Identifying Policy Barriers to Multi-Unit Residential Building Design Elements that Promote Good Indoor Environmental Quality in Canada

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Abstract

Designing buildings, particularly multi-unit residential buildings (MURBs), to promote occupant comfort is a relatively underexplored field of study. The objective of this work was to identify elements of building design which contribute to promoting good indoor environmental quality (IEQ). This involved a global search of award-winning MURBs to identify unique building features which are designed to promote good IEQ. Features selected for discussion were divided into three categories: building form, internal layout, and fenestration & façade. Analysis of relevant building policies, codes and standards revealed that there were no significant policy barriers that greatly limited the applicability of the identified features that could be used to promote good IEQ in Canadian MURBs. Such features are instead constrained by practical limitations, such as development cost and design complexity, as well as a lack of IEQ requirements within the relevant codes which tend to focus more on carbon emissions reduction and energy conservation. This gap represents a significant area for improvement in future code amendments.

Introduction

Background

Multi-unit residential buildings (MURBs) have become a popular form of residential housing in recent decades. According to housing start data from the Canadian Mortgage and Housing Association (CMHC, 2024) published in February of 2024 for calendar years 2022 and 2023: over 80% of new builds in Canada were MURBs. Despite the catch-all term, MURBs take many different forms and can vary greatly in size, layout, and construction. An example of this would be a three-storey attached townhouse and a thirty-floor high-rise apartment; two very different types of buildings which are both classified as MURBs.

Even within similar sub-categories, there can be variance in design elements, all of which have a significant impact on the building's performance and indoor environment (Andargie et al., 2019). Furthermore, MURBs suffer from IEQ-related issues which are less prevalent in detached houses, such as: airflow and contaminant concentration, poor daylighting, and sound transmission in shared walls and ceilings. This creates an inherent level of complexity in optimizing MURB design. However, one element all MURBs have in common is their purpose: to house people at a higher density than achievable with detached homes. And, ideally, these spaces are provided in a way that promotes occupant comfort.

Occupant comfort and well-being are characterized by the four domains of indoor environment quality (IEQ): thermal comfort, visual comfort, acoustic comfort, and indoor air quality (IAQ) (Tang et al, 2022). Statistics Canada (2016) census data for dwellings in Canada indicates that approximately one-third of Canadians live in MURBs. Despite this popularity and the known IEQ-related issues associated with typical MURB designs, occupant comfort is a relatively under-explored aspect of MURB design. Typical MURB design features include: large fenestration ratios, insufficient ability to naturally ventilate, and limited in-unit HVAC controls (Lozinsky and Touchie, 2024). With MURBs becoming increasingly relevant as a solution to global housing issues, it is important to understand which aspects of their design are most crucial to ensure they provide a comfortable, healthy, safe, and productive environment for their occupants (Horr et al., 2016; Wyon, 2004). One way to analyse IEQ elements which contribute to positive MURB design is to analyse existing buildings which have been formally recognized for excellence in design.

Previous Work

MURBs are not typically designed with occupant comfort as a priority but there are numerous building strategies or design elements which can be incorporated to improve IEQ. There are many examples of interventions which range in level of complexity and effect. For example, consider daylighting and visual comfort. Two different strategies which can be applied to improve daylighting controls include: adding exterior window shades or overhangs to control the amount of light and glare, or incorporating "step-backs" on higher floors to improve access to daylight.

Generally speaking, the addition of exterior shading elements is a much simpler design strategy than changing the building form through features such as step-backs, yet they both benefit occupant visual comfort. There is limited literature related to best practices for designing MURBs concerning occupant comfort. One of the main resources on this topic is the "MURB Design Guide" (Kesik et al., 2019).

This guide provides a series of suggestions for how to optimize MURBs for occupant comfort, both through physical building elements and building systems. Another design guide published by the Canada Mortgage and Housing Council also discusses MURB design but is primarily related to accessibility rather than occupant comfort (CMHC, 2021). Aside from these design guides, there are few publications which recommend best-practice designs to promote good IEQ in MURBs.

