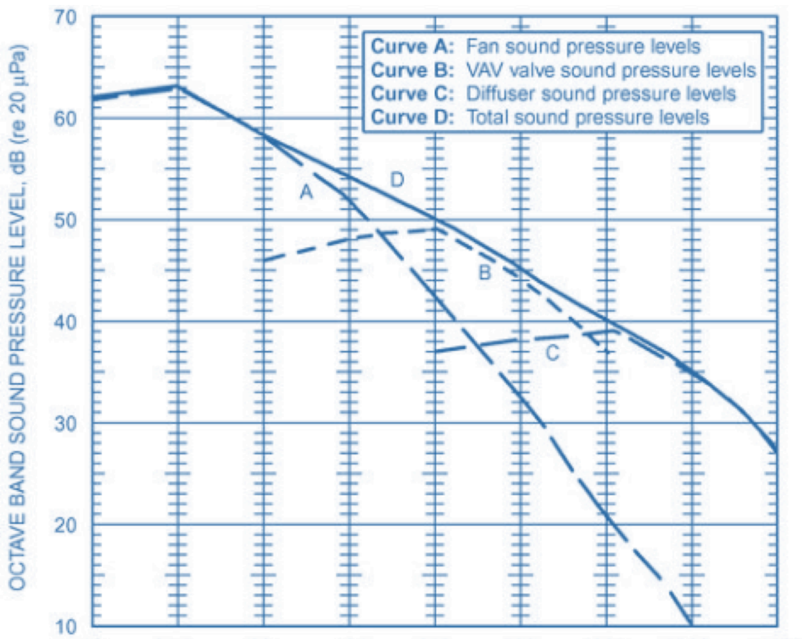


Figure.23 HVAC Sound Spectrum Components for Occupied Spaces

UBC LEED Implementaion Guide

In this guide, UBC did not require any credits in terms of sound which is indicated in LEED EQ10 section. It means that currently sound is not the major factor considered when green building design is under process by UBC.

UBC technical guideline (2018 edition):

In this guideline, UBC has identified the considerations as well as the requirements on acoustical effects. As well, acoustic performance on mechanical systems should be considered:

Section 10 00 10-Special Rood Requirements

1.16 Acoustical Design Standard for UBC classrooms

In this section, Classrooms fall into three types:

- Small Standard Classrooms (up to 100 seats, rectangular geometry, no speech-reinforcement system;
- Large Standard Classrooms (more than 100 seats, non-rectangular geometry, with a speech-reinforcement system;
- Critical Classrooms (e.g., for distance learning).

Under the same assumption in terms of occupancy, decoration, ceiling, UBC introduced a criteria similar to ANSI standard. However, sound performance is too dependent on occupancy ratio (60%) which, as source of sound absorption, varies by lectures or events. Therefore, we might consider to set a lower occupancy as a baseline in order to be more adaptive to actual use.

Section 20 00 05-Fan Systems:

- Selection of fan systems to consider maintenance and energy costs and sound levels.

Section 23 33 00-Sound Attenuators:

- Avoid specifying sound attenuators on fume hood exhaust fans. Select fans with lower sound level instead.
- Submit acoustical engineer's review of proposed sound attenuators performance to Technical Services.

These requirements have given a general consideration of facilities improvements but could specify more detailed sound level limitations in terms of equipment selection in order to contribute to meeting room acoustical requirements.

UBC SEED program-The Sound of Sustainability: An examination of sound sustainability in the Centre for Integrated Research on Sustainability and UBC Farms

This report focused in raising awareness of the importance of sound in providing further insight into the environment and therefore motivating researchers to perceive their surroundings through different perspectives, not just from a visual one. In addition, soundscapes also alter the perception and behaviour of species within the area, influencing their level of comfort and idea of sustainability within the space.

Chanlleges and Solutions in Building Acoustic Design

The challeges are categorized by function of occupied space:

Classroom	On any given day, many students are unable to understand one out of every four spoken words in classrooms due to inadequate acoustics.
Auditorium	From graduations to student theatre performances, auditoriums are used for a variety of events that make sound control critical. Acoustical needs can range from sound reflection for controlled vibrancy to sound absorption for less reverberation. Durability and aesthetics are also key considerations.
Cafeteria	Cafeterias are more than places to eat. These open multi-purpose spaces change from cafeterias to auditoriums requiring different acoustical and durability needs, depending on use.
Corridor	School corridors bustle with activity as they usher students from classroom to classroom and connect key areas of your project. In higher education, alluring wood or sleek metal options can add to the personality of the space.
Lobby	First impressions in schools are important. Many schools have signature spaces, like lobbies and entryways, that tell the world who they are, impacting the ability to recruit students and faculty, endowments, and community goodwill.

The solution to these problems is to improve acoustical performance. To be more specific, we should try to reduce the noise and block the sound. If we block noise from outside and neighboring spaces, our place will have a good start. In terms of maximizing speech intelligibility, we should absorb sound as well. Good sound absorption is another great move for improving the acoustic performance, because it makes spaces less noisy whereas more comfortable for working, learning and living. We need to do it so that unwanted reflections do not impair clarity. At same time, the whole room gets quieter, letting the speech to noise ratio close to the teacher's preference.

Natrual Ventilation Versus indoor Acoustical Performance

As we mentioned in thermo comfort part, we have to admit that the temperature in Vancouver is dradually growing. So we should consider the cooling issues of buildings in the future. However, that will bring extra energy consumption by mechanical cooling system. If we utilize natural ventilation as a major cooling source, it will dramatically decrease the cooling energy demand in summer. In fact, we do not give up mechanical cooling which is more controllable and reliable but we just try to mitigate the influence to UBC GBAP's net positive vision by 2035.

Recommendation

Based on ANSI 5tandard 12.60, we could update UBC technical guide line by identifying the acoustic requirement of mechanical systems. In order to satisfying it, UBC could encourage to apply acoustic-friendly type of terminals such as chilled-beams when implementing building design. In addition, the sound criteria could add another measure, combining occupants and areas. Moreover, requirements for other kinds of spaces are also introduced as optional ones.

Spaces	Seats	Reverberation time(s)		NC(dB)	Remark
		≤ 10000ft^3	> 10000ft^3		
Classroom	≤ 100	0.55~0.65	0.75~0.85	35	
	>100	0.75~0.85	0.75~0.85	35	
Critical Classroom	N/A	0.45~0.55		25	
Auditorium	N/A	1~1.2		40	Multi-function Room
Cafeteria	N/A	N/A		40	
Lobby	N/A	N/A		40	

Table 1. Sound criteria in institutional building

UBC could conduct a Reverberation Time Calculation to maintain the indoor sound performance in an beneficial level. Also, the result could be adjusted the ceiling and wall material selection which is included in building design as well. And this calculation should be based on an undated assumption including lower occupancy and general wall and ceiling materials which have been met by other components in GBAP.

Since we encourage to cool the space through natural ventilation by opening windows, we could consider the noise impact of events or activities from the outdoor areas when implementing zone planning. We need to ensure that this can not replace mechanical ventilation. We just try to improve the building performance by free cooling source.

3.2.3 Materials

This section discusses the role of Building Materials in the topic of Health and Wellbeing.
According to ''International Well Building Institute,'' Hazardous Material Reduction is one of the main issues in material and health and wellbeing subject. While most of the research in this field was regarding reduced exposure to hazardous heavy metals in building materials, this report tries to mention a different aspect of Hazardous Building Material and focuses on radioactive building materials, which could be hazardous for human health.

According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), there are four major sources of natural radiation: cosmic radiation, terrestrial radiation and intakes of naturally occurring radionuclides through inhalation and ingestion (UNSCEAR, 2000).

Cosmic Radiation

The earth's outer atmosphere is continually bombarded by cosmic radiation. Usually, it originates from a variety of sources, including the sun and other celestial events in the universe. Some ionizing radiation will penetrate the earth's atmosphere and become absorbed by humans that results in natural radiation exposure.

Regions at higher altitudes receive more cosmic radiation. According to a recent study by Health Canada, the annual effective dose of radiation from cosmic rays in Vancouver, British Columbia, which is at sea level, is about 0.40 mSv, [Table 1]. This compares to the top of Mount Lorne, Yukon, where at 2,000 m, a person would receive a dose of about 0.84 mSv annually.

Terrestrial Radiation

The composition of the earth's crust is a major source of natural radiation. The main contributors are natural deposits of uranium, potassium, and thorium that, in the process of natural decay, will release small amounts of ionizing radiation. Uranium and thorium are found essentially everywhere. Traces of these minerals are also found in **building materials** so exposure to natural radiation can occur from indoors as well as outdoors.

The average effective dose from the radiation emitted from the soil (and the construction materials that come from the ground) is approximately 0.1 mSv per year in Vancouver, [Table 2].

Inhalation

Most of the variation in exposure to natural radiation results from inhalation of radioactive gases that are produced by radioactive minerals found in soil and bedrock. Radon and thoron levels vary considerably by location depending on the composition of soil and bedrock.

Once released into the air, these gases will normally dilute to harmless levels in the atmosphere but sometimes they become trapped and accumulate inside buildings and are inhaled by occupants. Radon gas poses a health

risk not only to uranium miners but also to homeowners if it is left to collect in the home. On average, it is the largest source of natural radiation exposure.
The earth's crust produces radon gas, which is present in the air we breathe. Radon has four decay products that will irradiate the lungs if inhaled. The worldwide average annual effective dose of radon radiation is approximately 1.3 mSv, this amount in Vancouver is 0.4 mSv, [Table 2].

Ingestion
Trace amounts of radioactive minerals are naturally found in the contents of food and drinking water. For instance, vegetables are typically cultivated in soil and groundwater that contains radioactive minerals. Once ingested, these minerals result in internal exposure to natural radiation. Some of the essential elements that make up the human body, mainly potassium and carbon, have radioactive isotopes that add significantly to our background radiation dose.

Natural radiation from many sources penetrates our bodies through the food we eat, the air we breathe and the water we drink. Potassium-40 is the main source of internal irradiation (aside from radon decay). The average effective dose from these sources is approximately 0.3 mSv a year in Vancouver, [Table 2].

