

**LIGHT, SITE DENSITY AND
FORM: A STUDY OF DAYLIGHT
AVAILABILITY IN CANADIAN
RESIDENTIAL BUILDINGS**

Report prepared for:
Canada Mortgage and Housing Corporation

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A STUDY OF DAYLIGHT
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RESIDENTIAL BUILDINGS***

FINAL REPORT

March, 1998

Prepared by

**Enermodal Engineering Limited
650 Riverbend Drive
Kitchener, ON N2K 3S2
Tel: 519-743-8777
Fax: 519-743-8778
e-mail: office@enermodal.com**

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EXECUTIVE SUMMARY

Natural lighting or daylight, is desirable and preferable to electric lighting. Most people prefer daylight to artificial light and, in fact, it has been suggested that daylight can improve psychological well-being and speed up hospital recovery rates. For some people, however, the lack of light can lead to depression and Seasonal Affective Disorder (SAD).

This study attempts to find performance indicators to evaluate the capacity of housing units to gather daylight in different urban settings. A combination of computer simulation and physical testing was used to determine natural light levels in a wide range of building and urban designs. The results are synthesized into graphical information that researchers, designers and planners can use to assess the amount of daylight in high and low-rise residential buildings.

The term (Diffuse) Daylight Factor is a commonly used quantity to assess the daylight design of a structure. This term is defined as the ratio of the interior illuminance to the exterior illuminance on a completely overcast day. For this study, the Daylight Factor concept has been extended to encompass total (beam and diffuse) daylight availability. A new term, Total Daylight Factor (TDF), is introduced and defined as the ratio of the interior illuminance to the exterior illuminance over a specific time period. If there are no exterior obstructions, the TDF is a measure of the daylight acceptance of a building.

A second new term, Overhang and Density Obstruction Factor (ODOF) is defined as the ratio of interior illuminance for a building with exterior obstructions (e.g., adjacent buildings, overhangs) to the same building without exterior obstructions. The ODOF is a measure of daylight reduction due to urban density effects (100% means no reduction, 0% means complete reduction). The product of TDF (without obstructions) and the ODOF is a measure of the daylight acceptance of the building in an urban setting.

Daylight levels in three housing types (single detached, townhouse and apartment) for three cities (Toronto, Calgary and Vancouver) were predicted using a modified version of the SUPERLITE Version 1.0 computer program. The accuracy of the predictions was checked by comparing program predictions to measurements made in three buildings.

Overhang and Density Obstruction Factors for rooms in the house and townhouse are typically above 80%, indicating only a modest loss in daylight due to exterior obstructions. It is possible that the ODOF for north-facing rooms can be above 100%. North-facing rooms benefit from light bouncing off adjacent buildings to the north. The

ODOF for apartment buildings is reduced to approximately 50% by adjacent buildings and to 20% with the addition of balconies.

Unobstructed values of TDF vary considerably with orientation and the time period considered (e.g., winter versus annual). TDF values are higher in the winter because of the low sun angle (light is more normal to the window). Winter values for south-facing rooms are six times higher than for north-facing rooms. On an annual basis, the difference between north- and south-facing rooms is reduced to 2.5 times. The Diffuse Daylight Factor is a reasonable approximation of the Annual Total Daylight Factor averaged for the four orientations.

The daylight availability of the three housing types was compared by combining room design and urban density effects. The Annual Total Daylight Factor for individual rooms ranged from 0.5 to 3%. The house and townhouse rooms had similar TDF values whereas the apartment rooms were significantly lower especially when facing north. DOF and TDF values for entire buildings were determined by area-weighting the individual room values. The house and townhouse had annual DOF values of 53 and 64% respectively. The apartment building values were much lower at between 32 and 43% depending on orientation. The total building values of TDF ranged from 0.58 % for the north-facing apartment suite to 1.45 % for the townhouse.

Based on the simulation results, a promising methodology was developed toward predicting values of ODOF, TDF and number of hours above 1000 and 2000 lux as a function of room design, urban design and orientation. The next step is for the methodology to be tested and developed further for evaluation and comparison of building and urban designs for daylight design. Further validation and simulation work is needed to refine the predictions and extend the results to a wider range in building designs and climates.

RÉSUMÉ

La lumière naturelle, ou éclairage diurne, est souhaitable et préférable à l'éclairage électrique. La plupart des gens préfèrent la lumière du jour à la lumière artificielle et, d'ailleurs, on croit même que la lumière du jour peut améliorer le bien-être psychologique et accélérer la guérison en milieu hospitalier. Pour certaines personnes, le manque de lumière peut entraîner une dépression et une affection appelée Troubles affectifs saisonniers.

Cette étude vise à trouver des indicateurs de performance afin d'évaluer la capacité d'un bâtiment résidentiel à laisser entrer la lumière du jour dans différents milieux urbains. Les chercheurs ont eu recours à des simulations informatisées et à des essais sur le terrain pour déterminer les niveaux de lumière naturelle pour un large éventail de bâtiments et de milieux urbains. Les résultats obtenus sont synthétisés au moyen de graphiques que les chercheurs, les concepteurs et les urbanistes peuvent utiliser pour évaluer la quantité d'éclairage diurne dont bénéficient les bâtiments résidentiels de grande et de faible hauteur.

Le terme Coefficient d'éclairage diurne (diffus) est un facteur couramment utilisé pour évaluer la manière dont un bâtiment est conçu pour laisser entrer la lumière naturelle. Ce terme est défini en tant que rapport entre l'éclairement intérieur et l'éclairement extérieur lorsque le ciel est complètement couvert. Pour cette étude, le concept de Coefficient d'éclairage diurne a été étendu à la disponibilité totale de la lumière du jour (rayonnement et diffusion). Un nouveau terme le Coefficient d'éclairage diurne total (CÉDT) est introduit et défini comme le rapport entre l'éclairement intérieur et l'éclairement extérieur pendant une période donnée. En l'absence d'obstructions extérieures, le CÉDT constitue une mesure de la pénétration de la lumière du jour dans un bâtiment.

Un second terme, le Coefficient d'obstruction lié à la densité et au débord de toit (Codd), nouveau lui aussi, est défini comme le rapport entre l'éclairement intérieur d'un bâtiment comportant des obstructions extérieures (p. ex. les bâtiments adjacents, les débords de toit) et le même bâtiment dépourvu d'obstructions extérieures. Le Codd est une mesure de la réduction de la lumière naturelle causée par des facteurs inhérents à la densité urbaine (un rapport de 100 % correspond à une absence de réduction tandis qu'un rapport de 0 % signifie une obstruction complète). Le produit du CÉDT (sans obstruction) et du Codd représente une mesure de l'importance de la pénétration de la lumière du jour dans un bâtiment situé en milieu urbain.

Les niveaux d'éclairage diurne dans trois types d'habitation (maison individuelle isolée, maison en rangée et appartement) situées dans trois villes (Toronto, Calgary et Vancouver) ont fait l'objet de prédictions à l'aide d'une version modifiée du logiciel

SUPERLITE, version 1.0. La précision des prédictions a été vérifiée en comparant les prédictions du logiciel aux mesures prises dans les trois bâtiments.

Les CODD pour les pièces de la maison isolée et de la maison en rangée atteignent normalement un niveau supérieur à 80 %, signe d'une perte modeste d'éclairage diurne causée par des obstructions extérieures. Il est possible que les CODD des pièces donnant sur le nord soient supérieurs à 100 %. En effet, ces pièces bénéficient de la lumière qui reflète sur les bâtiments adjacents situés au nord. Le CODD pour les immeubles d'appartements est réduit d'environ 50 % par les immeubles adjacents et de 20 % en présence de balcons.

Les valeurs obtenues pour le CÉDT sans obstruction varient considérablement selon l'orientation et la période prises en considération (hiver vs année entière). Les valeurs CÉDT sont plus élevées en hiver parce que le soleil est plus bas à l'horizon (la lumière pénètre mieux par les fenêtres). Les valeurs hivernales pour les pièces donnant sur le sud sont six fois plus élevées que pour celles qui donnent sur le nord. Annuellement, la différence entre les pièces donnant sur le sud et celles donnant sur le nord est réduite de 2 fois et demie. Le CÉDT diffus représente une approximation raisonnable du CÉDT pour une année, pondéré pour les quatre orientations.

On a comparé la disponibilité de la lumière diurne pour les trois types d'habitation en combinant les effets liés à la conception des pièces et à la densité urbaine. Le CÉDT annuel pour les pièces individuelles varie dans une fourchette de 0,5 à 3 %. Les pièces de la maison isolée et de la maison en rangée affichaient des valeurs CÉDT similaires tandis que celles des pièces de l'appartement étaient beaucoup plus faibles, surtout les pièces donnant sur le nord. Les valeurs CODD et CÉDT pour les bâtiments complets ont été déterminées en effectuant une pondération de l'aire pour les valeurs des pièces individuelles. La maison isolée et la maison en rangée ont obtenu des valeurs CODD annuelles de 53 % et 64 % respectivement. Les valeurs du bâtiment abritant l'appartement étaient beaucoup plus basses, oscillant entre 32 et 43 % selon l'orientation. Les valeurs CÉDT pour les bâtiments variaient entre 0,58 %, pour l'appartement donnant sur le nord, et 1,45 % pour la maison en rangée.

À partir des résultats des simulations, on a pu mettre au point une méthode prometteuse pour prédire les valeurs CODD et CÉDT ainsi que le nombre d'heures d'éclairement supérieur à 1000 et 2000 lux en fonction de la conception des pièces, de l'aménagement urbain et de l'orientation. La prochaine étape consiste à mettre cette méthode à l'essai et à la développer davantage dans le but d'évaluer et de comparer des bâtiments et des aménagements urbains sur le plan de l'éclairage diurne. De plus amples travaux de validation et de simulation sont requis afin d'améliorer les prédictions et d'étendre les résultats à un large éventail de modèles de bâtiment et de climats.



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Table of Contents

1. INTRODUCTION	1
2. BACKGROUND.....	3
2.1 Need for Daylight.....	3
2.2 Implications for Building Design and Site Planning	4
3. DAYLIGHT ASSESSMENT METHODOLOGY	7
3.1 Computer Program Selection and Modification.....	7
3.2 Weather Data	8
3.3 Simulation Study	8
3.3.1 Building Types and Densities	9
3.3.2 Variations in Simulations	19
4. MODEL VALIDATION	21
4.1 Procedure.....	21
4.2 Building Descriptions	21
4.2.1 Comparison.....	23
4.2.2 Office Results.....	24
4.2.3 House Results	25
4.2.4 Apartment Results.....	25
4.3 Sources of Error	26
5. RESULTS OF DAYLIGHTING SIMULATIONS	29
5.1 Definitions	29
5.2 Outdoor Daylight Availability.....	32
5.3 Effect of Overhang and Urban Density Blockage on Daylight Availability	34
5.4 Interior Daylight Availability - No Exterior Obstructions.....	38
5.5 Total Daylight Availability.....	44
5.6 Synthesis of Results	47
5.7 Characterizing Canadian Housing and Urban Densities	53
6. CONCLUSIONS	55
7. REFERENCES	57
APPENDIX A: RESULTS OF COMPUTER SIMULATIONS.....	57

1. INTRODUCTION

Natural lighting or daylight, is desirable and preferable to electric lighting. Most people prefer daylight to artificial light and, in fact, it has been suggested that daylight can improve psychological well-being and speed up hospital recovery rates. The lack of light can lead to depression and, in some people, Seasonal Affective Disorder (SAD). Daylight is also desirable because, if properly utilized, it can reduce the energy consumed for electric lighting. Furthermore, in comparison to artificial light, daylight produces more light per Watt of energy (115 lumens per Watt of solar gain, whereas fluorescent lighting produces only 80 lumens per Watt) and is full spectrum.