Objectives

The goal of this paper is to analyse various features from award-winning MURBs which positively contribute to effective IEQ and assess their viability from a Canadian perspective. The findings presented in this paper are based on the hypothesis that identifying common elements between MURBs recognized for excellence in design and exceptional occupant comfort can provide a qualitative standard for said features that MURB designers can follow. The findings presented here are an important step towards improving our understanding of the relationship between MURB design and occupant comfort.

This paper is limited to discussing three types of features identified in the award-winning MURBs: building form, internal layout, and facades. Each section includes: a brief description of the design element, an example from the MURB scan, and a technical description of why it positively contributes to occupant comfort. Furthermore, limitations to the application of the feature due to Canadian building codes, if any, are also discussed. The outcome of this is a series of recommendations related to how MURB design can be improved to better focus on occupant comfort.

Methodology

The first task in this work was to research relevant architectural and engineering award categories. All of the awards identified have comprehensive lists of previous recipients and nominee buildings on their respective websites. Awards from reputable organizations and programs such as: the American Institute of Architects (AIA), Council on Tall Buildings and Urban Habitat (CTBUH), and Ontario Association of Architects (OAA) were among those considered. Only awards related to sustainability, design innovation, or general demonstration of best practices for residential buildings were selected for this study. It should be noted that IEQ was not an explicit award criterion. Hotels, retail buildings, and offices were all excluded.

MURBs were identified using a keyword search in each award-winning building. Only buildings constructed after 2000 were considered in the search. However, the majority of recognized MURBs were awarded after 2010. Only the winners of such awards were included in the final search. Nominees for such awards were excluded from the search, with an exception for any award featuring a “people’s choice” category. The final selection of MURBs included 112 buildings from over 30 different types of awards across 23 countries.

The next step was to analyse each building and identify specific features which could contribute to good IEQ and occupant comfort. The majority of information regarding the buildings was obtained from the award databases and additional research was conducted on the specific buildings and respective architects, where required. Furthermore, several of the MURBs had dedicated reports which provided additional information. Sources such as the “MURB Design Guide” which provides information and recommendations regarding best design practices were used as the basis for the analysis.

The final step involved researching national, regional, and provincial building codes and standards that either originate from or are relevant to Canada. International building codes were not considered for the analysis as the focus is on the applicability of features within Canada. Particular emphasis was placed on sections relating to MURB IAQ and thermal comfort requirements, as these are typically covered extensively in codes and standards. Toronto and Vancouver were the focus of the municipal search as they both have the most well-established municipal standards related to high-performance buildings. The most recent versions of the Ontario and British Columbia building codes were also studied to understand the associated provincial requirements. This search was then extended to various other standards often referenced in the municipal, provincial and national standards, such as the ASHRAE standards. The following codes and standards were included in the search:

- ANSI/ASHRAE Standards 55, 62.2, & 90.1
- British Columbia Building Code
- National Building Code of Canada (NBC)
- National Energy Code of Canada (NECB)
- Ontario Building Code (OBC)
- Toronto Green Standard
- Vancouver Climate Emergency Action Plan – High-Performance Building Standard

Results

This section discusses the major findings from the review and describes their associated benefit. The findings of this paper only represent a small subset of the total number of features identified during the MURB scan. Selected features were chosen based on: relevance concerning IEQ according to literature, and representation within the MURB scan (i.e., features which appeared in more examples were prioritized). Furthermore,

an effort was made to identify different categories of features to provide diversity among results. Three categories were chosen which best represented the selected results: building form, internal layout, and façade. Table 1 summarizes the features of the following sections.

Table 1: Summary of the main building design features identified during the MURB scan.