Sources and Average Effective Dose from Natural Background Radiation in Selected Canadian Cities

Canadian City	Total (mSv/y)	Cosmic radiation (mSv/y)	Terrestrial background (mSv/y)	Annual inhalation dose (mSv/y)	Radionuclides in the body (mSv/y)
Worldwide	2.4	0.4	0.5	1.3	0.3
CANADA	1.8	0.3	0.2	0.9	0.3
Whitehorse	1.9	0.5	0.2	0.9	0.3
Yellowknife	3.1	0.4	1.4	0.9	0.3
Victoria	1.8	0.5	0.1	0.9	0.3
Vancouver	1.3	0.5	0.1	0.4	0.3
Edmonton	2.4	0.5	0.3	1.3	0.3
Regina	3.5	0.4	0.3	2.4	0.3
Winnipeg	4.1	0.4	0.2	3.2	0.3
Toronto	1.6	0.4	0.2	0.8	0.3
Ottawa	1.8	0.4	0.2	0.9	0.3
Iqaluit	1.9	0.5	0.2	0.9	0.3
Québec City	1.6	0.4	0.2	0.7	0.3
Montreal	1.6	0.4	0.3	0.7	0.3
Fredericton	1.8	0.3	0.3	0.9	0.3
Halifax	2.5	0.3	0.3	1.5	0.3
Charlottetown	1.8	0.3	0.2	0.9	0.3
St-John's	1.6	0.4	0.2	0.7	0.3

Table.2: Canadian safety nuclear commission, 2013 nuclearsafety.gc.ca

Natural Radiation Doses

According to ‘’Nuclear Regulatory Agency’’, ‘’Dose’’ is a general term that refers to the amount of energy absorbed by tissue from ionizing radiation. The dose is measured in sieverts (Sv) and is more commonly expressed in units of either millisievert (mSv) – which represents a thousandth of a sievert – or microsieverts (µ Sv) – one-millionth of a sievert.

On the other hand, The S.I. units for radon concentration in air and in water are Becquerels per cubic meter (Bq/m3) and Becquerels per liter (Bq/l) respectively. The Becquerel is the base unit of radioactivity, equal to a disintegration rate of one per second. It is the measure of the “amount of activity” of a radioactive source or radioactive material. The unit for radon progeny concentration in air is also Bq/m3. (Copes, R., 2009)

To calculate the Annual Effective Dose (AED) in units of millisievert (mSv) to a person working for 2000 hours in a known average concentration of radon - R (Bq/m3), the following formula can be used.

AED (mSv) = R (Bq/m3) / 150,

It means 1 (mSv) for each 150 (Bq/m3)

For example, exposure to a concentration (R) of 600 Bq/m3 gives an AED of 600/150 or 4 mSv. If the exposure was for 1000 hours per year instead of 2000, the AED would be half or 2 mSv. It assumes radon to progeny ratio of 0.5 and applies to a breathing rate for moderate work. (Copes, R., 2009)

Risk Impact of Natural Radiation in UBC

The current federal occupational limit of exposure per year for an adult 3 mSv of natural sources of radiation and any medical radiation. As it is shown in the diagram, The world average annual effective dose from internal and external exposure, due to the natural radiation background, is equal to 2.4 mSv/y.

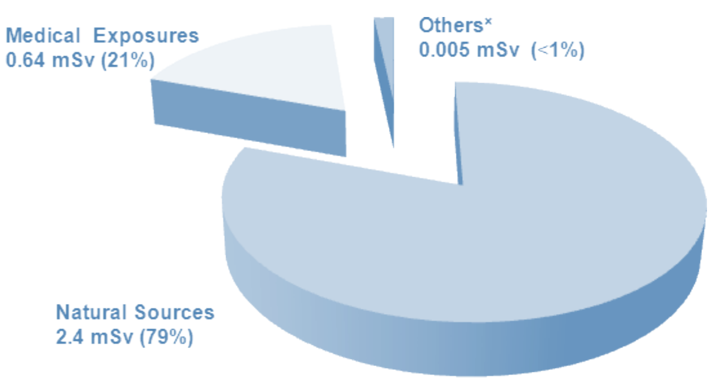


Figure.24: www.iaea.org

As it is shown in Table 2, the amount of natural radiation in Vancouver is 1.3 mSv per year. This amount is significantly lower than 2.4 mSv considered by international safety regulation. Therefore, the risk impact of natural radiation in UBC is low. Although natural radiation in UBC is below 2.4 mSv, the usage of some building materials might increase the number. The emanation of 222Rn from the radium present in building materials will also contribute to the concentration of 222Rn indoors. The relative contribution from building materials is generally more important where the total concentration of 222Rn indoors is low. Radon-222 released from building materials is rarely the dominant contributor to high concentrations of 222Rn indoors. (IAEA, 2015)

Radioactive Building Material

According to U.S Centres for Disease Control and Prevention, some building materials contain low levels of radioactive material. Building materials that are made up of sandstone, concrete, brick, natural stone, gypsum, or granite are most likely to emit low levels of radiation. Radioactive materials in sandstone, concrete, brick, natural stone, gypsum, and granite contain naturally occurring radioactive elements like radium, uranium, and thorium. These naturally occurring elements can break down or decay into the radioactive gas radon. Depending on the amount of these materials present, they may also cause small increases in radiation levels. Amounts (doses) of radiation in building materials depending on the type and amounts of materials used. These materials would influence the radiation dose of human beings due to natural radioactive substances (Centres for Disease Control and Prevention, 2015). Radioactive material in building materials may add to indoor radon levels. Elevated indoor radon levels may pose a risk to human health (Centres for Disease Control and Prevention, 2015).

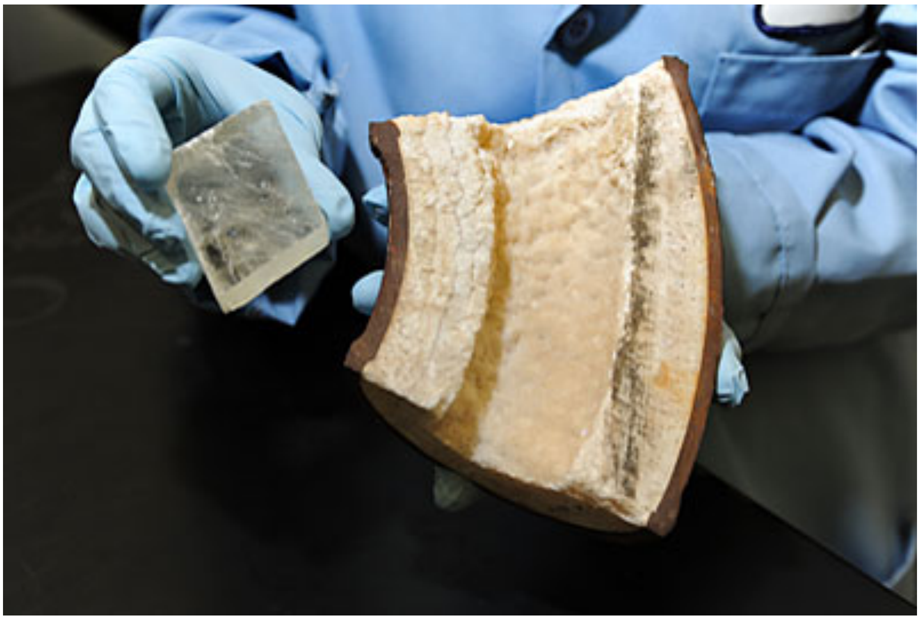


Figure.25: Building cement 'prison' for old radioactive waste (https://phys.org)

Material		Emanation Coefficient (mSv / year) Variations	References
Concrete		0.1 - 0.3	1-2-3-4-5-6
Brick		0.1 - 0.2	6
Light weight expanded clay aggregate		0.1 – 0.4	3-5
Soil	Clay	0.2-0.5	7
	Sand	0.1-0.4	7
	Gravel	0.05-0.3	7
	Tile	0.1-0.4	7
Natural stone		0.2 - 0.4	7
Slag brick, Granite		0.4 – 2	6
Phosphogypsum		0.4 - 2	8
Wood		0	8

1- Krisiuk E.M., A study on 19 radioactivity of building materials. **2**-Ingersoll, J.G. A survey of radionuclide 20 contents and radon emanation rates in building materials used in the U.S. Health Physics. **3**-Stranden E. and Berteig L., Radon in dwellings and influencing factors. **4**-Mustonen R., Natural radioactivity in and radon exhalation from Finnish building materials. **5**-Markkanen M. Unpublished results of gammaspectrometric measurements performed by STUK as service for various producers of building materials in Finland during **6**-European nuclear society, Radiation exposure, building material **7**-Markkanen M. and Arvela H. Radon emanation from soils

Table.3: Radon emanation coefficients for some building materials

As it is shown in this table, phosphogypsum and granite have high natural radioactive measures. Also, the radiation in buildings made out of bricks or concrete is higher than in buildings made out of wood. These materials could increase the radiation dose above the low levels of background radiation we receive on a daily basis.

Main Factors Influencing Radiational Dose

Time is an important factor in limiting exposure to the public and to radiological emergency responders. The amount of radiation exposure increases and decreases with the time people spend near the source of radiation (American nuclear society, 2018).

$$Dose = Dose\ Rate \times Time$$

Distance can be used to reduce exposure. The farther away people are from a radiation source, the less their exposure. Doubling the distance from a point source of radiation decreases the exposure rate to 1/4 the original exposure rate. Halving the distance increases the exposure by a factor of four. (American nuclear society, 2018)

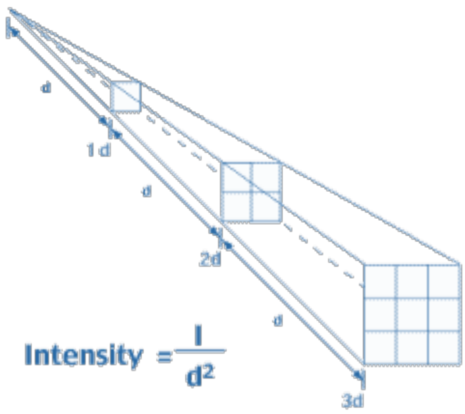


Figure.26: www.nde-ed.org

Shielding

As ionizing radiation passes through matter; the intensity of the radiation is diminished. Shielding is the placement of an “absorber” between you and the radiation source. An absorber is a material that reduces radiation from the radiation source to you. Alpha, beta, or gamma radiation can all be stopped by different thicknesses of absorbers (American nuclear society, 2018).

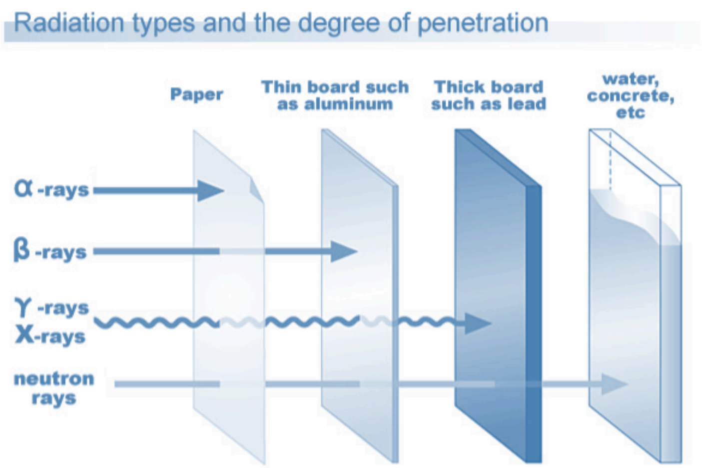


Figure.27: www.mirion.com

Calculation Method

A method is presented in this section for calculating dose due to external gamma radiation from building materials on the basis of the approach of the International Atomic Energy Agency (IAEA), The results are given in tabular form as specific dose rates. This allows the most typical dose assessments to be made without computer calculations.