The National Building Code addresses the need for windows and daylighting by specifying a minimum allowable window area of 10% of the floor area for residential buildings. This specification is based more on common building practice and the need for egress in a fire than on adequacy of light levels. Recent research has categorized light levels of 1000 lux and 2000 lux as biologically "imperceptible" and "stimulative" respectively [Begemann et al, 1996]. Given that we spend most of the daylight hours in dwellings, offices, factories or other indoor spaces, what levels of illumination are we normally exposed to? This study attempts to assess light levels in residential environments, as well as to develop a method for predicting them.

This study uses computer simulation and some site measurements to determine natural light levels in a range of residential building and urban designs. The results are synthesized into graphical information that could be used by researchers, designers and planners to assess the amount of daylight in high and low-rise residential buildings.

2. BACKGROUND

2.1 Need for Daylight

One of the most comprehensive studies on the effect of lighting on human health was conducted by researchers at Dalhousie University [Rusak et al, 1995]. They summarized current research in this area and identified the human needs for daylighting. They divided the effects of light into two areas: physiology and mental health.

One of the most important physiological effects of light exposure mediated by the eyes is the synchronization of the body's daily rhythms to local time. Disturbing the body's time clock can cause jet lag or sleeping and eating disorders. Some researchers have suggested that relatively bright light (above 2000 lux) is needed to reset the body's time clock. This issue has raised the question as to whether the light levels in buildings should follow a daily pattern peaking at noon rather than being fixed at a constant level. Light also effects the secretion of the hormone melatonin by the pineal gland. Upsetting the rate of secretion can effect sleep, body temperature and tumor development.

Light can have many physiological effects on the skin and as mediated through the eye. The most familiar effect on the skin is tanning and burning due to exposure to UVB and, to a lesser extent, UVA wavelengths. Ordinary window glass screens out most of the UVB radiation which means that indoor daylight exposure would not produce a tan or add to the risk of skin cancer.

Light (the lack there of) can affect human mental health. Seasonal affective disorder (SAD) is the term applied to the mental depression associated with the short and dull days of autumn and winter. People suffering from SAD experience depression, fatigue, hypersomnia and overeating. Remission of these effects occurs with the brighter and longer days of spring. One study showed that, on average, daily human sunlight exposure is 3 hours in the summer but only 1.2 hours in the winter; almost a two hour difference.

Estimates of people suffering from SAD range from 1.4% to 10% of the population with women making up 68 to 75% of the cases. A further 13% of the population may experience mild SAD effects but do not meet the clinical criteria for SAD.

Light therapy is often an effective treatment for SAD. Treatments typically consist of bright light exposure (2500 lux) for at least two hours a day for one week (making up for

the two hour shortfall in winter versus summer light exposure). The treatments can be given at any time of the day, although some evidence indicates that morning treatments are more effective. Recent research (as summarized in Rusak et al, 1995) indicates that the effectiveness of light in treating SAD is a function of the total dose, that is the intensity times the length of exposure. Light exposure of 10,000 lux for 0.5 hours per day may be just as effective as 2,500 lux for 2 hours per day in treatment of SAD. Conversely, exposure of 2,500 lux for only 0.5 hours per day for one week was found to be ineffective. Other research has shown that extending the length of treatment (e.g., to two weeks) may allow lower light intensities to be used effectively.

Light from fluorescent, incandescent and natural sources have all been effective in treating SAD. There is no evidence that particular light wavelengths are required for treatment. Ultra-violet light has been shown to be not necessary since most light treatments screen out these wavelengths. Window glass also screens out much of the UV wavelengths.

2.2 Implications for Building Design and Site Planning

As discussed in Section 2.1, light has beneficial biological and psychological effects. It appears that relatively high light levels are necessary to achieve these benefits; approximately two to three hours per day of over 2000 lux light. Typically, homes and offices are artificially lit to only about 500 lux. (These light levels are only approximate and further research is required to better define the required daylight levels.)

Since we spend most of the time indoors, it is advantageous to design buildings and plan cities to achieve the high light levels indoors. Ideally, buildings would be designed to achieve this intensity with daylight without having to resort to artificial light. Unfortunately, little information is available on the light levels found in housing and there is no simple means of predicting indoor light availability.

There are many factors that affect indoor light exposure: location, urban density and exterior obstructions, sky conditions, window area, glazing properties, room shape and orientation to name a few. Some research has been done to identify the important factors. Most of this research has focused on the energy benefit of daylight and results are expressed in terms of savings in lighting electricity use; not necessarily relevant for this study. For example, Johnson et al [1985] showed that as window size (i.e., illumination level) is increased artificial lighting electricity use falls almost linearly up to the point where the electric lights are fully dimmed. Their research is important in that it

shows this linear relationship and that the light levels are dependent on the product of the window-to-wall ratio and the glazing visible transmission.

It is not possible to examine the impact of all the factors that effect light levels over the range of possible values and their interaction with the other factors. The most important factors are location, window size, window orientation, window visible transmission, room shape, and shading by buildings or overhangs. These factors are discussed in more detail in Section 3. Future studies could examine some of the secondary factors affecting light levels including room colour, furniture, window shape/position and ground reflectance.

3. DAYLIGHT ASSESSMENT METHODOLOGY

In Section 2, the need to quantify daylight availability was identified. The methodology used to assess daylight availability in housing is described in this section. The methodology is based on computer simulation supplemented with site measurements. Computer simulation is used to estimate indoor daylight levels for a range in housing and urban designs. Physical measurements are used to assess the accuracy or uncertainty in the computer simulated results.

3.1 Computer Program Selection and Modification

Computer simulation is used to predict the daylight levels in housing for a range of building designs and urban densities. The daylighting program must be accurate, validated and capable of accounting for the many factors affecting indoor light levels. The SUPERLITE program Version 1.0, developed by Lawrence Berkeley National Laboratory, was selected for this study to calculate indoor and outdoor light levels.

The SUPERLITE program calculates interior light levels for a particular building design at a given time and atmospheric condition. To determine the seasonal and annual frequency of light levels, the program must be run for each hour of the year or, at least, for each sky condition and position.

The input and output routines of the SUPERLITE program were modified to allow processing of an entire year of weather data at one time. The description of the room is read from the standard SUPERLITE data file. The program marches through the year reading hourly values of global and diffuse illuminance from typical meteorological year weather files produced by Environment Canada. Each hour the program calculates illuminance values throughout the room. Average room illuminances are determined, the results are stored and the program moves on to the next hour.

The accuracy of the SUPERLITE program and modelling technique were assessed by comparing the program predictions to light measurements made in three different building types: an office at Enermodal Engineering Limited, a single-detached house in Mississauga, and a two-bedroom apartment in Mississauga. Illuminance measurements were made over a one-to-two day period at each site in July, 1997. The results are discussed in Section 4.

3.2 Weather Data

The best type of weather data for use by the program is measured global and diffuse illuminance data. Few locations in Canada measure these parameters. The only active Environment Canada station making these measurements is in Egbert, north of Alliston, Ontario. The measurements are for global illuminance only (no diffuse observations) and there are some concerns about the accuracy of the measurements [pers. comm. Robert Morris, Environment Canada]. Dr. James Love of the University of Calgary has been collecting global and diffuse daylight measurements for approximately two years as part of an International Daylight Measurement Program. Unfortunately, this data has not processed to a form that could be used in this project.

Environment Canada collects hourly values of global and diffuse radiation for many locations across Canada. They have assembled data from 1953 to 1993 into typical meteorological year weather files for 144 Canadian locations, referred to CWEEDS (Canadian Weather Energy and Engineering Data Sets). These files also contain hourly values of global and diffuse illuminance data that have been estimated from the solar radiation values using a procedure recommended by McCluney at the Florida Solar Energy Center. These data sets are used in this study.

3.3 Simulation Study

The purpose of the simulation study is to determine the range in natural light levels found in typical Canadian housing. Thus, the simulation covers a range in building types, building designs and urban densities. Three building types were studied (single-detached, townhouse and high-rise residential), each in an urban setting typical of that building type. The floor plans and elevations were taken from actual buildings, however, the other input parameters (e.g., urban densities, building blockages, surface reflectivities and window transmission) were chosen to be typical of that type of housing. The SUPERLITE input file information is given in Appendix A. The simulations were done for a full year because we are interested in the level of natural light the housing units receive on a seasonal and annual basis.

Building occupants do not remain in one position in one room but move about the house. It is important, therefore, to determine the light levels in the major living areas of each type of dwelling. The results for each room type can then be weighted by the amount of time a person spends in that room to determine potential annual daylight exposure. To obtain the spatial variation in daylight levels, average illuminance values are determined for three zones in each room: perimeter, centre and interior. Each zone

is one third of the room depth. The orientation of the rooms is varied to examine its effect on daylight levels.

3.3.1 Building Types and Densities

Building Form

Three building forms were examined: single detached housing, townhouses and apartment buildings. Buildings were chosen so as to ensure that their forms are typical of at least some Canadian housing. Figures 3.1 to 3.3 show the floor plans for the three buildings. The single detached house is two storeys with four bedrooms and is located in Mississauga, Ontario. The townhouse is a recently constructed three-storey building in Ottawa. The apartment suite has two bedrooms and is part of a 20 storey building in Mississauga, Ontario. The house and apartment suite were also used in the validation exercise (see Section 4). The results of the validation exercise should give an indication of the accuracy of the simulation results for these buildings.

There are some significant differences between the three housing types. The rooms in the single detached house tend to be rectangular and slightly larger than for the other two housing types. The townhouse rooms tend to be narrow and deep. The apartment suite has the smallest rooms. The most significant difference with apartments is, however, the daylight blockage caused by the balcony and the balcony railing.

Simulations were performed for two commonly used rooms in each of the housing types: the family or living room and one of the bedrooms (as shown on Figures 3.1 to 3.3). Corridors, entrance ways, basements, and bathrooms were not investigated since occupants spend little time in these areas. Each room is divided into three daylight zones: closest to the window, middle of the room and farthest from the window; and the daylight levels calculated for each zone at a height of 1.2 metres above the floor.