Feature		Description	IEQ Efficacy
Building Form	Stepped Design	Building which gradually introduces a series of setbacks in the floorplate over its vertical axis. This results in a structure which is larger at the base and narrower at the top.	Improves daylighting, and visual comfort. The setbacks increase the surface area of the external walls and reduce instances of unintentional shading of lower levels by other parts of the building (Alghamdi, 2022).
	Mass Distribution	Breaking up large rectangular forms into "towers" of varying height.	Beneficial from a daylighting and IAQ perspective (Rizi et al., 2023). Distributing the building's mass results in more openings for light and air movement to the interior environment. Also reduces shadows from one part of the building to another and promotes airflow between them.
	Enclosed Space	MURB with an open centre, with each section of the building acting as an external wall to a central courtyard. Promotes a sense of community amongst occupants through larger, open shared spaces.	Improves acoustic comfort and view quality. A semi-enclosed space which is isolated from the surrounding area allows for a less noisy space on one side of the units and a more private environment (Mezeredi et al., 2022). Courtyards with green spaces also provide better view quality for occupants.
Internal Layout	Corridors	Includes single-loaded corridors: units on only one side of the corridor, and skip-stop: an uncommon layout in which corridors are located on every other floor, and units are two storeys.	Single-loaded corridor: Promotes effective daylighting and natural ventilation by creating openings on both sides of the unit (Majeed et al., 2019). Improves privacy by reducing the density of units per floor. Skip-stop plan: Promotes airflow and light penetration deeper into each unit by allowing for larger and taller units.
	Scissor Stairs	Staircase layout with two sets of interlocking stairs adjacent to one another. Increases available floorplan for units, and greatly reduces cost.	Promotes effective daylighting and airflow. Allows for a narrower building form so units can be designed with an advantageous aspect ratio (i.e., greater exterior wall area per floor area of unit) (McKeen and Fung, 2014).
Façades	Solar Control	Any method of controlling the amount of daylight within a unit. Two most common methods are external shading elements, and use of a low window-to-wall ratio (WWR).	Promotes visual comfort by reducing glare and optimizing daylight (Xue et al., 2015). Low WWR also reduces heat loss/gain through windows which results in localized thermal discomfort.
	Multi-Orientation Glazing	Operable windows on more than one exterior wall orientation. Often limited by the fact that most MURBs do not have multiple external walls with the exception of corner units.	Advantageous from an IAQ perspective. Providing several openings via operable windows on different exterior walls promotes effective cross-mixing of air through a unit (Brager et al., 2004; Mora, 2023).

Building Form: Stepped Design

There were several examples of stepped buildings identified during the MURB scan. Most of these buildings fell into the mid-rise category and were most prevalent in Europe. One notable example is a mid-rise apartment building called Mountain Dwellings, shown in Figure 1 below. The architects for this project specifically designed the building to optimize daylighting for all occupants regardless of the placement of their unit. This 10-storey building's south-facing façade features a stepped design. All 80 units have significant access to sunlight due to the staggered construction between units and the inclusion of sunrooms, further increasing the exposed surface area for each unit. Each level features a large terrace spanning the width of the building, further taking advantage of the wide floorplate and increased surface area.

Figure 1: Mountain Dwellings in Copenhagen, Denmark.

Building Form: Mass Distribution

Perimeter block buildings were well represented in the MURB search. Most perimeter block buildings are mid-rises, although there are several examples of small high-rises. One example is Star Apartments, shown in Figure 2 below, a mid-rise social housing apartment complex.

Figure 2: Star Apartments in Los Angeles, United States.

The building has a unique appearance, contributing to both its aesthetic and IEQ qualities. The breaks in the walls allow for better natural ventilation through the inner portions of the building, while also providing external staircases. Furthermore, the openings are spaced out in such a way that promotes daylighting to the innermost areas of the interior structure.

Building Form: Enclosed Space

By enclosing a central courtyard, these designs can promote good daylighting, views, and acoustic comfort with windows opening to this quiet space, as seen in many examples. However, a feature demonstrated by a select few was strategically orienting each unit's layout to take advantage of the increased privacy and comfort provided by the design. A MURB which illustrated a particularly effective use of this design approach is Hunter's View Housing Blocks 5&6. The floor plan of which is shown in Figure 3 below.

Each unit is arranged such that the bedrooms and living spaces open to the interior courtyard. This shelters the main sleeping areas from the noisy nearby streets, and also provides much higher view quality for the most commonly occupied spaces.