The method is based on calculating the dose rate for a rectangular building constructed of building material of uniform density and containing radionuclides of uniform activity concentration. The dose rate indoors is calculated by summing the separately calculated dose rates due to radionuclides in the walls, floor and ceiling of a room as presented in the effects of doors and windows will lower the dose rate by only a minor amount and so for simplicity doors and windows are not considered in the calculation. The reference level of 1 mSv/a used for building materials is defined as due to the 'excess exposure' caused by these materials above the exposure due to normal background levels of radiation. The basic approach in determining the 'excess exposure' is as follows:

- First, the total exposure due to the building material and the background levels is calculated, after allowance for the shielding provided by the building material against gamma radiation in the terrestrial background.
- The exposure to gamma radiation in the terrestrial background is then subtracted.
- The result for comparison with the reference level is referred to as the 'excess exposure'.

In the example calculations presented below, a world population-weighted average dose rate of 60 nGy/h is assumed for gamma radiation in the terrestrial background (UNITED NATIONS, 2000). The gamma dose rate is calculated in the middle of the standard sized room shown in Fig. 28. The specific gamma dose rates contributed by the walls, floor and ceiling are given in Table 4. The total dose rate indoors is calculated by summing the separately calculated dose rates due to walls, floor, and ceiling. Various dose assessments resulting from the use of the specific dose rates given in Table 4 are described in the first example. A conversion factor of 0.7 Sv/Gy is used for converting the absorbed dose in the air to an effective dose. (UNITED NATIONS, 1993)

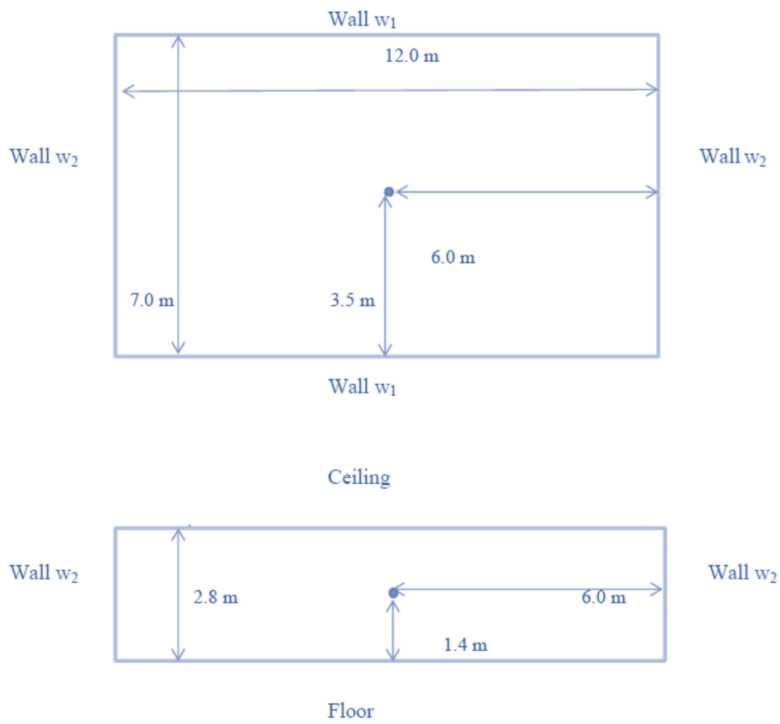


Figure.28: The geometry used in the calculation of the gamma dose rate indoors due to building materials. (IAEA, 2015)

The dose rates are calculated for the center point of the room. It can be shown that because of the 4π type exposure geometry, the dose rates at other points in the room do not vary by more than about 5–10% from that at the center point. The dose rate at the center point is, therefore, a good approximation for the dose rate within the whole room. (IAEA, 2015)

Mass per unit area of wall, ceiling or floor material[a] (kg/m^2)	Wall, ceiling or floor material (top layer)[b] (pGy/h per Bq/kg)			0.2 m thick concrete behind the wall, ceiling or floor material[c] (pGy/h per Bq/kg)		
	^{226}Ra	^{232}Th	^{40}K	^{226}Ra	^{232}Th	^{40}K
Wall w_1: Dimensions 12.0 m × 2.8 m, distance 3.5 m						
0	0	0	0	95	110	8.0
25	9	10	0.73	87	100	7.3
50	18	21	1.5	80	94	6.7
100	35	40	2.8	65	77	5.6
150	50	56	3.9	52	62	4.6
200	61	70	4.9	40	50	3.8
300	79	91	6.4	24	31	2.5
500	96	110	8.1	8	12	1.0
Wall w_2: Dimensions 7.0 m × 2.8 m, distance 6.0 m						
0	0	0	0	32	37	2.7
25	2.7	3.1	0.22	30	35	2.5
50	5.5	6.2	0.44	28	32	2.3
100	11	12	0.85	22	27	2.0
150	15	18	1.2	19	23	1.7
200	20	22	1.6	16	19	1.4
300	26	30	2.1	10	13	1.0
500	33	38	2.7	3.7	5.4	0.45
Floor or ceiling: Dimensions 12.0 m × 7.0 m, distance 1.4 m						
0	0	0	0	350	420	30
25	46	52	3.7	310	370	27
50	90	100	7.1	270	330	24
100	160	190	13	200	250	18

Mass per unit area of wall, ceiling or floor material[a] (kg/m^2)	Wall, ceiling or floor material (top layer)[b] (pGy/h per Bq/kg)			0.2 m thick concrete behind the wall, ceiling or floor material[c] (pGy/h per Bq/kg)		
	^{226}Ra	^{232}Th	^{40}K	^{226}Ra	^{232}Th	^{40}K
150	220	250	18	150	180	14
200	260	300	21	110	140	11
300	310	360	26	56	78	6.3
500	350	420	30	15	27	2.2

Table.4: Specific gamma dose rate in the air due to the different structures in the room shown in figure 28

Example 1

Exposure to gamma radiation in a concrete room where the concentrations of 226Ra and 232Th are slightly above average. The walls, floor, and ceiling of a room are constructed of concrete, as shown in Fig.28. The concrete is assumed to have slightly elevated levels of radionuclides of natural origin. The room is assumed to have the specifications shown in Table 5.

Radionuclide	Floors, ceiling, walls (concrete)
	Activity concentration
^{226}Ra	80 Bq/kg
^{232}Th	80 Bq/kg
^{40}K	800 Bq/kg
Other parameters	
Density of concrete	2350 kg/m^3
Thickness of concrete	0.20 m

Table 5. Example 1: Specifications Of The Room Shown In Fig.28

The mass per unit area of the walls, floor, and the ceiling is 2350 kg/m3 × 0.20 m = 470 kg/m2, thus the specific dose rates for a mass per unit area of 500 kg/m2 in Table 4 are used. The dose rate in the room is calculated as shown in Table 6.

Source	Calculation	Dose rate
w_1 (concrete)	2 × (96 × 80 + 110 × 80 + 8.1 × 800)	0.0459 µGy/h
w_2 (concrete)	2 × (33 × 80 + 38 × 80 + 2.7 × 800)	0.0157 µGy/h
Floor and ceiling (concrete)	2 × (350 × 80 + 420 × 80 + 30 × 800)	0.1712 µGy/h
Total dose rate in a room (cosmic radiation excluded)		0.2328 µGy/h
Terrestrial gamma radiation outdoors: the concrete structures of the building shield against this radiation		–0.06 µGy/h
Excess dose rate caused by building materials		0.1728 µGy/h
Excess effective dose	0.7 Sv/Gy × 0.172 8 µGy/h	0.121 µSv/h

Table 6. Example 1: The Dose Rate In The Room As Shown In Fig. 28

The annual excess effective dose to an occupant depends on the annual occupancy time:

100% occupancy: 8760 h/a × 0.121 µSv/h = 1060 µSv/a = 1.1 mSv/a

80% occupancy: 7008 h/a × 0.121 µSv/h = 848 µSv/a = 0.85 mSv/a

60% occupancy: 5256 h/a × 0.121 µSv/h = 636 µSv/a = 0.64 mSv/a

Example 2

Exposure to gamma radiation in a room where the walls are made of a material with elevated concentrations of 226Ra and 232Th and the floor and ceiling are made of typical concrete. The floor and ceiling of the room in Fig. 28. are constructed of concrete that contains the world population-weighted average concentrations of radium, thorium, and potassium in the soil in of 33 Bq/kg, 45 Bq/kg and 420 Bq/kg for 226Ra, 232Th, and 40K, respectively. The walls are made of brick with elevated levels of radionuclides of natural origin. The material specifications are as shown in Table 7.

Radionuclide	Floor, ceiling (concrete)	Walls (brick)
	Activity concentration	Activity concentration
^{226}Ra	33 Bq/kg	200 Bq/kg
^{232}Th	45 Bq/kg	300 Bq/kg
^{40}K	420 Bq/kg	1500 Bq/kg
Other parameters		
Density of concrete	2350 kg/m^3	2000 kg/m^3
Thickness of concrete	0.20 m	0.15 m

Table 7. Example 2: Specifications Of The Room As Shown In Fig. 28

The mass per unit area of the walls is 2000 kg/m3 × 0.15 m = 300 kg/m2 and the mass per unit area of the floor and ceiling is 2350 kg/m3 × 0.20 m = 470 kg/m2, thus the specific dose rates for a mass per unit area of 300 kg/m2 for the walls and 500 kg/m2 for the floor and ceiling in Table 4 are used. The dose rate in the room is calculated as shown in Table 8.