Figure 3.1: Single Detached House Floor Plan

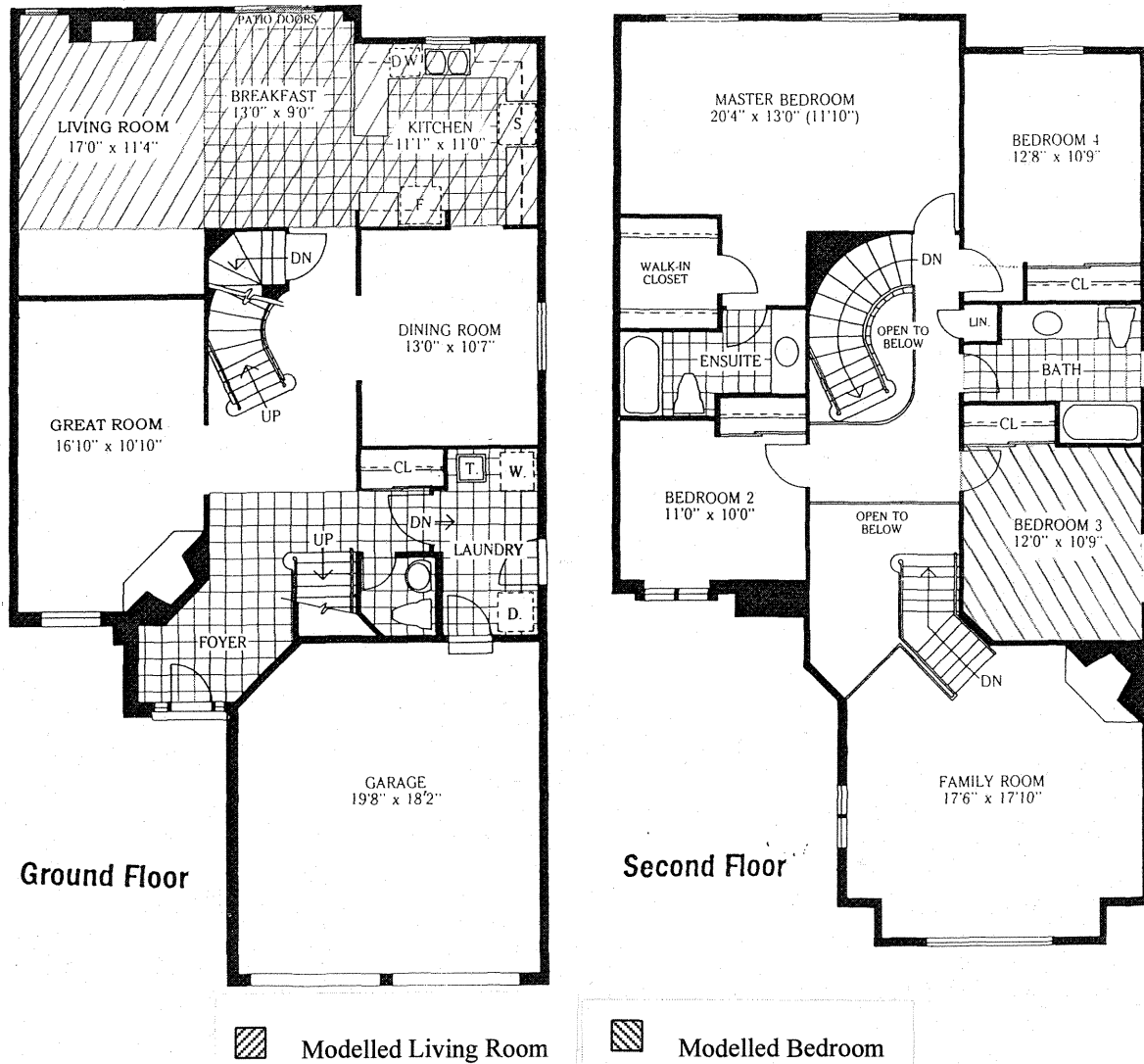


Figure 3.2: Townhouse Floor Plan

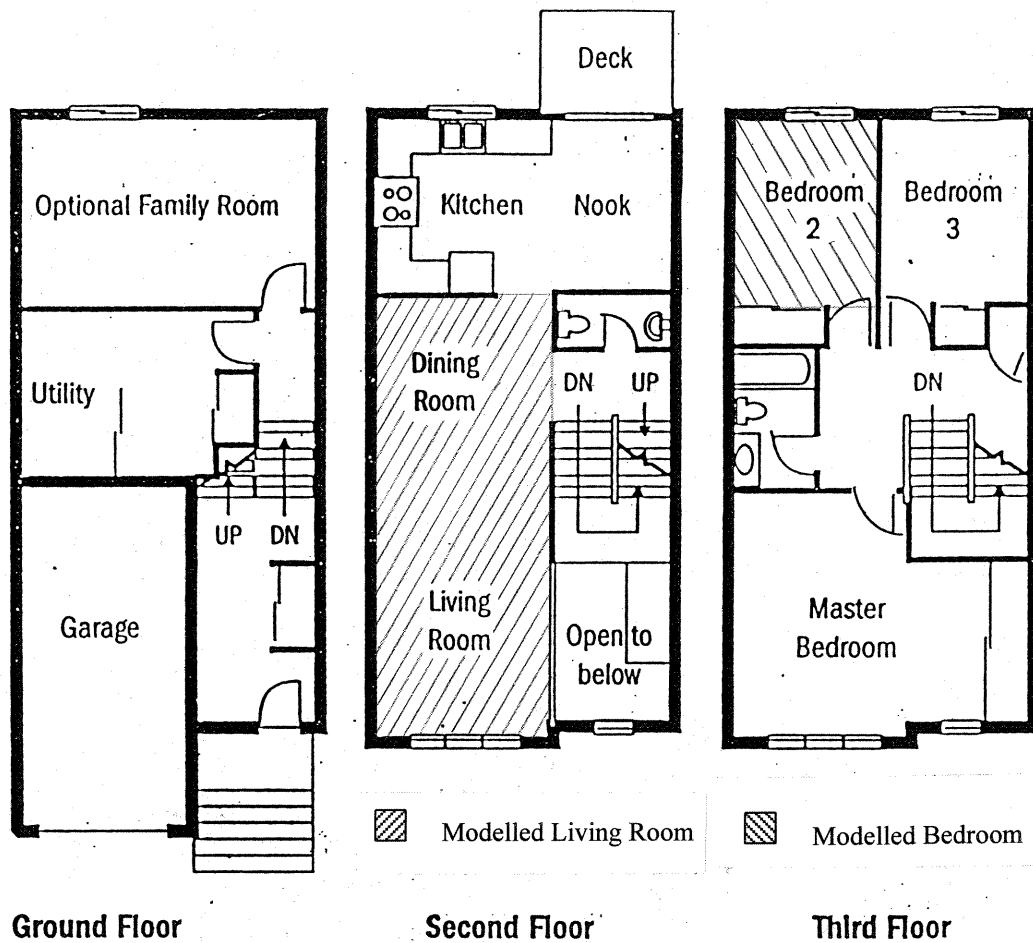
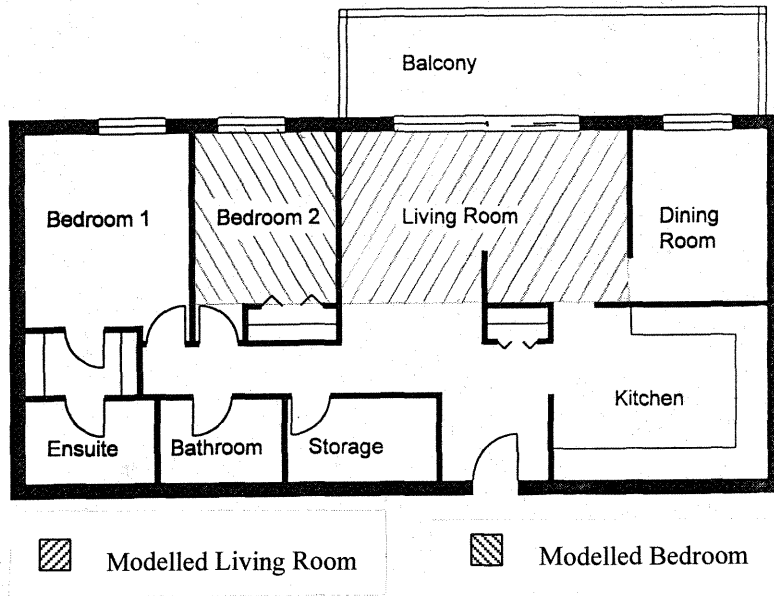


Figure 3.3: Apartment Suite Floor Plan



Building Density

Building density affects the daylight reaching building interiors because of blockage by adjacent buildings. Building density is increased by reducing the distance between buildings, increasing building height or both. In most cases, increasing building density results in an increase in the sun altitude required to clear the facing buildings (referred to as the density blockage angle, see Figure 3.4). This increase can be a result of either decreasing the distance between two buildings or increasing the building height.

In this study, each housing type is evaluated for the building densities typical for that housing type (and not necessarily the actual density for the actual houses). The position and height of housing facing the front and back of each house type is shown in Figure 3.4. Municipal by-laws define building density in terms of housing units per hectare for low-rise buildings and building coverage (ratio of building floor area to land area) for high-rise buildings. In most cities, suburban areas are low-density development; defined as 15 to 45 housing units per hectare (6 to 18 units per acre). Single-detached housing is close to the low end of this range and townhouse projects are close to the upper end of the range.

Figure 3.5 shows a typical suburban street. Municipal bylaws typically require an 18 metre (60 foot) road right-of-way. Adding on 7.5 metre setback requirements, means that houses are approximately 33 metres apart when facing a street. A typical two-storey house is 7 metres high and a first floor window is 1.2 metres above ground. Using these dimensions, a density blockage angle of 10 degrees can be calculated for first floor windows. This angle is consistent with the streetscape in Figure 3.5. The density blockage angle for the second floor windows is about half this value.

At an urban density of 15 units per hectare and 18 metre wide lots, the backyard is 10.5 metres deep. The spacing between house backyards is thus 21 metres. The density blockage angle for the windows facing the back yard is 15 degrees for the first floor windows and 7.5 degrees for the second floor windows. The density blockage angle for side yards is much higher (63 degrees, based on 3 metre building spacing), but of little relevance. In most urban and suburban settings very few windows face side yards and, even then, they are very small.

For townhouse developments, the road and setback allowances are less. Rows of townhouses are often spaced 20 metres apart. For this case, the density blockage angle for first floor windows is 15 degrees, similar to that for backyards in detached housing. The density blockage angle for second floor windows is approximately half this value.

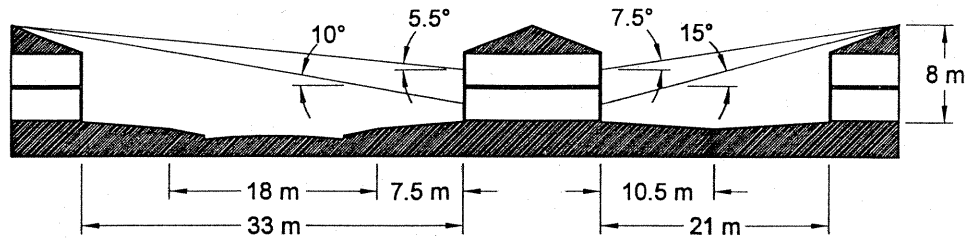
Apartment buildings are considered high-density development (see Figure 3.6). The density blockage angle will vary according to which floor is being considered. For a middle floor in 20-storey building (see Figure 3.6), the density blockage angle is 44 degrees (i.e., the facing building is 10 storeys higher than the suite being considered). For the top floor, there would be little blockage and results would be similar to that for single-detached housing.

Building Overhangs

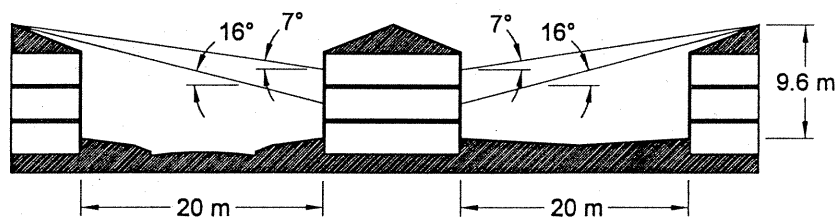
Detached housing and townhouses normally have eaves over the upper storey windows. The eaves are typically 0.6 metres (2 feet) wide and positioned approximately 0.4 metres (1.3 feet) above the tops of windows. An overhang blockage angle can be defined as the angle from the vertical that is blocked by the overhang relative to the midpoint of the window (see Figure 3.7). The total blockage angle is the sum of the density blockage angle and the overhang blockage angle (the amount of the sky blocked). If the total blockage angle is equal to or greater than 90 degrees there is no beam illuminance on the window. The overhang blockage angle for top floor windows in detached housing is 40 degrees. The overhang blockage angle for first floor windows in a two storey house is only 13 degrees.

Many apartment buildings have concrete balconies. Balcony widths range from 1.2 metres (4 feet) to 3 metres (10 feet). For these dimensions, the overhang blockage angle can be from 50 to 75 degrees. Thus, it is possible that the total blockage angle could be a complete 90 degrees (50 degrees or more for the overhang and 44 degrees for adjacent buildings).