Figure 3: Floor plan of Hunter's View Housing Blocks 5&6 in Los Angeles, United States.

Internal Layout: Corridors

Single-loaded corridors, with units on a single side of the corridor, are significantly less common than double-loaded corridors where units are on both sides, with the latter being most common in low-cost housing since it allows for high-density unit layouts per floor. An example of a single-loaded corridor identified during the search was a residential complex, AMANI. The floor plan of this building's 8th floor is shown in Figure 4. This MURB features two towers that are connected by a series of catwalks, with each unit being accessed by exterior corridors, as highlighted in the floorplan. The elevators and staircases are located in the northern tower. This specific design was intended to promote natural light and ventilation. The use of two single-loaded towers rather than one double-loaded building allows for greater access to light and natural ventilation for all parts of the building. This design also improves privacy by reducing traffic in each corridor.

An example of the other corridor type, skip-stop plans, is the VM Houses. As the name implies, this MURB consists of two buildings: one shaped like a "V" and the other an "M". Both buildings are approximately ten storeys and contain three double-loaded access corridors as highlighted in Figure 4. All units are two storeys with an internal staircase and alternate between accessing upper and lower floors relative to the corridor. The double height of each unit and balcony allows for effective daylighting within each unit.

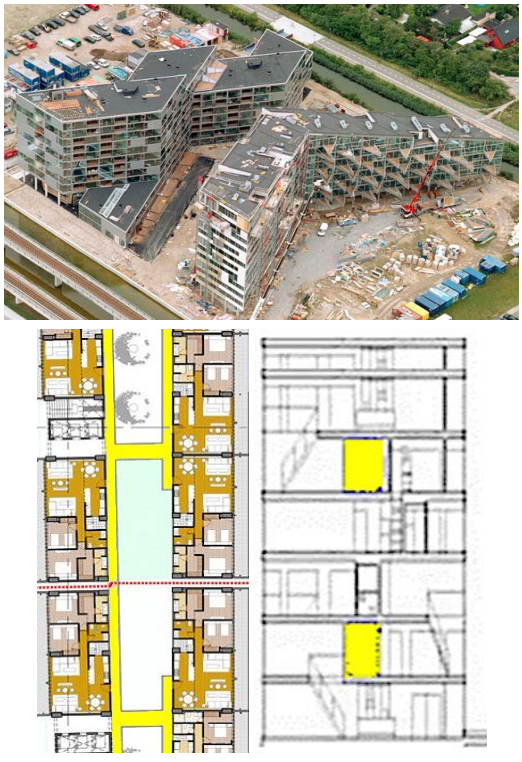

Figure 4: Photograph (top) and cross-section (bottom-right) of VM Houses in Copenhagen, Denmark, and the floor plan of AMANI in Puebla, Mexico (bottom-left).

Internal Layout: Scissor Stairs

An important yet often overlooked aspect of interior building design is the design of the circulation strategy to promote IEQ. Scissor stairs were featured in several high-rise buildings outside of Canada. Two general MURB archetypes were identified in the MURB scan which demonstrated the effective use of the scissor stair design:

1. Narrow buildings with densely arranged units, and
2. Compact footprint with a centralized stairwell.

An example MURB for each option is Collins Street Residential Building and 56 Leonard Street, respectively. The floor plan for both buildings are shown in Figure 5.

Collins Street Residential Building is a 60-storey market rate housing MURB. The architects designed the building with an incredibly narrow floor plan, being only 11.5 m wide with 4 to 7 units per floor. The floorplan in Figure 5 illustrates the aspect ratio of each unit. Each unit is designed to optimize daylighting in the living. Outside-facing rooms are divided by a partition wall but maintain an advantageous ratio relative to the internal walls' depth. However, the large number of units relative to the building's floor area represents a significant trade-off as parts of the unit further into the building will receive less daylighting. This also illustrates how scissor stairs located on an external wall are not an optimal feature.