Source	Calculation	Dose rate
w_1 (brick)	2 × (79 × 200 + 91 × 300 + 6.4 × 1500)	0.1054 µGy/h
w_2 (brick)	2 × (26 × 200 + 30 × 300 + 2.1 × 1500)	0.0347 µGy/h
Floor and ceiling (concrete)	2 × (350 × 33 + 420 × 45 + 30 × 420)	0.0861 µGy/h
Total dose rate in a room (dose rate due to cosmic radiation excluded)		0.2262 µGy/h
Terrestrial gamma radiation outdoors: the concrete structures of the building shield against this source		–0.06 µGy/h
Excess dose rate caused by building materials		0.1662 µGy/h
Excess effective dose	0.7 Sv/Gy × 0.1662 µGy/h	0.116 µSv/h

Table 8. Example 2: The Dose Rate In The Room As Shown In Fig. 28

The annual excess effective dose to an occupant depends on the annual occupancy time:

100% occupancy: 8760 h/a × 0.116 µSv/h = 1016 µSv/a = 1.0 mSv/a

80% occupancy: 7008 h/a × 0.116 µSv/h = 813 µSv/a = 0.81 mSv/a

60% occupancy: 5256 h/a × 0.116 µSv/h = 610 µSv/a = 0.61 mSv/a

UBC Action Required

Material Resource Transparency

According to Global Industry Analysts, Inc. (GIA) report, the global construction building materials market is projected to exceed $1.1 trillion by 2020. Over the past few years, the sector has seen considerable growth as a result of a number of interrelated factors, the largest of which a growing population, a rise in urbanization, expanding industry and the upswing in the global economy. According to George Reddin of FMI Capital Advisors, market conditions for buying and selling building materials businesses in 2018 are among the best the industry has seen in a decade.

On the other hand, The global supply chain for building materials is becoming ever more complex. Therefore, it is suggested for UBC to pay more attention to the issue of transparency regarding lifecycle assessment in building materials and therefore, choose the building materials that have been provided by transparent resources.

For example, Granite has different types from different origins, and each one has a specific radiation amount (Table 9). UBC should choose the building material that has the value of the ‘’Activity Index’’* is 1 or less.

^{226}Ra, ^{232}Th and ^{40}K activity concentrations of the granite samples

Sample code	Origin	Color	Activity concentrations ($Bqkg^{-1}$)		
			^{226}Ra	^{232}Th	^{40}K
G1	Iran	White	1.54 ± 0.4	1.11 ± 0.3	19.47 ± 0.6
G2	Italy	White	3.17 ± 0.5	0,85 ± 0,2	28.85 ± 0.6
G3	Egypt	White	3.13 ± 0.86	1.14 ± 0.4	33.17 ± 1.1
G4	China	Brown with black	77.16 ± 3.8	77.82 ± 4.7	1152.30 ± 16.5
G5	China	Gray	45.99 ± 4.1	66.64 ± 1.9	1130.73 ± 13.3
G6	China	Black with red	72.94 ± 5.7	61.53 ± 2.9	1114.4 ± 9.1
G7	Pakistan	Ruby red color	64.95 ± 8.5	77.31 ± 2.5	1272.98 ± 12.6
G8	Pakistan	Brown	7.89 ± 08	3.77 ± 0.6	30.29 ± 0.9
G9	Iran	Light color red	2.31 ± 0.5	0.55 ± 0.1	L.D.L
G10	Italy	White with gray	1.53 ± 0.4	L.D.L	L.D.L
G11	India	Green	7.73 ± 1.8	1.18 ± 0.01	L.D.L
G12	Italy	Black	3.71 ± 0.5	6.05 ± 0.7	21.63 ± 0.7
G13	Boringly	Rosa	1.99 ± 0.9	0.51 ± 0.1	L.D.L
G14	Saudi Arabia	Black with red	54.87 ± 7.67	71.43 ± 3.33	1632.37 ± 18.49

Table.9: J.H. Al-Zahrani / Journal of Radiation Research and Applied Sciences

Activity Index*: Representative level index (Ir) is used to estimate the standard of gamma radiation hazard associated with the natural radionuclides in specific building materials. It is calculated using the following formula (Asaduzzaman et al., 2016; UNSCEAR, 2000):

$$I_1 = \frac{C_{Th}}{200\ Bq/kg} + \frac{C_{Ra}}{300\ Bq/kg} + \frac{C_K}{3000\ Bq/kg}$$

(Ir) value of the activity index is 1 or less, the corresponding material can be used, with regard to radioactivity, without restriction. If the value exceeds 1, the responsible party (producer or dealer) is required to assess the radiation exposure caused by the material and show specifically that the safety requirement is fulfilled.

Furthermore, it is suggested for UBC to pay attention to each step of the lifecycle assessment process, particularly in relation to recycling building materials.

According to Metro Vancouver report, Mineral aggregates constitute 34% of the construction and demolition waste stream generated annually in Metro Vancouver (445,000 tonnes annually). Concrete represents the bulk of this category and is generally sent to a small number of Lower Mainland concrete recycling facilities (Metro Vancouver, 2012). Therefore, using recycling building material has been increasing annually, and different building materials with different origins are mixed and recycled. If the amount of radiation of each building material is not measured before the recycling process, the newly recycled building material could even have more amount of radiation.

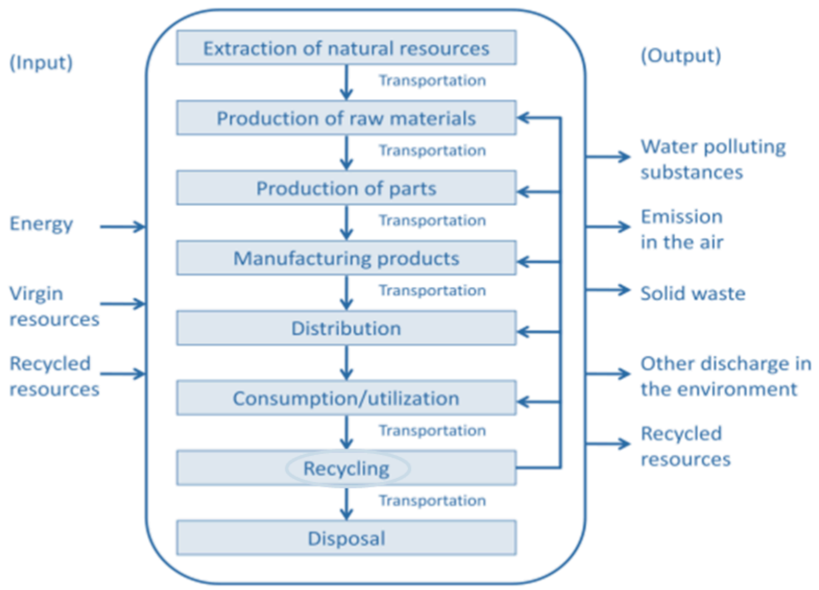


Figure.29: Transparency of Building Life Cycle Assessment (Sophia Lisbeth Hsu)

In addition, it is suggested for UBC to ensure the safety in usage of every building material before installation, and be fully aware of materials' radiation amount.

Existing Building Material

UBC needs to check the amount of radiation in existing building materials in their buildings. Since the length of the gamma ray is too short, UBC needs to check the building materials in each building and each room separately with radioactive radiation detector tools.

Radon Prevention Strategies

As it was previously mentioned, because of the geographical location of UBCs' campus, the risk impact of radon gas exposure from the soil and land in UBC is low, however such risk impact could also be reduced.

Most prevention strategies address steps to limit soil gas infiltration due to air pressure differences between the soil and the indoor occupied space. (IAEA, 2015).

Renovation of Old Building

Radon is more likely to get into the buildings through cracks and holes in the foundation. The air pressure at ground level in most buildings is slightly lower than the outdoor air pressure, as the indoor air is usually warmer. This causes air from the ground to be drawn into buildings, carrying 222Rn with it. The access routes are principally gaps between floors and walls, cracks in floors and gaps around pipes and cables. (IAEA, 2015). Therefore, UBC needs to renovate the foundation and ground floor of the old buildings.

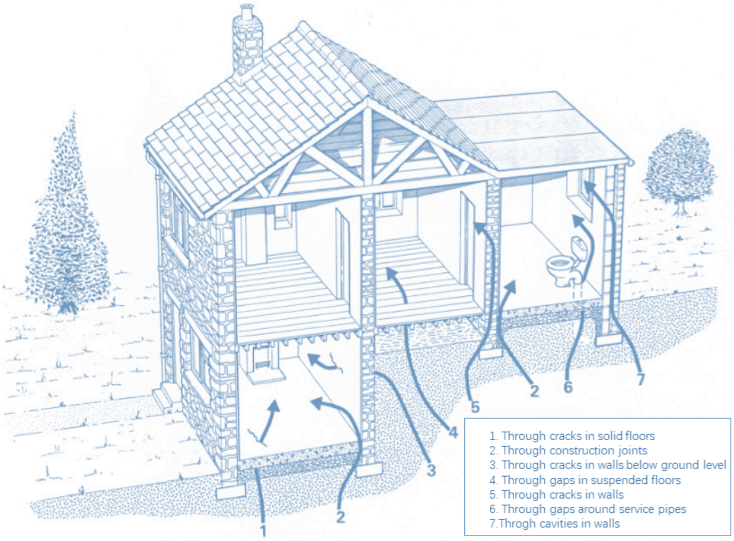


Figure.30: WHO handbook on indoor radon, 2005

Active Soil Depressurization (ASD)

The active soil depressurization radon reduction (ASD) system is the most popular and successful method used today for lowering radon levels ASD is simple to install and provides greater radon reduction, the below picture shows different parts of the ASD system. (WHO handbook on indoor radon, 2005).

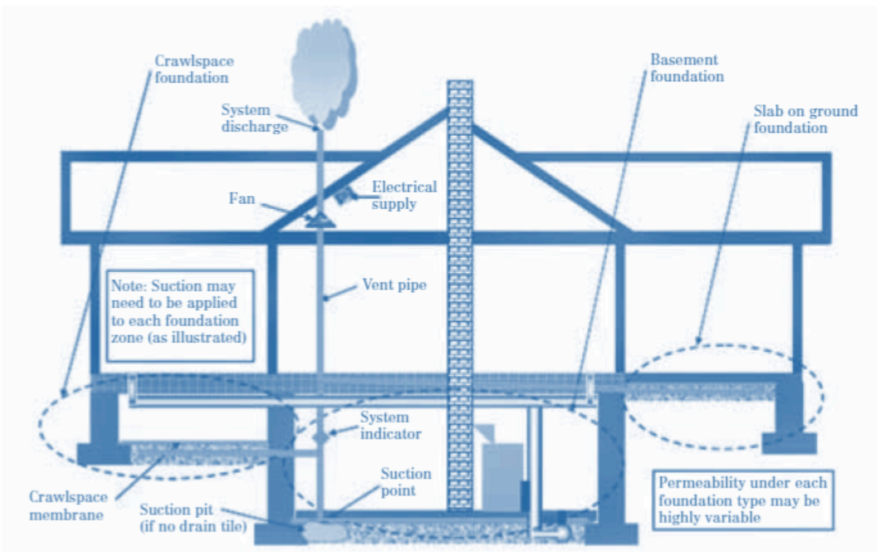


Figure.31: Active soil depressurization for radon control in new constructions (WHO handbook on indoor radon, 2005)

Section point located below the ground-contacted floor or slab of the building and connected to continuous and uniform permeable aggregate layer. A discharge point located in a manner that minimizes the opportunity for human exposure, for the example above the highest roof. A continuously operating inline fan is located outside and above the conditioned space of the building.