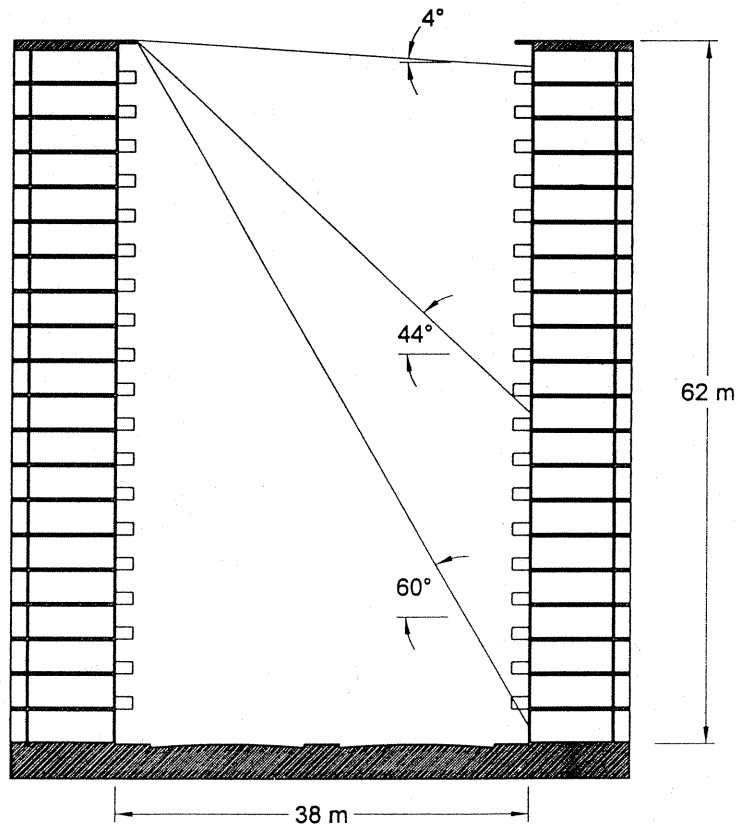
Figure 3.4: Position and Height of Facing Buildings Used in Study



BUILDING BLOCKAGE ANGLES FOR SINGLE DETACHED HOUSES



BUILDING BLOCKAGE ANGLES FOR TOWNHOUSES



BUILDING BLOCKAGE ANGLES FOR APARTMENT BUILDINGS

Figure 3.5 Density Blockage Angle for Low-Density Urban Development

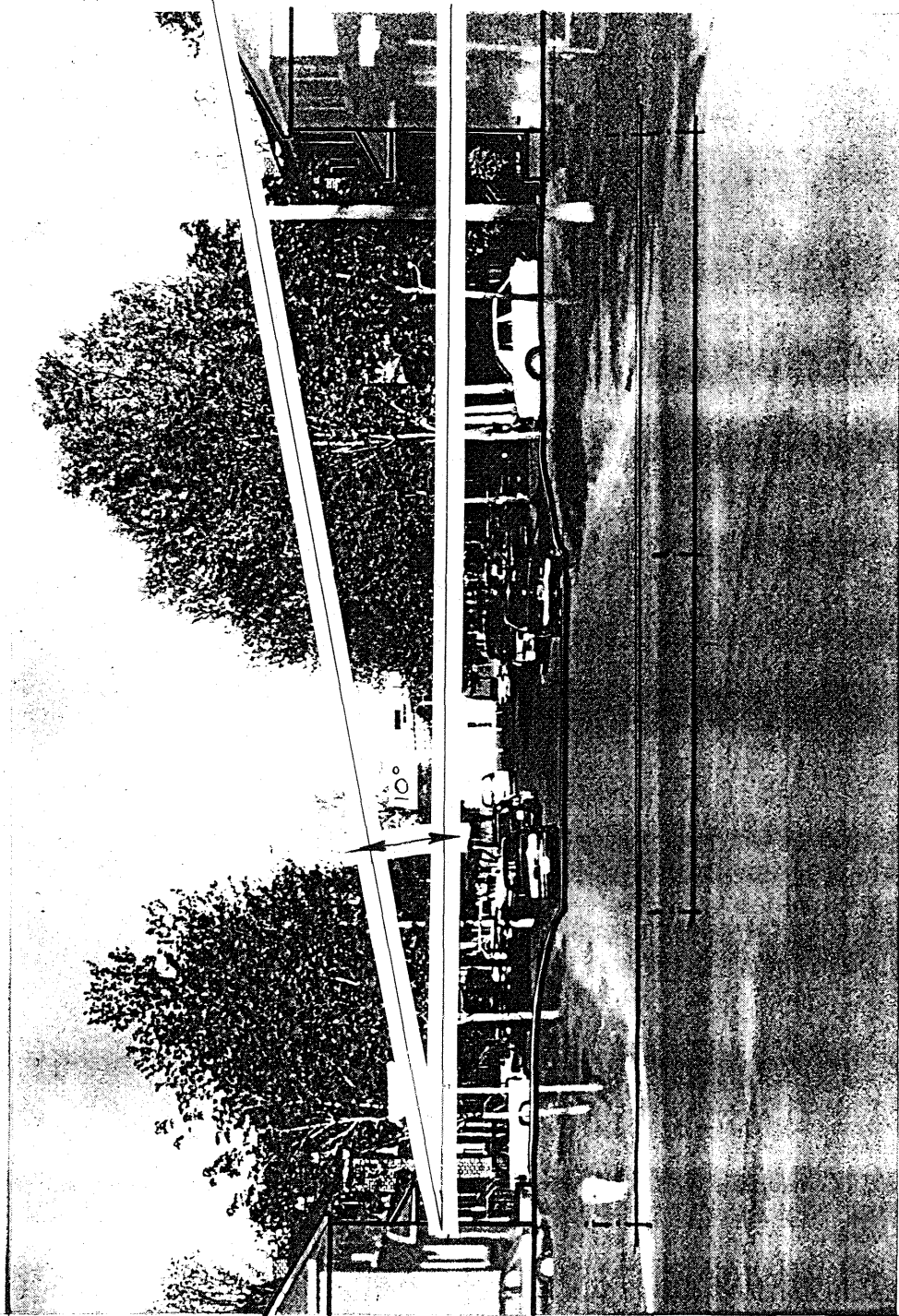


Figure 3.6: Density Blockage Angle for High-Density Urban Development

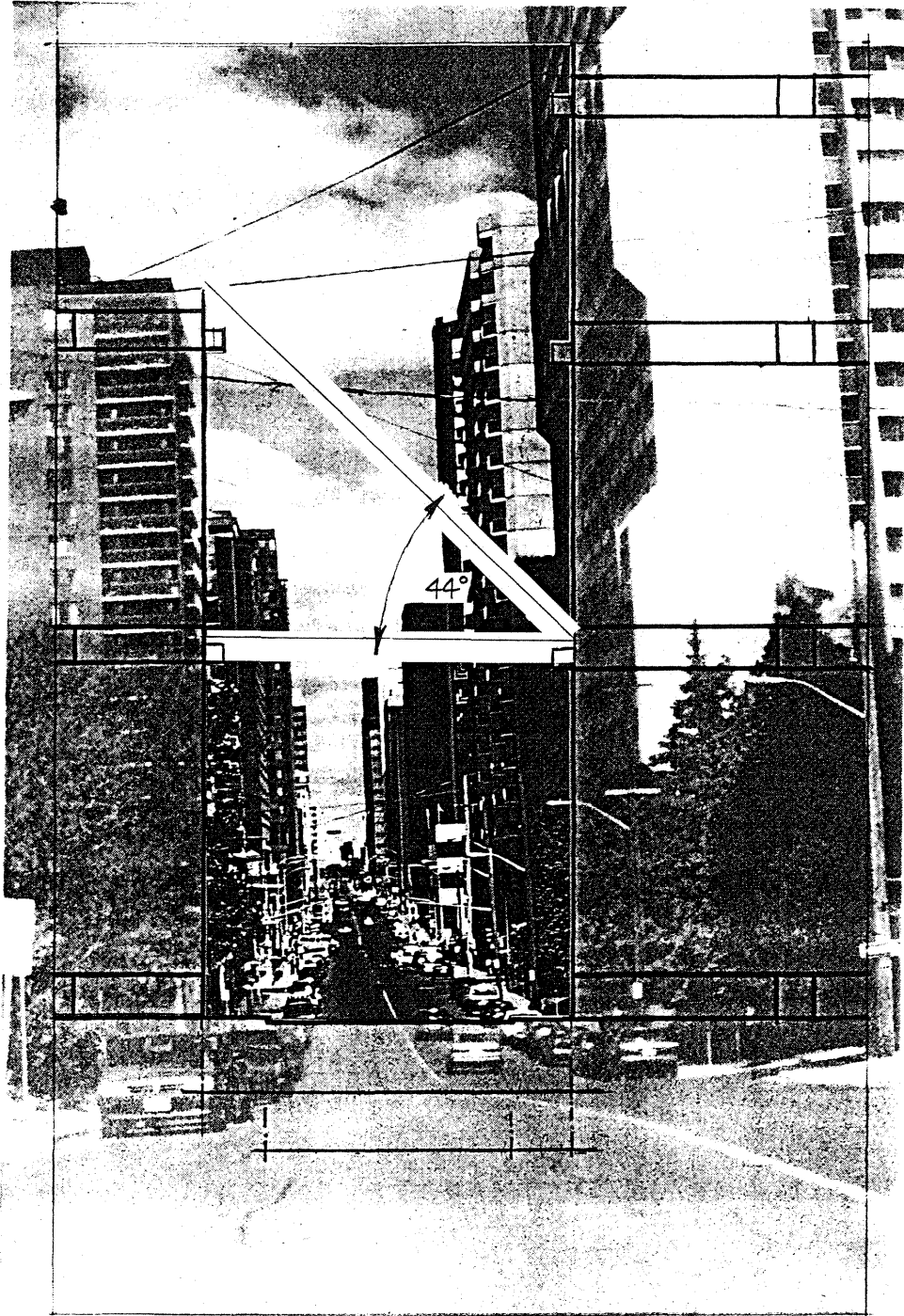
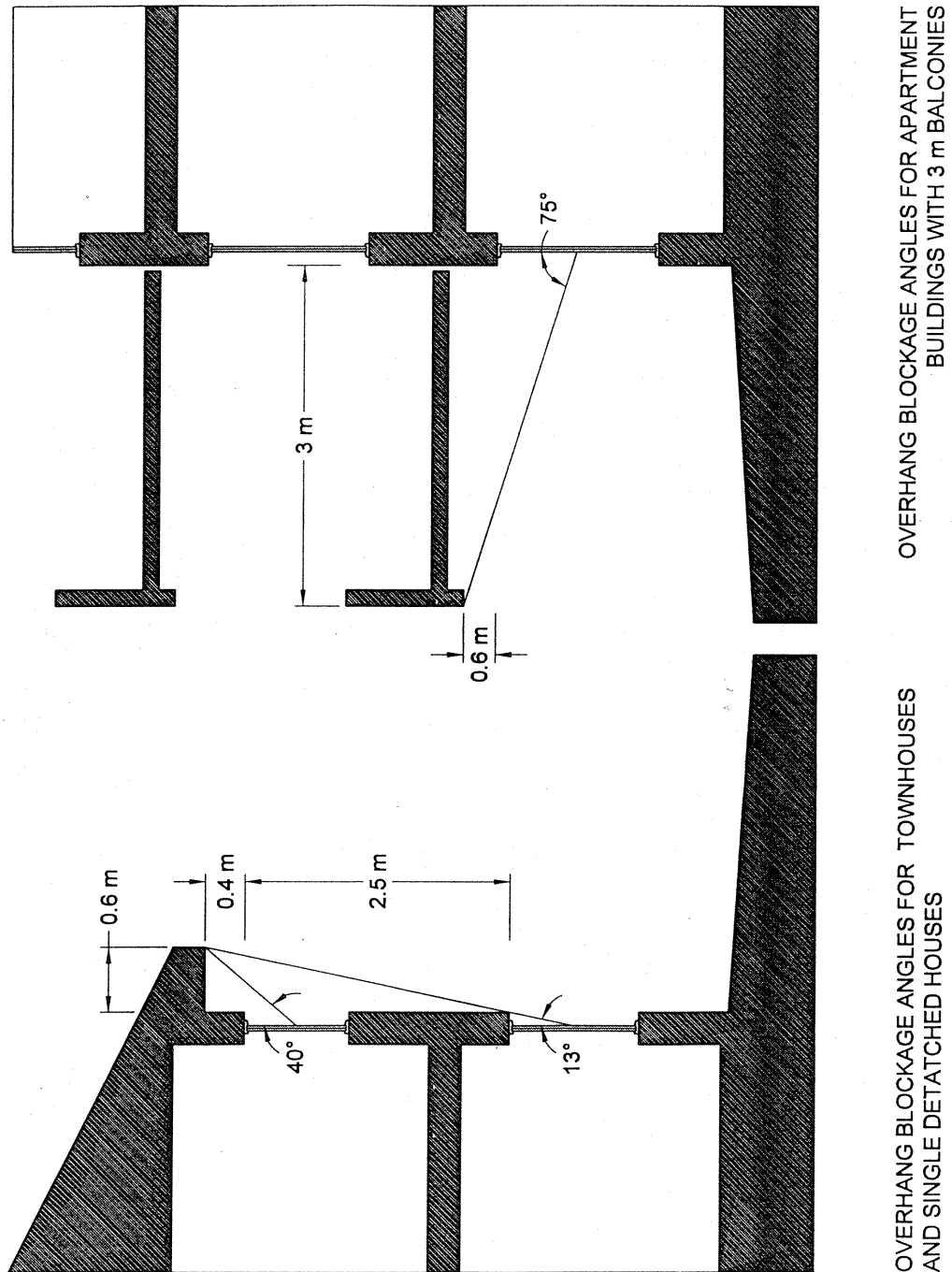