An alternative design can be seen in 56 Leonard Street; a 57-storey private market-rate housing MURB. This building is not as narrow as the previous example but also features scissor stairs. However, the stairs are located at the centre of the building rather than at an exterior wall. This demonstrates both a highly effective floor plan and optimal unit design. Dedicating more space at the centre of the building for vertical circulation frees up the layout by promoting fewer deep units with greater access to sunlight.

Figure 5: Floor plan of Collins Street in Melbourne, Australia (left) and 56 Leonard Street in New York, United States (right).

Façades: Solar Control

It is not uncommon, especially for mid- and high-rise apartment buildings, to have WWR exceeding 70% (Kesik et al., 2019). In fact, many projects had nearly floor-to-ceiling glazing on the perimeter wall. However, this is far more window area than necessary to provide adequate daylighting. Some of the award-winning MURBs have lower WWRs, such as the Picasso on Richmond: a high-rise apartment building shown in Figure 6 below. The WWR is approximately 30-40%, which is within the recommended range for such MURBs. Thus, reducing the likelihood of excess daylighting and glare and improving thermal comfort.

The other type of common MURB solar control, exterior overhangs, are fixed shading elements which sit above the fenestration. However, several of the award-winning MURBs displayed a more unique type of shading element: operable shades. La Borda is a 7-storey co-op housing building which features exterior fabric screens, shown in Figure 6. These screens are placed outside of each unit's balcony and can be opened and closed by the occupants. This greatly improves visual comfort because occupants can adjust the shades to fit their individual needs. Furthermore, with the screens outboard of the balcony, they can support good visual comfort even while outdoors.

Figure 6: Picasso on Richmond in Toronto, Canada (left), and La Borda in Barcelona, Spain (right).

Façades: Multi-Orientation Glazing

Most MURB designs do not allow for dual aspect, multi-façade windows. Typically, there can be several windows on one façade, possibly split between different rooms, but this approach is not effective at promoting natural ventilation in units. One simple method of achieving multi-façade windows is to build a MURB which consists entirely of corner units, such as the 360º Building, shown in Figure 7, which was common to several of the award-winning MURB designs.

Figure 7: 360º Building in Paulo, Brazil.

This 22-storey MURB has a unique façade design and layout. Each floor has between two and four units, all of which have at least two exterior walls. This allows for excellent ventilation and daylighting in all the units. However, a major disadvantage is the constrained use of the floorplate (e.g., the maximum number of units per floor for a typical rectilinear MURB is four; one for each corner).

It should be noted that single-loaded corridor design also typically allows for the use of multi-façade windows. As seen in Figure 5 for Amani, units which are the entire depth of the building have windows on both sides, thus, providing natural ventilation within the unit.

Discussion

This section identifies any major barriers which would prevent the implementation of each feature based on Canadian building codes and policies. The primary building codes of concern for this analysis are the NBC and NECB, both model codes based on consensus data. The former is designed to prioritize the health and safety of building occupants. It provides minimum requirements that all buildings must meet. The most relevant categories included in the NBC for this study are: accessibility, fire safety, occupant health, and structural design.

All buildings in this study are classified under Division B - Part 3 of the building code; buildings which are three or more storeys, or which have a footprint greater than 600 m^2. While British Columbia, Alberta, Ontario, and Quebec have their own building codes, they are still based on the NBC with some minor alterations based on regional requirements. The NECB is a regulation designed to improve the energy efficiency of new buildings. This is relevant for the discussion regarding fenestration and daylighting controls. If no policy barriers were identified, then each section instead briefly discusses general issues associated with each design which may prevent wide-scale adoption in Canada.

Building Form

Of the three building form features identified during the MURB scan, there are no codes or policies which would prevent stepped building form, mass distribution, or perimeter block design. In fact, several Canadian jurisdictions' by-laws, such as the town of Whitby, require step-backs in high-rise towers. Further research revealed that there are examples of each building in Canada already. One example of this is 50 Scollard in Toronto, Canada: a 41-storey residential building with a stepped design. As such, there are no specific policy barriers for building types in Canada as they need only meet the requirements set out for Part 3 buildings in the NBC. However, such MURBs may be limited by zoning by-laws and space availability. Many municipalities have limited land available for Part 3 buildings which may discourage and limit the use of such large buildings (Dachis and Thivierge, 2018).