Ventilation of unoccupied spaces

Ventilation of unoccupied spaces between the soil and the occupied space (e.g. vented crawlspaces) can reduce indoor radon concentrations by separating the indoors from the soil and reducing the concentration of radon below the occupied space. The effectiveness of this strategy depends upon a number of factors. These include the air-tightness of the floor system above the vented unoccupied space, and, with passive ventilation, the distribution of vents around the perimeter of unoccupied space. A variation of this approach involves the use of a fan to either pressurize or depressurize the unoccupied space. However, fan-driven depressurization of crawlspaces may pose problems such as back-drafting of combustion appliances and energy loss. (ASTM 2003).

3.2.4 Community

Community Wellbeing

It is the combination of social, economic, environmental, cultural, and political conditions identified by individuals and their communities as essential for them to flourish and fulfil their potential. Communities are characterized by groups of people with diverse characteristics who are linked by social ties, share common perspectives and engage in joint action and experiences in shared settings or locations. Within every built space there exists a unique community, one where people live, age, work, socialize, play and learn. These communities develop social networks, cultural norms and organizational structures.

The global, national and local conditions that surround an individual are known as the social determinants of health, which include physical determinants, or the physical and built conditions that impact the health of an individual. Addressing these determinants of health can have a profound influence on the health and well-being of not just individuals but also communities at large. Designing built spaces in a way that enables all individuals to access, participate and thrive within the systems and structures of each community is essential to shaping individual and collective health outcomes.

The concept of community well-being is one of the frameworks for community assessment along with other concepts (e.g. local community quality-of life studies, community health or community capacity). Measuring well-being in a community is vital to and it provides critical information for decision-making regarding sustainable development in regional communities. It is focused on understanding the contribution of the economic, social, cultural and political components of a community in maintaining itself and fulfilling the various needs of local residents (Kusel and Fortmann, 1991)

Figure.32: Community Wellbeing: A Framework for the Design Professions(Julia Markovich, Monika Slovinec D'Angelo, and Thy Dinh)

Academic Sector

The relationship between the built environment and wellbeing of students, faculty, and staff is acknowledged in schools, universities/ colleges, and other academic institutions. This acknowledgement has historically focused on physical health, but recent academic studies stress the importance of adopting a broader view of wellbeing that includes mental, social, and physical health. There is also a clear link between physical environments at schools and universities and academic performance.

This link is acknowledged by institutions such as the Association for Supervision and Curriculum Development, the U.S. Centres for Disease Control and Prevention (CDC), and WHO, which notes that "healthy children achieve better results at school, which in turn are associated with improved health later in life." This is especially important, given education's social and economic effects. Academic institutions have developed a variety of initiatives to create physical environments that lead to better wellbeing outcomes. Key elements of these principles include air quality, furniture, lighting, connections to nature, art and colour, inclusive physical spaces, and social connection.

Stakeholders including designers, developers, administrators, and governments—who work toward ensuring the academic sector is designed to encourage healthy and happy users—including employees, students, and others in the community are more likely to experience the economic benefits from a business, individual, and societal perspective.

Design Features Associated with Wellbeing and Economic Gains in Academic Settings

Design features are frequently cited as having a positive impact from a wellbeing and business perspective.

Social Domain

Spaces that welcome students and make them feel safe encourage learning and are important for their envelopment. For early learning centres, for example, spaces should be "cozy," inviting, bright, and linked to the outdoors. Several academic institutions are moving away from a traditional methodology that emphasizes a top-down approach to providing "instruction" to one that is focused on enabling "learning, including the curation of the corresponding learning environments that nurture personal exploration and collaboration.

Environmental Domain

Biophilia and views of nature are associated with improved classroom learning rates. Environments that foster student and staff wellbeing tend to incorporate views of nature and enhance building interior environments with indoor plants.

Presence of natural light/daylight is related to educational achievement and students' performance in academic settings. For example, positive correlations have been demonstrated between classroom daylighting levels and academic performance. Low-quality light can make it difficult for students to see and to process information, decreasing their capacity to learn and thus increasing their levels of stress. Control over light is also important; teachers who could control the amount and type of light were found to be healthier, happier, and more efficient. The quality of views and the amount of daylight in buildings and workspaces have also been shown to be significantly related to the amount of sick leave taken by teaching staff.

Acoustic conditions, including background noise and reverberation time (the length of time sounds remain in a defined space), have been linked to several indicators of student and staff wellbeing. For instance, background noise in the classroom and isolated "noise events" in the surrounding environment have been found to lead to poorer student academic performance, especially among students with special needs. High reverberation times and exposure to sound were associate with lower job satisfaction, increased fatigue after work, and reduced motivation among teachers, leading some teachers to express interest in leaving their jobs.

Indoor air quality, mainly poor ventilation, can lead to declines in academic performance through decreases in students' reaction times, ability to associate text and colour, memory, and word recognition.

Cultural Domain

Spaces that support a full spectrum of learning needs, mainly collaboration, individual study, point-of-need services, or "occasional" sessions taught by campus faculty, are deemed to be important for academic performance and wellbeing in academic settings. Many Canadian post-secondary institutions are actively trying to increase their international students and/or continued education enrolment. They are also acknowledging the imperative of indigenizing their curriculum and campus (including spaces and symbols). Success in these ventures is contingent upon their ability to create physical environments that foster a sense of cultural and social wellbeing.

Political Domain

Spaces that foster individualization, ownership, flexibility, and connection are linked to wellbeing by benefiting students' learning process and behaviour. For example, personalized spaces are better for absorbing, memorizing, and recalling information. Ownership of the classroom sets the stage for cultivating feelings of responsibility. A classroom that has distinct architectural characteristics (e.g., unique location [bungalow or separate buildings]; shape [L shape shape]; embedded shelf for display; facilities specifically designed for pupils; distinctive ceiling pattern) also seems to strengthen the pupils sense ownership.

Spaces that create a collaborative learning environment are associated with higher levels of social presence, satisfaction with the learning environment, and collaboration among students. Spaces that are visually transparent allow both teachers and students to observe and learn from teaching and learning occurring in other learning spaces, and to be observed in return. Visual transparency allows for teaching practice to be observable by those passing by the learning space, supporting a more collaborative and shared style of teaching. Shared space also promotes collegiality and enhances informal professional discussions and collaboration among teachers/ professors. Community health and wellbeing requires further research to identify the metrics for community wellbeing as it is a very broad aspect

Well Building Standard v2

The WELL Community concept aims to support access to essential healthcare, workplace health promotion and accommodations for new parents while establishing an inclusive, integrated community through social equity, civic engagement and accessible design.

C01 HEALTH AND WELLNESS AWARENESS

This requires projects to provide a guide to occupants that highlight the relationship between health and buildings and annual communications about health resources and programs. By supporting awareness of health and wellness programs and policies and enhancing health literacy, projects can encourage engagement in WELL features and support overall health and well-being.

Implementation Requirements

Providing well feature guide - Materials and communications are provided to allow occupants to familiarize themselves with and benefit from features that are achieved by the project, including:

- A guide (prominently displayed and/or made widely available to all occupants) describing the WELL features pursued by the project.
- Information that explains the impact of the built environment and other environmental factors on occupant health, well-being and comfort.

- Annual communications (e.g., emails, modules, trainings) to occupants about available health education, resources and policies available to them through WELL features pursued by the project

Promote Health and Wellness Education

For All Spaces all occupants are offered a digital and/or physical library of health and wellness educational materials that meets the following requirements:

- Covers ten unique evidence-based health topics.
- Topics are tailored to the health concerns of building occupants (based on available regional, local and building-level demographic and health-related data) and should focus on primary prevention. Topics can include any aspect of health and wellness covered in WELL in addition to any other health topic relevant to the occupant population.
- If physical, library is open during regular business hours.

Education can come in the form of trainings, brochures, videos, posters, pamphlets, newsletters and/or other written or online information. All educational materials must be checked annually to confirm information is relevant and up-to-date

Recommendations Based on Observations

UBC has bi-monthly Wellbeing Round-up email contains wellbeing-related news from across our campus. UBC Wellbeing is a collaborative effort to make the University a better place to live, work and learn through a systems-wide approach to wellbeing across our campuses. The work of UBC Wellbeing is guided by the Okanagan Charter, a shared call to action for partners, leaders, and community members to make UBC a leading wellbeing-promoting university.(details at https://wellbeing.ubc.ca)

Figure.33: Banners to promote H&W functions of building

Figure.34: IK Barber Learning Centre, UBC, British Columbia

For Existing Well Features

Eye catching sign boards may be used to indicate the best features of the building which promote health and well-being along with the updates in the websites and reports. It is very useful for new students at UBC to utilize the features of health and wellbeing. For example, in “IK BARBER LEARNING CENTRE”, which has active workstations and adjustable-height desks there are no specific sign boards or details about these features. It can improve utilization further especially for new students.

C02 INTEGRATIVE DESIGN

Requires projects to facilitate a collaborative design and development process from commencement to completion of WELL Certification. Can be achieved by engaging stakeholders from project onset creates the opportunity for dialogue between key decision-makers, planners and occupants. Collecting stakeholder input can help the project identify and address the essential components of a WELL project, including the ten concepts of WELL, while celebrating local culture and place, which reinforces a project's unique culture and identity and enriches the space for occupants and visitors. A stakeholder input process supports the project as it develops and progresses toward its health and well-being goals, creating a space that meets the needs of all stakeholders.

Implementation Requirements:

Facilitate Stakeholder Charrette

Projects engage stakeholders upon point of registration in project design and development and conduct the following activities:

- Identify project stakeholder groups, including (as applicable) the owner, manager, facilities management team, architects, engineers, occupants, residents and human resources and workplace wellness staff.
- Perform a values assessment and alignment exercise with the team to inform any project goals or strategies to meet stakeholder expectations.
- Engage new stakeholders who join the process after the initial meeting, such as contractors, sub-contractors, anticipated users of the space or new hires to the project's leadership team (as applicable). d. Set future meetings to stay focused on the project goals, develop a plan of response to stakeholder feedback and maintain a record of response.