Figure 3.7: Building Overhang Dimensions Used in Study



3.3.2 Variations in Simulations

The daylight levels in the three housing types and urban densities described in Section 3.3.1 were evaluated for three Canadian locations and four orientations. Three cities are Vancouver, Calgary, and Toronto. These cities were chosen because they are major centres and represent a wide range in climate from cloudy and warm Vancouver to cold and clear Calgary. Furthermore, Calgary is in the region of low turbidity and atmospheric moisture content whereas Toronto has the opposite atmospheric conditions. For each location, four building orientations were examined: north, south, east and west.

A sensitivity study of the effect of window daylight transmission on interior light levels was undertaken. It was found that there is a direct relationship: increasing window transmission results in a similar increase in light level. Therefore only one value of daylight transmission was used in the simulations, nevertheless, the resulting daylight levels can be scaled according to the window transmission. The glazing daylight transmission was set at 80% (clear double glazing).

4. MODEL VALIDATION

4.1 Procedure

The accuracy of the SUPERLITE program and modelling technique were assessed by comparing the program predictions to light measurements made in three different building types: an office at Enermodal Engineering Limited, a single-detached house in Mississauga, and a two-bedroom apartment in Mississauga. Illuminance measurements were made over a one to two day period at each site in July, 1997. Measurements were made using two portable illuminance meters: one intended for outdoor measurements and one intended for indoor measurements. Total and diffuse illuminance measurements were made outside each building away from any obstructions. Immediately following the outdoor measurement, 15 indoor measurements of total illuminance were made in a grid of 3 X 5. (For the office, only two indoor measurements were made.) The meter was placed on a tripod, 1.2 metres above and parallel to the floor. In all cases, window coverings were opened, and artificial lights were turned off. The outdoor measurement was repeated to ensure that the outdoor conditions had not changed significantly during the test period. For each of the measurements, the weather was clear with only modest cloud cover. One hourly period of measurements were rejected because the cloud condition changed significantly over the measurement period.

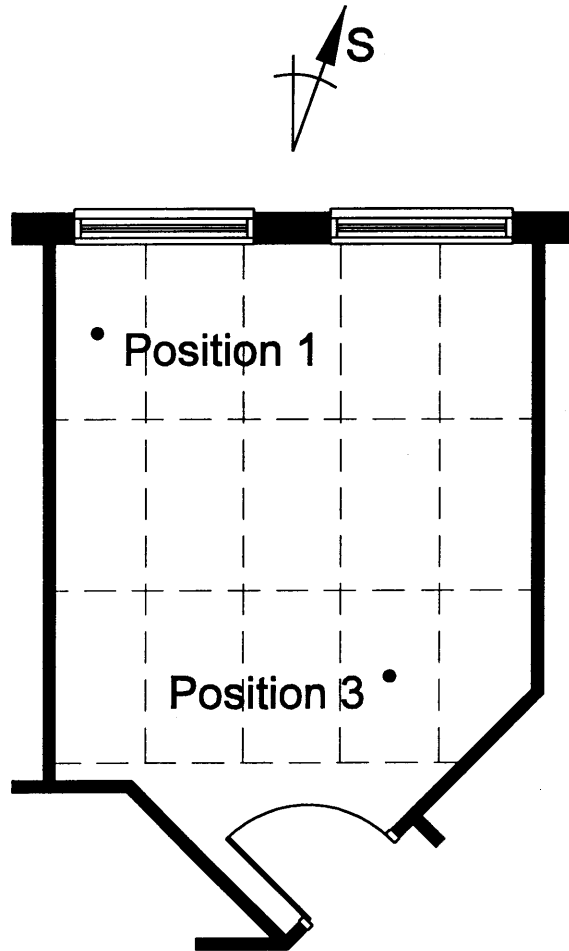
The modified SUPERLITE computer program (see Section 3.2) was run for each of the measurement periods. The program uses as input a datafile description of the room, the outdoor total and diffuse illuminance and the time of day and year the measurements were made. It is important to note that the input data (room reflectivities, window type and exterior obstructions) were for the actual room and not the typical values presented in Section 3.3. The program was set up to calculate 15 illuminance values: 5 values across the width of the room in three rows across the depth of the room. The program averages the illuminance levels across the width of the room giving average illuminance levels at three distances from the wall with the window. These three values are compared to the averaged measured values.

4.2 Building Descriptions

The office at Enermodal Engineering Limited: The office is approximately 3.8 m wide by 4.0 m deep (see Figure 4.1). It is on the second floor of a two-storey office building. The office is not perfectly rectangular; the back wall with the door, has an irregular-

shaped alcove. There are two windows in the office: 1.3 m by 1.4 m each. The room faces 20° east of south. The windows look onto an open field. A modest overhang is above the windows. The walls and ceiling are painted an off-white although furniture and pictures are darker colours. The floor is a light brown linoleum. The input data for the SUPERLITE program are given in Appendix A.

Figure 4.1: Office Floor Plan



The single-detached house in Mississauga: The room that was monitored and modelled is a living room and kitchen at the back of the house on the main floor. It is essentially 9.6 m wide by 4.1 m deep. There is an alcove in the living room portion as well as a fireplace. These features result in a room that is not perfectly rectangular. There is a hallway without a door coming into the family room as well. There are two windows and a set of patio doors in the room. The patio doors are French-style and were modelled as two separate windows. The windows are: 0.7 m by 1.2 m, two at 0.7 m by 1.9 m, and 0.7 m by 0.6 m. The room faces 43° west of south. A wooden fence surrounds the backyard. The lower portions of the walls are painted green and the upper portions and ceiling are an off-white. The flooring (carpet and wood) is brown. A layout of the house is provided in Figure 3.1.

The two-bedroom apartment in Mississauga: The apartment is on the second floor of a 10-storey condominium building. There are no high-rise buildings facing the apartment. The room that was modeled and measured in the apartment is an L-shaped living room. The rectangular portion of the living room that is adjacent to the window is the only part that was modeled, and is approximately 6.0 m wide by 4.0 m deep. There is a doorway into the kitchen at the back of this portion of the 'L' that does not have a door, as well as a doorway into a dining room to the side. There is only one large window in the room including a patio door onto the balcony. The whole window, not including the portion at the sides that is obscured by curtains and the portion in the middle with an air conditioner, is approximately 2.5 m by 1.6 m. The walls and ceiling are an off-white and the west wall is completely covered by a mirror. The carpet is a dark brown. The balcony is approximately 3 metres wide and is enclosed above and on the sides as well. The balcony railing is solid and approximately 1 metre high. There are two big trees in front of the apartment: one is directly in front, but on the left hand side (as viewed from the interior), and one is further away and to the right. The room faces 23° west of south. Figure 3.3 shows the apartment floor plan.

4.2.1 Comparison

Tables 4.1 to 4.3 compare the results of the light measurements taken in the rooms, and the light levels predicted by SUPERLITE. For these tables, time refers to the time that the measurements were taken, corrected to Eastern Standard Time (EST). In most cases the time was not exactly on the hour, and the closest hour was chosen. Position refers to the depth into the room, and the light level is the average of five readings across the width of the room. Position 1 refers to the measurements made in the third of the room closest to the window. Position 2 refers to the light level in the middle third of

the room. Position 3 refers to the light level in the third of the room furthest from the window.

4.2.2 Office Results

For the office, only two indoor measurements were made: one close to and in front of a window and one at the back of the room. Although light measurements were made every hour, the measurements at 10 am were not included since the cloud conditions changed significantly during the measurement period. All but three of the sixteen predictions are within 30% of the measured values. This is felt to be reasonable agreement given that the simulated values are predicted based on outdoor values that are two orders of magnitude larger. There is a trend to under-predict the illuminance levels in the morning and over-predict in the afternoon. The large discrepancy at 9:00 is because the meter was in direct sunlight but for the time and position given the model, the predicted value was not in direct sun. This is likely just a timing problem and the model would have predicted direct sunlight at a slightly different time. Potential reasons for the discrepancies between measurement and prediction are given in Section 4.4.

Table 4.1: Measured and Predicted Illuminance Levels for the Office

Time EST	Room Position	Measured (LUX)	Predicted (LUX)	% Difference
8:00	1	2780	2316	-17
	3	898	793	-12
9:00	1	16200	3361	-79
	3	1480	1135	-23
11:00	1	4340	4197	-3
	3	1040	957	-8
12:00	1	2210	2850	29
	3	610	690	13
13:00	1	2010	3533	76
	3	610	1099	80
14:00	1	2000	2603	30
	3	610	739	21
15:00	1	2530	3298	30
	3	670	803	20
16:00	1	1740	2239	29
	3	500	512	2
average				4

4.2.3 House Results

The results for the house are given in Table 4.2. Of the twelve readings, only one of the differences is significantly greater than 30% (position 1 at 16:10). This measurement was problematic again because of direct sunlight. The model predicted that at least two of the five readings closest to the windows were in direct sunlight. However, the kitchen cabinets (which cannot easily be accounted for in the model) shaded one of the measurements. This point was removed from the averaging, but similar problems could have occurred with the other measurements.

Table 4.2: Measured and Predicted Illuminance Levels for the House

Time (EST)	Room Position	Measured (LUX)	Predicted (LUX)	% Difference
9:45	1	634	698	10
	2	312	384	23
	3	328	280	-15
10:05	1	986	698	-29
	2	362	384	6
	3	221	280	27
11:15	1	631	701	11
	2	383	416	9
	3	238	287	21
16:10	1	5454	9659	77
	2	631	854	35
	3	421	556	32
average				17

4.2.4 Apartment Results

The results for the apartment suite are shown in Table 4.3. Outdoor light levels were measured at 8 am and 9 am. The indoor measurements were made at approximately 8:30. Therefore the predicted light levels at 8 am and 9 am were averaged and compared to the 8:30 readings. Similarly, outdoor levels were measured at 3 pm and 4 pm, with the indoor measurements made in between. The predicted light levels were averaged for these two hours and compared to the measured values. The percentage difference between measured and predicted illuminance values is quite large for this case. The absolute difference (in Lux) is, however, similar to the other two building types at about 300 Lux. Thus, there may be a large percentage error in the simulations at very low light levels, however, these values are of less interest since they are well below the

light levels required for biological stimulation. The apartment suite has illuminance readings 3 to 6 times lower than for the other two buildings.

The prediction of light levels in the apartment is a more complicated case and is not easily handled by the SUPERLITE model used. The simplified SUPERLITE allows for only one outdoor obstruction. Outside the apartment there is a tree on both the left side and the right side, as viewed from the interior, and a balcony wall made of concrete. The effects of the wall and the tree on the right side have been summed as it is felt that the effects of these two obstructions are cumulative. The tree on the left side has not been used in the simulations and would serve to lower the predicted indoor light levels by reducing the amount of diffuse light entering the room. There is also a column on the balcony that cannot be modeled. The combination of trees and balcony walls may be too complicated to obtain accurate illuminance predictions. Most apartment suites, however, are high enough off the ground that shading from trees does not occur.