Generally speaking, the building forms identified are not uncommon and have many practical IEQ benefits. Furthermore, such building designs also require larger plots of land due to their wide design.

Internal Layout

The two corridor design features identified, single-loaded and skip-stop, are permitted by the Canadian building codes. Residential building corridors, or public corridors as they are defined in the NBC, are not required to have a specific layout relative to each unit, nor are they required to have one on each floor. The only stated requirements in the NBC involve minimum width (1,100 mm), use of sprinkler systems, means of egress, fire-rated access doors, and ventilation requirements.

Scissor stairs are a slightly more contentious point with regards to building codes. All Part 3 buildings in Canada are required to have two means of egress for fire safety purposes. The NBC does allow for the use of scissor stairs as two means of egress provided the exits are not directly adjacent and the stairs are separated by a smoke-tight fire barrier. This contrasts the U.S.'s building code: the International Building Code where it is generally not allowed. Interestingly, the MURB identified above, 56 Leonard Steet, would not be code-compliant in the US if it were built today. The skyscraper was constructed in 2007, but in 2008 the UBC was updated to consider scissor stairs as a single point of egress in the U.S.

Façade

NECB Part 4 and ASHRAE 90.1 Part 9 are related to lighting, and thus daylighting systems. However, neither the code nor the standard mentions specific requirements for solar shading or daylighting control. Their primary concern is providing sufficient interior illuminance from artificial interior sources. This can be achieved either through prescriptive or trade-off compliance. The former involves pre-set values for lighting density for a given type of space, but makes no mention of daylighting systems. The latter involves calculating a building's net energy consumption required due to artificial internal sources by determining the internal daylit area based on an archetypical lighting schedule. Daylight control systems can be accounted for, but must be represented as venetian blinds; the most common form of daylighting control according to the codes. Otherwise, there are no specific requirements for shading.

The NECB provides prescriptive requirements for maximum allowable fenestration and door area to gross wall area ratio (FDWR) in Part 3: Building Envelope. This ratio is dependent on the heating degree-days of the building, as defined in the previous Division B – Part 1 of the NECB which provides general requirements for baseline values. Generally speaking, the maximum allowable FDWR is 40%. However, the trade-off path may allow a larger FDWR if the designer can prove that a higher FDWR would not result in greater net energy loss than using the prescribed value. Regardless, this illustrates that the codes are in favour of low fenestration ratios, even if the purpose is not to promote effective visual or thermal comfort.

Conclusion & Recommendations

The search of global award-winning MURBs identified a number of features which promote good IEQ and occupant comfort. From the 112 buildings included in the final MURB scan, seven types of features were identified which were further divided into three categories: building form, interior layout, and façade. The findings of this paper only discuss a select few features which were found to be most common in the identified MURBs and is not a comprehensive list. Analysis of Canadian building codes and standards did not identify any significant barriers, as all of the features are code-compliant. This study was limited to discussing Canadian building codes and standards and did not consider international codes. This indicates a limitation in the current study which could be expanded in future work.

However, a major finding in reviewing the Canadian building codes is the lack of occupant-centric building design requirements. The NBC focuses primarily on building fire safety, structural design, and minimum requirements for maintaining occupant health. Likewise, the NECB is designed to optimize buildings with respect to energy efficiency rather than visual or thermal comfort. While the minimum specifications outlined in these codes provide a good baseline for construction standards, the designs do not specifically promote good IEQ. Thus, designing for occupant comfort is generally not required, and so this responsibility falls to the architects. This represents a significant gap in the current codes which should be addressed in future revisions. Such considerations could be incorporated into the current codes as many features which positively affect IEQ can be achieved without negatively impacting housing density, structural design, or energy efficiency. It is recommended that further work be conducted to determine specific alterations which could be made to improve IEQ representation within building codes and standards.

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