Integrate Beauty and Design

Projects have to develop a written narrative to address the following:

- Celebration of culture (e.g., culture of occupants, workplace, surrounding community)
- Celebration of place (e.g., local architecture, materials, flora, artists)
- Integration of art
- Human delight

Promote Health-Oriented Mission

A written document detailing the project's health-oriented mission is produced in consultation with all stakeholders, meeting the following requirements:

- Outlines objectives for health promotion.
- Connects supporting and improving occupant health to the organizational objectives or mission statement.
- Accounts for building site selection and/or conditions, including site factors that impact occupant health and wellness.
- Incorporates the ten WELL concepts: Air, Water, Nourishment, Light, Movement, Thermal Comfort, Sound, Materials, Mind and Community.
- Integrates operations and maintenance plans for facility managers and personnel managing policy requirements related to health and well-being.

Facilitate Stakeholder Orientation

Upon project completion, all stakeholders, including at minimum (as applicable) the owner, manager, facilities management team, architects, engineers, occupants, residents and human resources and workplace wellness staff:

- Tour the building as a group and make tours available to all interested occupants.
- Discuss how building operations, maintenance, programs and policy will support adherence to WELL
- Communicate with stakeholders (including building occupants) the planned or existing operations, maintenance and policies that support adherence to WELL.

Integrated design

It requires projects to facilitate a collaborative design and development process from commencement
Integrate beauty and design: For all space's projects develop a written narrative to address celebration of culture, space, integration of art and human delight

Figure.35: Musqueam / Camosun, UBC, British Columbia

This space is almost in the centre of UBC near book store, “MUSQUEAM” space or the small lake “CAMOSUN BLOG” which needs maintenance. It may become a breeding ground for waste plants, bacteria, mold, and parasites that can become harmful to health. This space needs to be addressed to make students passing by to feel more delightful

Promotes Health-Oriented Design

For all spaces outline the objectives for health promotion, accounts for building site selection, including site factors that impact human health and wellness

Figure.36: Frederic Lasserre Building, UBC, British Columbia

There is no water fountain in this building other than in the studio which requires a key card. students who have classes in this building with no key card has no access to water fountain.

C03 OCCUPANT SURVEY

This WELL feature requires projects to collect feedback from building users on their health and well-being and on topics related to WELL. Given the diversity in the operation and design of built spaces, it is difficult to prescribe a comprehensive set of features that are effective across all settings. For example, decision-makers and users of the space often experience things differently. Surveys that ask a representative sample of building users about their level of satisfaction with indoor environmental quality, access to nature, wellness policies and their health provide valuable insight into whether or not the people who live and work in the building are satisfied with their conditions.

Giving building users the ability to offer feedback helps identify problems and evaluate the effectiveness of interventions aimed at improving health and well-being for that particular population, and presents an opportunity to create a healthier environment.

Implementation requirements:

Select Project Survey

- 3rd party: To collect feedback from the building users on health and wellbeing choose between 3rd party survey provided annually by a survey provider approved by IWBI
- Custom survey which includes at least the general occupancy information, job type , time spent in the building , indoor environment quality of air, water ,light, sound and thermal comfort, ergonomics, layout and aesthetics, ,maintenance, cleanliness, amenities like access to nature, views, nourishment, workplace wellness initiatives or offerings , amenities to support healthy behaviour and other socio-demographic information (age & gender at minimum)

Administer Survey and Report Results

- Surveys are administered annually at minimum.
- Survey protects all participant-identifying data through appropriate protective measures such as anonymous reporting; any communication of results should be on an aggregated basis such that no participant can be identified.
- Analysis of responses is conducted by qualified personnel or a qualified third party.
- Aggregate results from the survey are reported annually and submitted through WELL Online.

C04: ENHANCED OCCUPANT SURVEY

It requires projects to collect and respond to an exhaustive spread of information from building users on their health and wellbeing before and during occupancy

For office spaces, to address three to six additional topics from the following in additional to the standard survey mentioned in the precondition

- Comparison to previous building.
- Mode of transportation to and from work and distance travelled.
- Individual work style, patterns, processes and space utilization to assess need for focus or collaboration.
- Water access and consumption.
- Safety and security.
- Access to nature.
- Health promotion programs (including physical activity promotion).
- Leadership investment in employee health.
- Social equity.
- Sleep satisfaction.
- Hours of physical activity per day.

- Number of breaks taken per day.
- Smoking habits.
- Hours worked (expected and actual over a four-week period).
- Workload and stress.
- Creative thinking.
- Sick building symptoms.
- Socio-demographic (e.g. education, ethnicity, income)

Recommendations

Based on the feedback if less than 85% people are very satisfied then conduct surveys validated surveys and questions, especially for measuring health, well-being and productivity, ensure that sensitive questions are framed appropriately and that they measure what they are intended to measure, combined with environmental satisfaction questions. Examples of abstract response scales using terms or icons (refer to the image below). This is a form of attitudinal or Likert scale, with or without numerical references. Many built environments surveys favour these scales, as scaling intervals based on emotions are believed to help respondents rank their subjective feelings towards conditions.

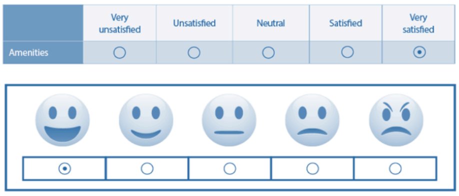


Figure.37 Likert Scale

In house post occupancy surveys will help to identify the key issues if any to be addressed before going for well certification. In general, the Measures of Health and Well-Being address three components:

1. Current health status
2. Sustainability of health (lifestyle behaviours and preventive services that determine future health)
3. Life satisfaction (overall well-being)

The above mentioned are the preconditions for well standard.

C05 HEALTH SERVICES AND BENEFITS

This WELL feature requires projects to provide access to essential health services, screenings and assessments and offer on-demand health services.

Basic healthcare services include essential primary care and preventive services such as medical, dental, vision, mental health, substance use, preventive screenings, disease management and biometric assessments. Providing timely access to health services can relieve both actual and perceived barriers to care. Studies demonstrate that the overwhelming majority of employees, aside from wanting basic health services, also want added flexibility to select and opt into coverage that fits their unique health needs. Projects offering benefits consultation and on-demand health services can support flexible healthcare coverage and maximize employee engagement in health benefit programs.

Implementation requirements:

Promote Health Benefits - health benefits are available to all eligible employees and their dependents, at no cost or subsidized by at least 50%, that include coverage for the following:

1. Access to medication/prescription.
2. Essential immunizations based on region.
3. Tobacco cessation programs.

Offer On-Demand Health Services - experienced and qualified healthcare providers (e.g., physician, nurse practitioner, physician assistant) are available to provide confidential medical treatment for episodic, recurrent, urgent or other illnesses before, during and/or after typical business hours.

C06 HEALTH PROMOTION

This WELL feature requires projects to cultivate a culture of health through various health promotion strategies, including communications, stakeholder involvement and health risk assessments. Organizations can build an internal culture of health through health promotion programs that are customized to an organization's unique needs, integrated into their operations and business strategy, promoted through consistent communications, championed by leadership at all levels, given dedicated resources and supported by high student / staff engagement. Communication campaigns can effectively increase awareness about workplace or community health programs, opportunities and services. Furthermore, building incentives into wellness programs can help raise student/ staff participation and motivate behaviour change such as weight loss and smoking cessation. Health risk assessments, combined with education on assessment results, are a cost-saving component of health promotion that can effectively address a range of health factors, including tobacco use, alcohol use, seat belt non-use, dietary fat intake, blood pressure, cholesterol, absenteeism and healthcare services use.

Implementation requirements:

Promote Culture of Health - a narrative describes how occupant health is promoted through at least two of the following:

- Posters, signage or digital communication that reinforce the project’s culture of health and market health promotion programs to employees.
- A program that highlights occupants who exemplify the building’s health culture.

- Incentive programs to increase participation in health promotion initiatives and programs (e.g., health risk assessments).
- Incentives could include gift certificates, cash, paid time off, product or service discounts, reduced health insurance premiums, employee recognition or other prizes.
- Competition programs combined with incentives to support engagement in health behaviours (e.g., walking, bringing healthy lunch)

C07 COMMUNITY IMMUNITY

This WELL feature requires the provision of annual influenza (flu) immunizations, flu prevention campaigns and support in accessing other necessary vaccines.

Vaccination is the most effective way to prevent the flu. Providing on-site, free and actively-promoted flu vaccines is a highly effective method of increasing vaccination rates and reducing seasonal flu cases. Employer-sponsored vaccination programs are relatively inexpensive, cost-saving and effective, as simply reducing out-of-pocket costs alone can improve vaccination rates. Additionally, providing education on good health habits, such as hand hygiene and cough etiquette, can help stop the spread of germs and prevent illnesses like the flu. Beyond the flu, other essential immunizations are recommended based on a variety of factors including age, lifestyle and medical history. By reducing common barriers to vaccination and providing vaccine education, immunization programs can minimize the many health and productivity costs of vaccine-preventable diseases while supporting the health of individuals and the wider community.

Implementation requirements:

Promote Seasonal Flu Prevention:

- Alerts eligible employees and students (as applicable) regarding the availability of on-site flu vaccine clinic, coverage or vouchers and encourages or incentivizes individuals to receive the vaccine.
- Provides education for eligible students (as applicable) on the health reasons to receive the vaccine, good hand hygiene and cough etiquette.

C08 NEW PARENT SUPPORT

This WELL feature requires paid parental leave, supportive services for parents returning to work and resources to ensure workplace support and inclusion (for staff):

- Offer New Parent Leave
- Promote Workplace Support

C09 NEW MOTHER SUPPORT

This WELL feature requires the provision of designated lactation rooms with supportive design and amenities, as well as initiatives and educational opportunities that help women initiate and sustain breastfeeding. There are designated breastfeeding-friendly Spaces at UBC Vancouver.

C10 FAMILY SUPPORT

This WELL feature requires projects to offer programs that support individuals with childcare, eldercare and other family caretaking needs

Projects must provide at least three of the following:

a. On-site childcare centres compliant with local childcare licensure, operated by either the employer or a separate organization, or subsidies of at least 50% for off-site child care.

b. Back-up childcare assistance.

c. Seasonal childcare programs or policies for occupants with school-age children

C11 CIVIC ENGAGEMENT

This WELL feature requires a commitment to civic engagement and social responsibility with a focus on charitable activities and contributions and voting support.

C15 EMERGENCY PREPAREDNESS

This WELL feature requires projects to have an emergency management plan in place and to have accompanying supportive resources for responding to an emergency. By focusing on prevention and preparedness, buildings and communities can support collective safety, survivability and well-being during emergency situations

Implementation requirements:

Develop Emergency Preparedness Plan - an emergency management plan is in place outlining response in the case of emergency situations within the building or surrounding community, including at least the following hazards:

- Natural (e.g., tornado, flood, wildfire, earthquake, heatwave).
- Fire.
- Health (e.g., acute medical emergency, infectious disease outbreak).
- Technological (e.g., power loss, chemical spill, explosion).
- Deliberate (e.g., human-caused threat).