Table 4.3: Measured and Predicted Illuminance Levels for the Apartment

Time	Room Position	Measured (LUX)	Predicted (LUX)	% Difference
8:30	1	225	46	-80
	2	140	59.5	-58
	3	95	42	-56
12:00	1	402	732	82
	2	140	592	323
	3	92	385	318
15:30	1	135	226.5	68
	2	201	127	-37
	3	37	77.5	109
average				74

4.3 Sources of Error

This section discusses some of the sources of error that might explain the discrepancies between the measured and the predicted light levels. There are three sources of error: measurement errors, data input uncertainty and model limitations.

Measurement Errors: Indoor measurements are made using a light meter mounted on a tripod. The tripod may not be in the identical position as the center of the simulation node as calculated by SUPERLITE. Experimentation showed that the illuminance levels could vary by as much 15% due to slight variations in the height and distance from the walls at which the instrument is held. The length of time to take the measurements is also an issue. It took approximately 1 hour for 15 measurements in the room, and the

solar intensity and solar angles change during this time. It was found that outdoor illumination levels varied by as much as 40%, from minimum to maximum, over the course of an hour. This will have a corresponding effect on the illuminance levels inside.

Data Input Uncertainty: It was found that the reflectance of the interior surfaces greatly affects the predicted light levels in the room, yet it is difficult to get an accurate value for the average surface reflectance accounting for furniture and pictures. Values of reflectance were taken as 0.7 for white painted ceilings and between 0.4 and 0.6 for wall reflectances depending on their colour.

Model Limitations: The version of SUPERLITE that was used for this project can model simple, rectangular, rooms with no interior obstructions and only one exterior obstruction. As a result, L-shaped rooms, or rooms with alcoves, wall-mounted cabinets, etc. cannot be accurately modeled, although simplifications and assumptions can be made. A more complex model could be used (e.g., RADIANCE), however, these models require several weeks to prepare an input data file and the number of runs that could be made for the same project budget would have to be reduced.

5. RESULTS OF DAYLIGHTING SIMULATIONS

5.1 Definitions

The daylight availability was evaluated for two rooms in each of three building types/urban densities. Descriptions of the rooms are given in Table 5.1. The interior surface reflectivities were made the same for all the rooms and set to 0.5 for walls, 0.7 for ceilings and 0.3 for floors (approximately the average values used in the validation exercise).

Table 5.1: Description of Rooms used in Simulations

	Single Detached		Townhouse		Apartment Suite	
Parameter	Living Room	Bed-room	Living Room	Bed-room	Living Room	Bed-room
Floor Area (m ²)	39.1	12.1	29.1	9.7	24.0	10.9
Room Width (m)	9.6	3.7	3.5	2.8	6.0	2.8
Room Depth (m)	4.1	3.3	8.4	3.5	4.0	3.8
Window Area (m ²)	3.69	0.85	3.25	1.64	3.88	2.01
Window to Floor Area Ratio (%)	9.5%	7.0%	11.2%	16.9%	16.1%	18.4%
Window to Wall Area Ratio (%)	15.9%	10.0%	40.4%	25.5%	26.7%	29.0%
Density Blockage Angle (deg)	15	7.5	16	7	44	44
Overhang Blockage Angle (deg)	13	39	13	35	75	0
Visibility Angle(deg)	62	43	61	48	0	44
Diffuse Daylight Factor - no obstructions	2.5%	1.4%	2.8%	3.3%	3.8%	3.5%
Diffuse Daylight Factor - with obstructions	1.7%	0.7%	1.9%	1.7%	0.0%	1.8%

Notes: windows are clear double-glazed; wall reflectivity is 0.5, ceiling reflectivity is 0.7 and floor reflectivity is 0.3

The Daylight Factor is a common measure of the daylight acceptance of a room. It is defined as the ratio of the indoor illuminance to the outdoor illuminance (times 100 to express as a percentage). The Daylight Factor (DF), besides varying with room design, varies throughout the room and is function of the sun position and sky conditions. The concept of Diffuse or Average Daylight Factor (DDF) has been defined to overcome this complication [University College Dublin, 1994]. The Diffuse Daylight Factor (sometimes referred to as minimum daylight factor) is the daylight factor for a uniform overcast sky averaged over the room. By basing the daylight factor on a diffuse sky, the DDF is independent of sun position and time of year. It is calculated as

$$\text{DDF} = T \cdot A_{\text{window}} \cdot V_{\text{angle}} / [A_{\text{surfaces}} \cdot (1 - R^2)] \quad (\text{as a percentage})$$

where T is the window daylight transmission (as a fraction)

A_{window} is the window area

V_{angle} is the angle of visible sky from the window (0 is fully obstructed, 90 no obstructions)

A_{surfaces} is the total area of room surfaces (walls, windows, floors and ceiling)

R is the average reflectivity of the surfaces

Table 5.1 contains the Diffuse Daylight Factor for each room for the obstructed and unobstructed cases. It is recommended that DDF values be between 1 and 5% if a predominantly daylight appearance is required [University College Dublin, 1994].

The problem with basing a design on the DDF is the same as its advantage: it does not take into account location, orientation or time of year. To achieve satisfactory daylight levels, a room with a south-facing window in a sunny location will require a small window area and a room with a north-facing window in a cloudy location will require a large window area. These differences are not accounted for in the DDF. Building designers need to know the Daylight Factor for the actual sky conditions in their location. The simulations performed as part of this study provide this information.

For the purposes of this study, we are not interested in the illuminance or Daylight Factor for a single hour but the total illuminance or Daylight Factor over an extended period (a season or a year). To that end, two terms are defined: Total (i.e., beam and diffuse) Daylight Factor - Annual (TDF Annual) and Total Daylight Factor – Winter (TDF Winter). These terms are calculated as the total indoor illuminance in lux-hours divided by the outdoor (unobstructed) illuminance in lux-hours for either the winter period (taken as December, January and February) or the full year.

Table 5.2: Summary of Light Levels for the Living-Room in the House - Toronto

City:		Toronto					
Residence Type:		House					
Room:		Living Room					
Total Available Lux-Hours Whole Year:		149,097,800					
Total Available Lux-Hours Winter:		23,404,800					
Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	94%	2.26%	2.13%	2.89	0.52
		Centre	90%	0.76%	0.68%	0.01	0.00
		Interior	83%	0.53%	0.44%	0.00	0.00
		Average	92%	1.18%	1.09%	0.97	0.17
	East	Perimeter	95%	4.58%	4.34%	4.50	1.88
		Centre	86%	1.24%	1.07%	0.50	0.17
		Interior	75%	0.77%	0.57%	0.07	0.00
		Average	91%	2.19%	1.99%	1.69	0.68
	West	Perimeter	88%	5.05%	4.47%	4.26	1.75
		Centre	73%	1.78%	1.31%	0.72	0.25
		Interior	57%	1.03%	0.59%	0.19	0.00
		Average	81%	2.62%	2.12%	1.72	0.67
	South	Perimeter	95%	6.08%	5.76%	5.31	2.59
		Centre	83%	1.58%	1.30%	0.81	0.19
		Interior	71%	0.91%	0.65%	0.18	0.00
		Average	90%	2.85%	2.57%	2.10	0.93
WINTER	North	Perimeter	102%	2.34%	2.37%	0.44	0.02
		Centre	109%	0.78%	0.85%	0.00	0.00
		Interior	116%	0.54%	0.63%	0.01	0.00
		Average	105%	1.22%	1.28%	0.15	0.01
	East	Perimeter	81%	4.00%	3.25%	0.66	0.12
		Centre	53%	1.84%	0.98%	0.04	0.01
		Interior	36%	1.67%	0.61%	0.00	0.00
		Average	64%	2.50%	1.61%	0.23	0.04
	West	Perimeter	85%	4.11%	3.51%	0.64	0.14
		Centre	68%	1.71%	1.16%	0.06	0.03
		Interior	31%	1.98%	0.62%	0.02	0.00
		Average	68%	2.60%	1.77%	0.24	0.06
	South	Perimeter	87%	12.50%	10.87%	1.02	0.65
		Centre	71%	7.38%	5.27%	0.51	0.27
		Interior	58%	2.46%	1.42%	0.22	0.11
		Average	79%	7.45%	5.85%	0.58	0.34

Table 5.2 lists values for TDF Annual and TDF Winter for the house family room located in Toronto. A full set of these tables for the six rooms in the three cities is given in Appendix A. Values for TDF Annual and TDF Winter are given for four orientations and three zones in the room: perimeter, centre and interior. The zonal values are the average of five position values across each third of the room (see Section 4.1).

A term is included in the tables to define the daylight blockage due to exterior obstructions. This term, referred to as the Overhang and Density Obstruction Factor (ODOF) is the ratio of the obstructed total daylight factor to the unobstructed daylight factor (times 100 to obtain a percentage). It is a measure of the illuminance that makes it past exterior obstructions. An ODOF of 90 % means that the light level in the room is 90% of what it would be if the obstructions were removed, or 10% of the daylight is blocked by the obstructions. This factor includes the blockage due to adjacent buildings (i.e., urban density) and building overhangs (i.e., balconies). The ODOF is function of the period considered, either annual (ODOF Annual) or winter (ODOF Winter).

Finally, the tables include the number of hours per day that the illuminance exceeds 1000 and 2000 lux. There is an average of 12 daylight hours per day over the year and between 9 and 9 ½ hours per day over the winter.

5.2 Outdoor Daylight Availability

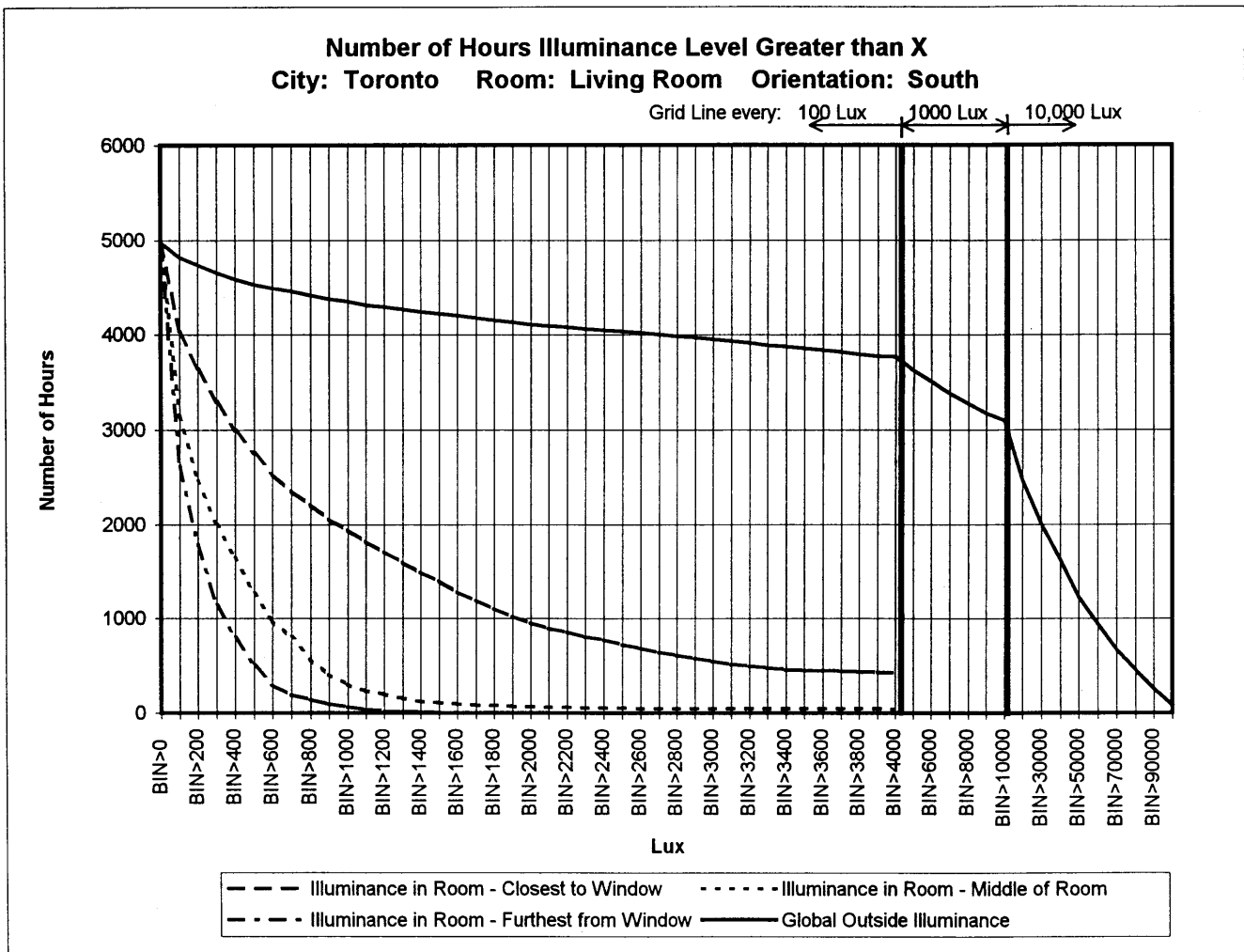
Table 5.3 summarizes the exterior daylight availability for the three locations studied. The values are the totals of the illuminance data given in the CWEEDS datafiles (see Section 3.2). There is not a large difference in daylight availability for the three cities on an annual basis. In the winter, however, Calgary receives almost 40% more daylight than Vancouver. If it is desired to have the same interior daylight availability over the winter, then the windows in Vancouver housing should be 40% larger than in Calgary housing.