A narrative is required on how the following are incorporated into the emergency management plan

- Roles and responsibilities of the emergency response team.
- Potential hazards and emergency situations.

- The needs of vulnerable occupants or groups (e.g., older adults, people with disabilities, pregnant women, children).
- Building response capabilities, including assessment of supplies, specialized personnel and physical structure.
- Plans for policy implementation and communication to building occupants, including occupant training on the emergency management plan and practice drills.

Promote Emergency Resources - a policy and accompanying resources are in place that support occupants in responding to an emergency, including at least five of the following:

- Database of building emergency equipment, supplies and procedures available to all occupants, including information cards indicating emergency procedures available to all guests upon entrance to the building.
- Emergency notification system in the building with auditory and visual indicators of emergency (e.g., speaker system, flashing lights).
- At least one first aid kit per floor meeting requirements of American National Standards Institute (ANSI)/International Safety Equipment Association (ISEA) Class A or Class B based on project need.
- AEDs within reach of any given occupant within 3-4 minutes and adoption of routine maintenance and testing schedule. The locations of building AEDs are identified through posters, signs or other forms of communication other than on the AED itself.
- Annual availability of a certified training course on cardiopulmonary resuscitation (CPR) and AED usage.
- Emergency response team for medical emergencies, including at least one certified medical professional or first responder present within the building.
- Rides subsidized by at least 50% to destination of need for emergency situations (e.g., urgent medical needs, personal or family emergency, public transit shutdown).

Application in strategic planning

The attributes of Health and Well-Being can provide valuable data for strategic planning for campus planning, landscaping for schools, policy makers, businesses and other community partners. The results will contribute towards a evidence based standard measurement approach to improving health and well-being for individuals as well as for communities.

3.2.5 Mind

Whilst is might seem obvious that human's bear the capacity for introspection, the mere concept that a being be able to distinguish itself from its environment and adjacent beings poses a condition that causes vulnerability of the 'mind' to be influenced by the day-to-day environment. The impact of outside forces can often cause negative changes to the mental state influencing normal human function, this is generally considered as mental illness and is of growing concern to public health. Consequences of mental health on the individual can be, but are not limited to, lacking productivity, poor stress coping mechanisms, low self-esteem and motivation, compromised physical health and risk of chronic disease. The increasing global burden of mental illness is recognised and in 2010 accounted for nearly 184 million disability-adjusted life years (DALYs), 8.6 million years of life lost to premature mortality (YLL) and over 175 million years lived with disability (YLD) worldwide[21].

Mental health, 'mind', can be simply broken down into two main categories: cognitive health, the ability to clearly think, learn and remember, and emotional health, the state of thoughts, feelings and behaviours which enable an individual to be able to function in society and meet the demands of everyday life. Both cognitive and emotional health are inherently linked however are influenced directly by different factors, and hence implemented prevention and treatment strategies should approach the problem of 'mind' accordingly.

The built environment makes up a strong majority of the average human experience whereby 90% of time spent occurs indoors[22], and hence is important to seriously consider the physical spaces that students, staff and faculty interface and have access to[23]. Institutional buildings represent significant indoor exposure time and should be bear responsibility for influencing positive change in mental health. The connection between determinants of human health, physiological, psychological, cognitive, and social functioning[24] (physical, mental and social health), and the built environment has grown recognition dramatically amongst policy makers, decision makers, the construction industry and financiers. Built environment responses to health through urban planning and public spaces have been researched and practiced in depth through a strong union between the public health and urban planning sectors[25], this relationship reflects like policy maker support.

Through the WELL Standard and UBC Wellbeing, the Green Building Action Plan gives tremendous support to the significance of mental health in the planning, execution and operation of the built environment on UBC's campus, however is yet to develop a measurable approach to policy implementation, and hence petitioning an effective method to monitor and execute successful cognitive and emotional wellbeing policy.

[21] WELL Building Standard v2 Website

[22] American Institute of Architects, Practicing architecture: design and health (2016)
[23] Committee on the Effect of Climate Change on Indoor Air Quality and Public Health, Climate Change, the Indoor Environment, and Health (2011)
[24] JH. Heerwagen, Green Buildings, Organizational Success, and Occupant Productivity, Building Research and Information vol.28 (2000)
[25] Jackson RJ , Dannenberg AL , Frumkin H, Health and the built environment: 10 years after, Am J Public Health (2013)

Institutional Building Implementation Feasibility

Health & wellbeing decisions at the building scale are generally supported by the economy of improved productivity or success which will in turn produce benefits to an agent, investor or decision maker. This trend is clearly supported by the availability of information regarding employee productivity through means of health promotion and implementation in urban and building design. The importance of an ongoing healthy mind from an informed employer perspective is paramount to success.

The Canada Green Building Council's Health and Wellbeing statement reads 'People who live, learn and work in these [green] buildings and homes have been found to be more productive, higher performing and healthier. Whether it is improved employee retention, fewer sick days or better math scores, the end result is clear: green buildings are good for you'. Occupant health and performance are generally attributed to a financial bottom-line or risk-adjusted return, as a consequence, health promotion in institutional projects is highly feasible for decision makers through typical financial pathways without the assistance of grants and other incentives. Hence, the decision to develop policy and monitoring of the mental health of students, staff and faculty at UBC via definitive data suggesting the effects of mental health on productivity and performance is expected.

Metric & Policy Development

Whilst attempting to decipher appropriate metrics to evaluate mental health in buildings, it is important to consider the inextricable link that 'mind' has to adjacent health & wellbeing sub-components: air, water, nourishment, light, movement, thermal comfort, sound, materials, mind and community. For example, the impact of poor acoustic barriers between service areas and teaching spaces could cause 'noise annoyance' for students which can cause psychological stress, feelings of irritation, discomfort, distress, or frustration[26] and effect the concentration of those students. Similarly, the impacts of interior lighting conditions can impact the circadian rhythms in cognitive performance[27] (sensory, motor, reaction time, time estimation, memory, verbal, arithmetic calculations, and simulated driving tasks) and thus having dramatic impacts on the measurement of overall mental health. As the impacts on mental health are often an indirect consequence of outcomes in other finite sub-components, the approaches to measure 'mind' can be a relatively grey and difficult to cumulate as a collective. In light of this, great consideration should be given to the unique basis of 'mind' and that its inclusion without any hierarchy be reviewed. The below graphic portrays the role that 'mind' plays within the health and wellbeing landscape.

[26] Chan, T.H, Harvard School of Public Health, 9 Foundations of a Healthy Building (2017)
[27] Valdez P, Ramirez, Garcia A, Circadian Rhythms in Cognitive Performance: Implications for Neuropsychological Assessment (2012)

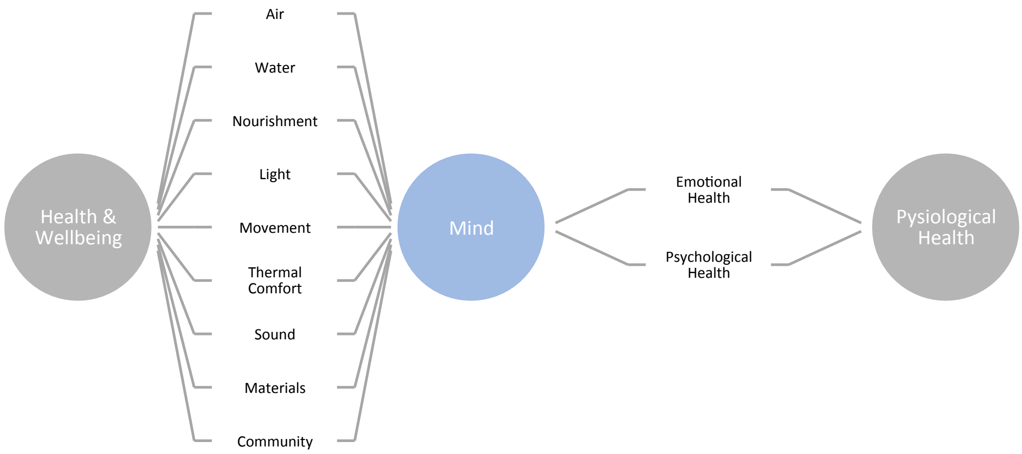


Figure 38: Health & Wellbeing Sub-components impacting 'mind'

It is under this theory that any attempt to measure cross correlating sub-components of health & wellbeing in parallel is ineffective and produces double counting, hence, like the WELL Building Standard, isolating 'mind' as a means to measure and promote effective prevention and support is most productive. The outcomes and risks formed as a consequence of other components and the successive management of those outcomes encompass the extent of concern for the 'mind' sub-component. To better understand this, adequate access to daylight would be a quantitative metric as part of the health & wellbeing sub-component 'light', although having significant impact on the cognitive and emotional mental health of subjects exposed to that measure of light, measures and policy recommendations for 'mind' should address only the awareness, education and treatment of effects on mental health without interference of subsequent 'light' metrics. Evaluation of metrics across sub-components should eventually be substantiated to create a the most complete picture, and to then inform policy change.

The WELL Building Standard harnesses the above framework to avoid the potential crossover in measuring health & wellbeing, whereby the following graphic explains the concepts that make up the 'mind' component.

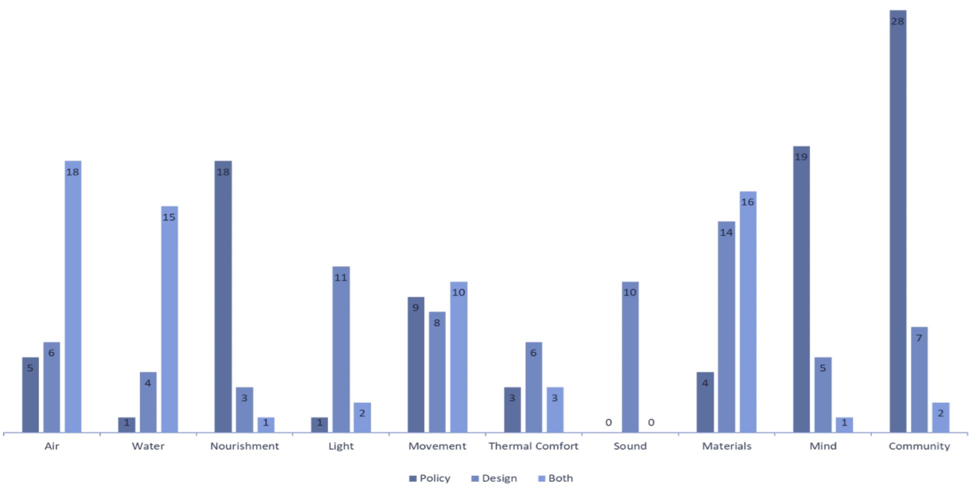


Figure 39: WELL Building Standard v2 concept points by policy/design

Policy

- M01 Mental Health Promotion
- M02 Access to Nature
- M03 Mental Health Support
- M04 Mental Health Education
- M05 Stress Support
- M06 Restorative Opportunities
- M08 Restorative Programming
- M10 Focus Support
- M11 Sleep Support
- M12 Business Travel
- M13 Tobacco Prevention and Cessation
- M14 Substance Use Education and Services
- M15 Opioid Emergency Response Plan

Design

- M07 Restorative Spaces
- M09 Enhanced Access to Nature
- M10 Focus Support

Figure 40: WELL Building Standard v2 ‘mind’ focus areas by policy/design

As seen in the WELL Building Standard concepts, categories such as mind are heavily weighted toward policy implementation rather than design, and hence suggesting that majority of design strategy that influences ‘mind’ has been constricted within its primary category (eg. light, movement, sound, etc.). The WELL Building Standard suggests a focus of concept implementation in treatment and prevention of mental illness through supportive environments and programs whilst majority strategy to avoid aggravation exists exclusively within more tangible primary categories.

The manner in which this concept framework is designed proposes that a focus on supportive pillars for mental health is the most appropriate method for policy and metric arrangement and will deliver an accurate overall health & wellbeing picture of how a case study performs but may not necessarily detail the extent of mental health considering its deep nesting in all other concept areas. The current WELL Building Standard v2 will give a very accurate idea of the mental health education and awareness, but will fail to provide a thorough narrative of cognitive aggravators and potentially overlook the prevalence of negative emotional health influences.

Recommendation to GBAP

As 'mind' is intricately imbedded within all sub-components of health & wellbeing, the most effective approach to building hierarchical metrics is to replicate the structure of the WELL Building Standard but to implement a more complete strategy for post-assessment of 'mind' by offering two final 'mind' scores for a project.

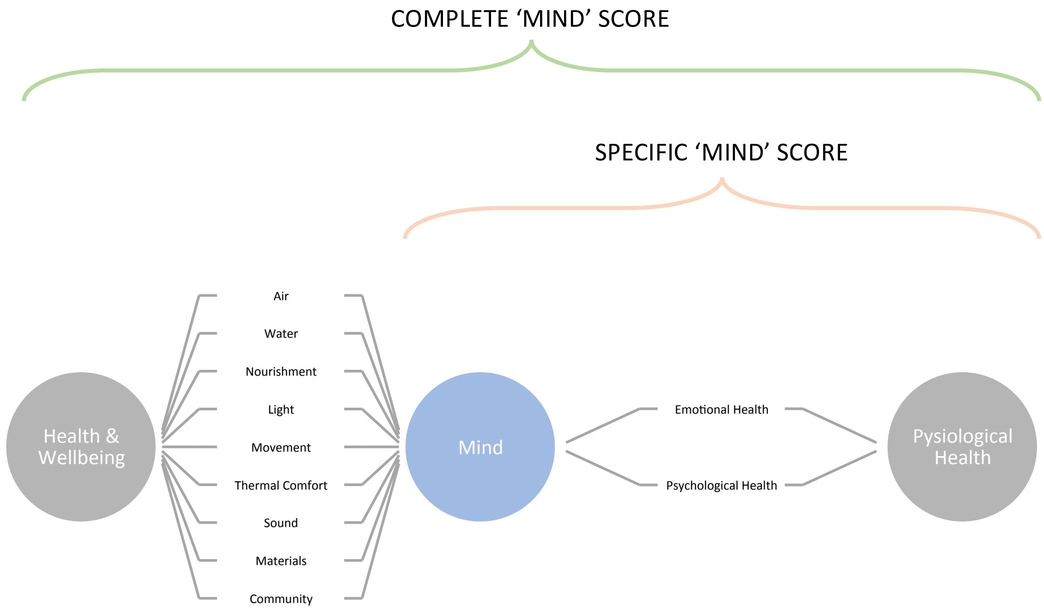


Figure 41: Understanding the scope of different measuring schemes for mental health, 'mind'

The first being a total quantitative score for policy implementation addressing treatment, education/awareness and prevention through programs and restorative spaces without the numerical influence of causal features of a project (eg. indoor environment quality and its impact on mental health), this assessment will provide an outlook of the projects attitude. Although, as we know, the presence of prevention and awareness is limited by the tangible influences of a project, to successfully assess a projects satisfaction of mental health it is extremely important to evaluate causes of negative change in mental health in institutional buildings, and hence conducting surveys of students, staff and faculty to populate a story of how the workplace or teaching space has contributed to their underlying mental wellbeing. The survey should cover all lengths of stimuli within the project despite overlap of metrics in other sub-components, and in doing so provide an isolated 'mind' score across the entire project. Metrics should be predetermined in weighting in order to give an accurate depiction of mind, for example, the 'level of natural daylight' to a work area would be far greater in influence of mind than 'access to vending machines', and hence a hierarchy of relevance would be developed.

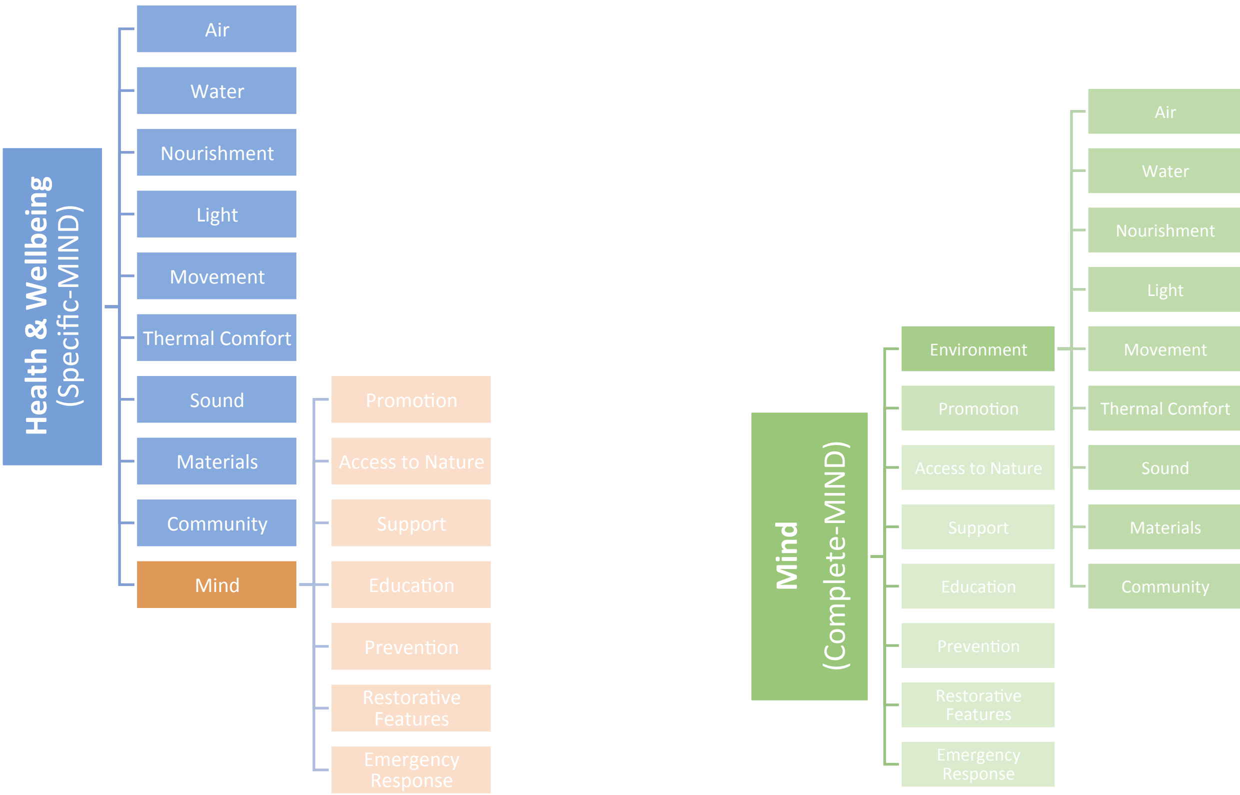


Figure 42: Suggested UBC GBAP Health & Wellbeing 'Specific-MIND' Score (left)
Figure 43: Suggested UBC GBAP Health & Wellbeing 'Complete-MIND' Score (right)

By obtaining a 'specific-mind' score and a 'complete-mind' score, the measuring process avoids overseeing influences provoking mental health and increases the probability of understanding a more relevant data set. The combination of both measuring methods will attempt to deliver a stronger metric for the most central sub-component to the success of health & wellbeing in a project.

Despite the long-rooted nature of 'mind' in health & wellbeing, it is still imperative that above metric scores should inform ongoing change in policy across all sub-components and continue to develop over time.

4.0 Recommendation & Conclusion

Thermal comfort and sound are both critical indoor parameters during building design. To reach GBAP visions, encouraging shading and operable windows as cooling methods is the easiest policies to be implemented. Afterwards, related guideline could be updated to give a more detailed requirements for future designing. Finally, connected to community collaboration and landscape design, integrated design process could help us have an entire understanding of comprehensively application. Community wellbeing is a very broad study which requires further research to understand the metrics of community health and well Being. To understand the health and wellbeing of a space, survey should be developed, customized to a space and conducted to understand the opinion of the student/ professor/staff.

It is suggested for UBC to pay more attention to the issue of transparency regarding lifecycle assessment in building materials and therefore, choose the building materials that have been provided by transparent resources. It is suggested for UBC to pay attention to each step of the lifecycle assessment process, particularly in relation to recycling building materials. UBC needs to check the amount of radiation in existing building materials in their buildings. Since the length of the gamma ray is too short, UBC needs to check the building materials in each building and each room separately with radioactive radiation detector tools. The risk impact of radon gas exposure from the soil and land in UBC is low, however, such risk impact could also be reduced through 3 main methods to limit soil gas infiltration due to air pressure differences between the soil and the indoor occupied space are: Renovation the Foundation of old buildings, Active Soil Depressurization (ASD), Ventilation of Unoccupied Spaces.

Considering the broad interconnectedness of mental health to the impacts from health and wellbeing measures of thermal comfort, sound, material and community, an underlying need to measure these components both in isolation and under the mental health microscope are essential in understanding the complete influence all components of health & wellbeing are having at the human scale.

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