Table 5.3: Daylight Availability for the Three Cities Studied

City	Annual Daylight Availability (Mlux-hrs)	Average Illumination over Annual Daylight Period (lux)	Winter Daylight Availability (Mlux-hrs)	Average Illumination over Winter Daylight Period (lux)
Vancouver	138.5	31,600	17.0	21,000
Toronto	149.1	34,000	23.4	27,400
Calgary	154.2	35,700	23.7	29,300

Figure 5.1 shows an hourly frequency plot of horizontal illuminance. Outdoor illuminance levels can be over 100,000 lux and most daylight hours are over 20,000 lux. Interior illuminance levels are only a fraction of the outdoor illuminance values. The combination of exterior obstructions and small window openings reduce indoor levels to under 2000 lux in most cases for areas near the window. In the centre and back of the room, light levels are typically under 1000 lux. The following sections address the impact of building and urban design on interior light levels.

Figure 5.1



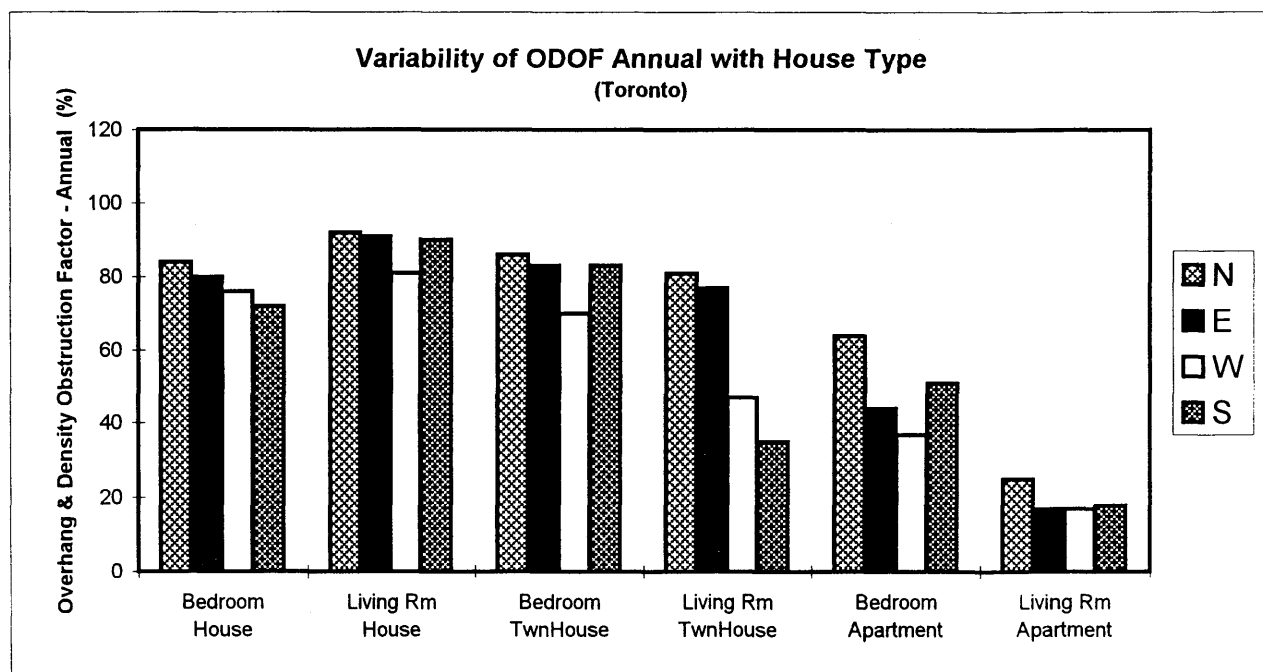
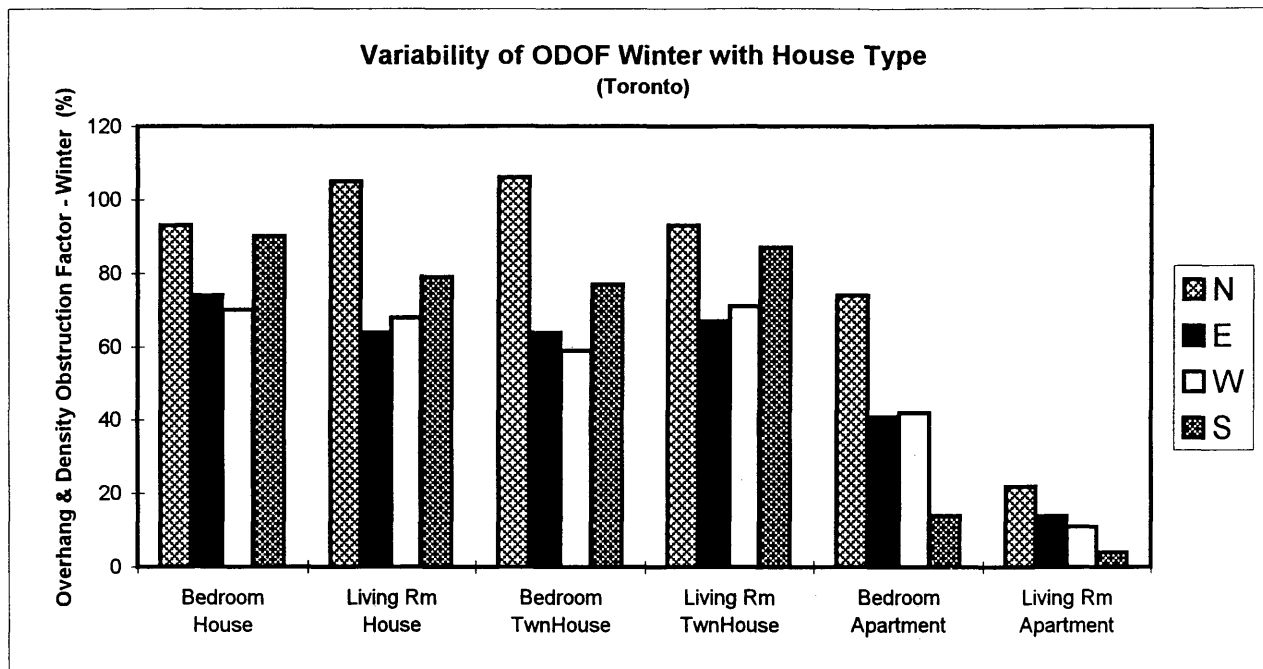
5.3 Effect of Overhang and Urban Density Blockage on Daylight Availability

The rooms studied have different amounts of blockage from exterior obstructions. The living rooms in the house and townhouse have a density blockage angle of 15 degrees. The upper floor bedrooms for these housing types have a blockage angle of only 7 degrees because they are at a higher elevation than the family/living rooms. The density blockage angle for the apartment rooms is much higher at 44 degrees. When the overhang is included, the total blockage angle increases to 28 degrees for the house and townhouse living rooms, 45 degrees for all the bedrooms and 90 degrees for the apartment living room.

Figure 5.2 shows the winter and annual Overhang and Density Obstruction Factors (ODOF) for each of these room groups in Toronto. The townhouse results are not shown because they were almost identical to the house values. The values are the average for the room, ODOF is not a strong function of depth into the room. The winter results show that as the density blockage angle increases, the ODOF Winter decreases, in other words, the sun must go higher in the sky to clear adjacent buildings. The winter ODOF ranges from an average of 80% for the house rooms to under 40% for the apartment rooms. The one curious result is that the winter ODOF values can be much higher for north-facing rooms than for other window orientations, and in fact, can go above 100%. A value greater than 100% indicates that the light level in the room is enhanced by adding an exterior building. For north-facing windows, the exterior obstruction acts like a mirror reflecting light coming from the south into the north-facing window.

The annual ODOF values show the same trends as the winter ODOF values. The house living room annual ODOF values are slightly higher than the winter ODOF values, because in the non-winter seasons the sun is higher in the sky and adjacent buildings have less impact. The bedroom annual ODOF values are slightly lower than the winter ODOF values. Although the adjacent building has less impact in the summer months, the house eave reduces summertime interior daylight levels. For the apartment living room, where the combination of adjacent buildings and overhead balcony reduce the sky visibility angle to zero (total blockage angle of 90°), the annual ODOF value is only 20%.

Figure 5.2:



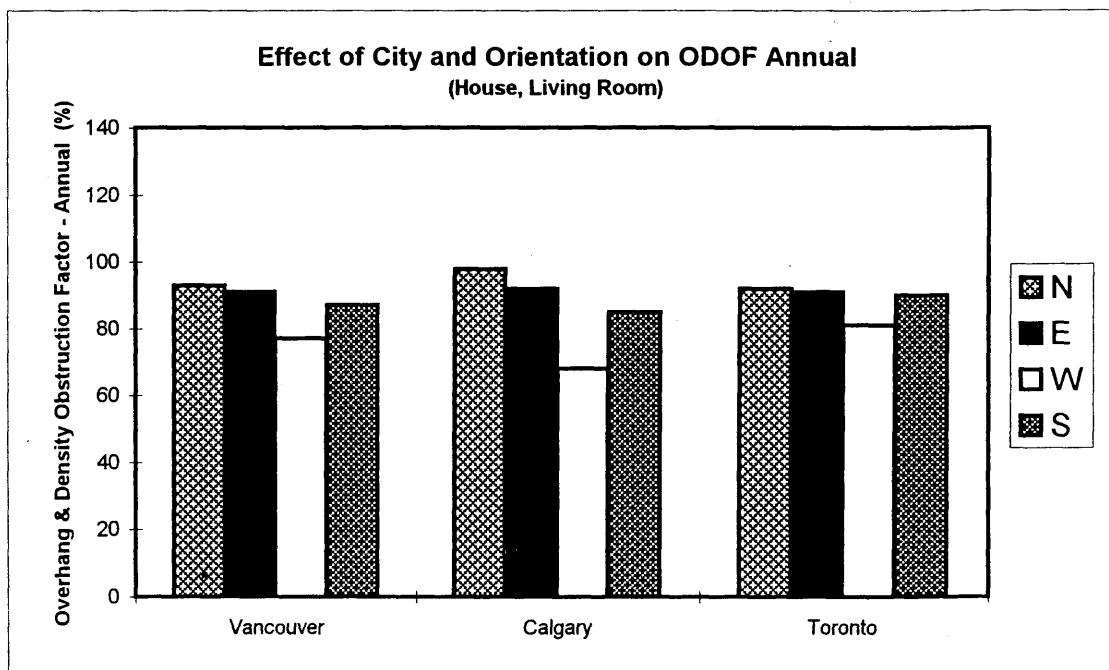
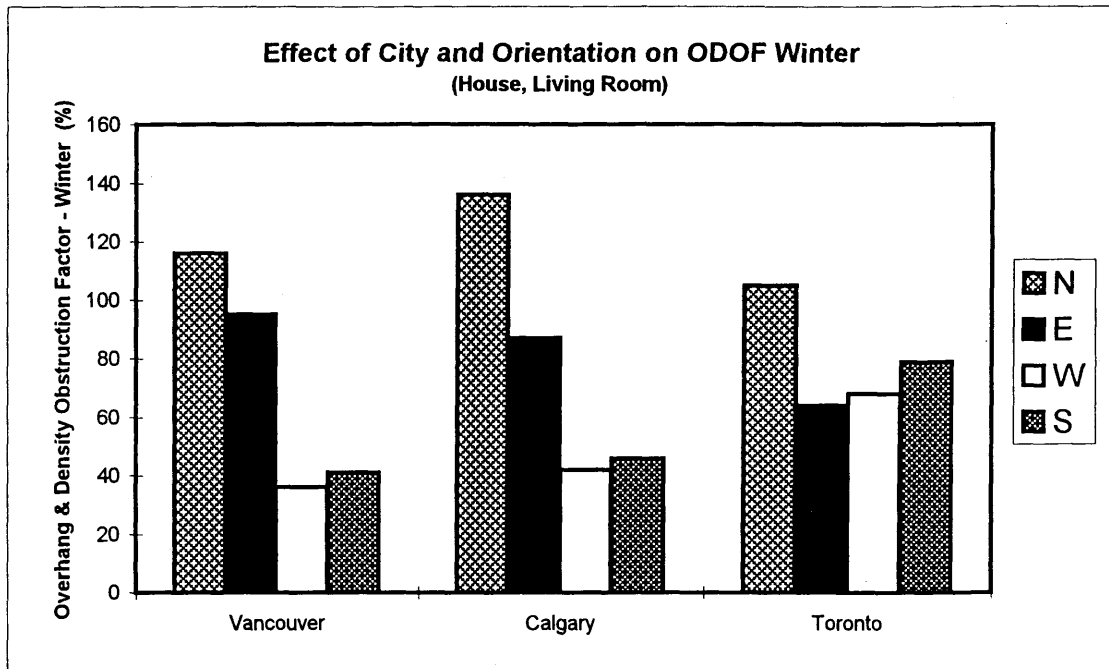
The results for the different room types can be used to separate the effects of urban density and building overhangs. The major difference between the results for the apartment bedroom and the apartment living room is that the living room light availability is reduced because of a balcony. The DOF (Density Obstruction Factor) for the apartment building is on average 45% and the OOF (Overhang Obstruction Factor) for the balcony is on average 35%. The two combine to give an average ODOF of 16%. The OOF is relatively constant whereas the DOF varies significantly with orientation.

For the house and townhouse, the urban density blockage is more significant for the first floor rooms (living room), whereas the window overhang is more significant for the second floor bedrooms. Given that both rooms have similar ODOF values, it is concluded that the DOF and OOF values are similar and each is typically over 80%. The actual value for each parameter is not as important since both values are so high.

Figure 5.3 shows values of ODOF for the three cities studied. On an annual basis, the ODOF values are fairly similar for the three cities. In the winter, however, Toronto has slightly higher ODOF values, presumably because of its lower latitude (higher winter sun angles). Orientation, however, has a much larger impact than location (for the cities studied).

In summary, exterior obstructions have only a modest impact on daylight levels in single-detached housing and in some cases can increase light through north-facing windows. Apartment rooms, on the other hand, receive only one quarter of the daylight of houses and townhouses because of exterior obstructions.

Figure 5.3:



5.4 Interior Daylight Availability - No Exterior Obstructions

The rooms studied vary in shape, size and window area. This can best be characterized by the window-to-floor ratio. The house living room and bedroom have the lowest window-to-floor ratio at 9.5 and 7 % respectively. The window-to-floor ratio for the townhouse living room and bedroom are higher at 11.2 and 16.9 % respectively. The apartment building living room and bedroom have the highest ratios at 16.1 and 18.4 % respectively. It may be that building designers are compensating somewhat for the lower DOF in apartments by using larger windows.

Figure 5.4 shows the unobstructed (i.e. no adjacent buildings or overhangs) Total Daylight Factor for the six rooms (values are average for the room). As the window-to-wall ratio is increased, the TDF - unobstructed increases. On an annual basis, the TDF - unobstructed varies between 1 and 6 %. Rooms with south-facing windows have unobstructed TDF values approximately 2.5 times the values for north-facing windows. In the winter, the trends are even more pronounced. The low sun angle in the winter results in much higher values of TDF - unobstructed. Rooms with south-facing windows get 3 times the amount of illuminance as rooms with east- or west-facing windows and 6 times the amount of rooms with north-facing windows.

Figure 5.5 shows the variation of TDF - unobstructed for the three cities studied for the living room house. The three cities show the same trends: high TDF - unobstructed for south-facing rooms and low TDF - unobstructed for north-facing rooms. For the winter period, TDF - unobstructed values are highest in Calgary especially for south- and west-facing rooms. The low winter sun angle for high latitude locations results in high values of unobstructed TDF. The values for Vancouver are lower than for Calgary even though they are at the same latitude because the cloudy Vancouver winters mean less direct solar radiation enters the room.

The Total Daylight Factor is also a function of depth into the room. Figure 5.6 shows winter and annual values of the house living room TDF - unobstructed for three regions in the room: perimeter, centre and interior. Curve fits were made to the values to estimate how they vary over the full room depth. As expected there is a significant reduction in unobstructed TDF with depth into the room. The TDF - unobstructed at the perimeter is between 4 and 10 times higher than at the interior. The curves show a slight increase at the back wall that could be a function of the curve-fit chosen or a result of reflection off the back wall. The south-facing winter TDF - unobstructed values can be very high because the perimeter zone can receive direct sunlight.

Figure 5.4:

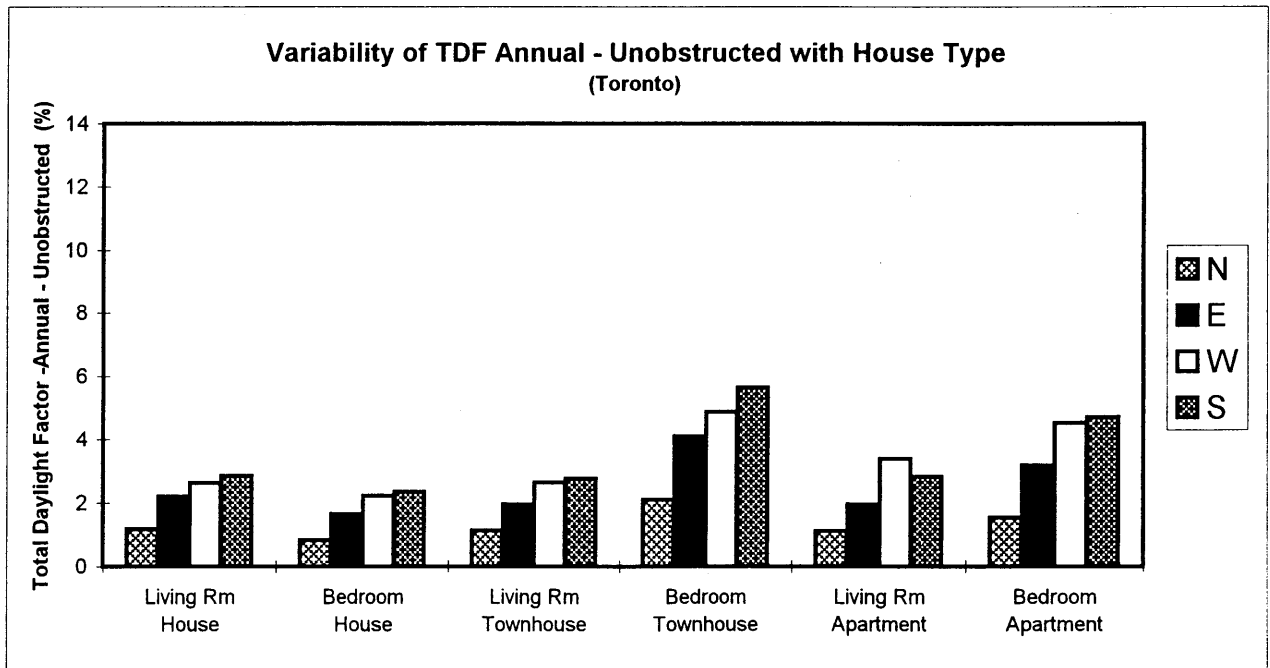
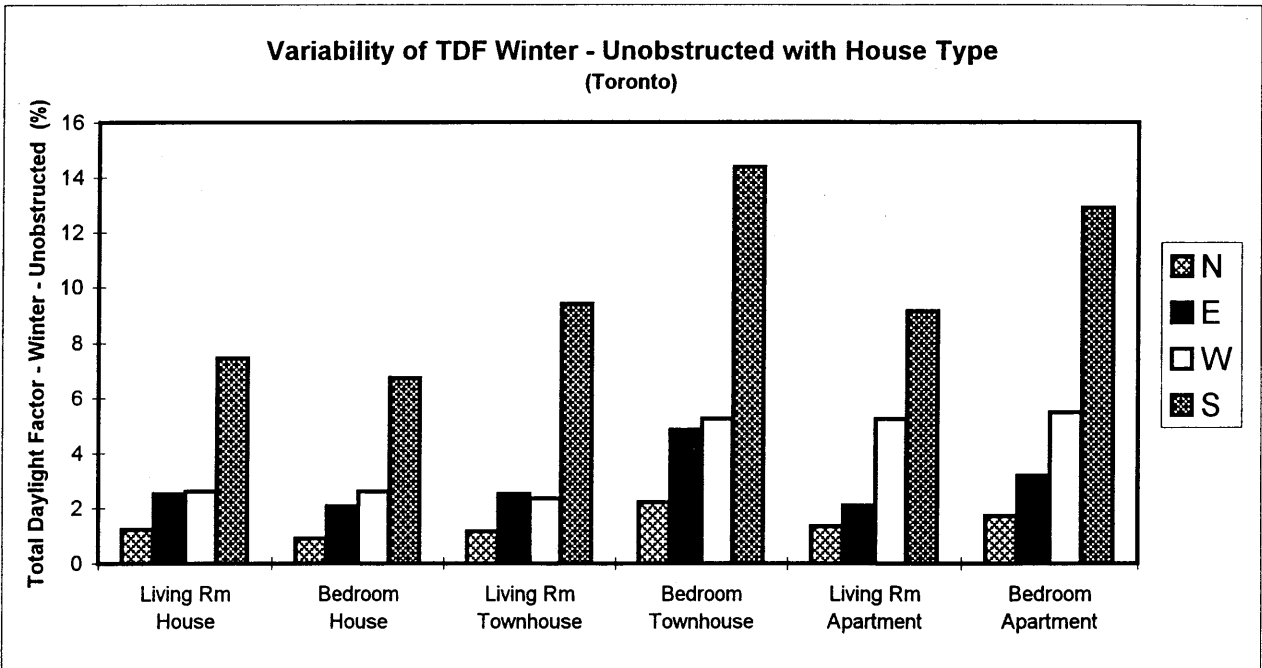


Figure 5.5:

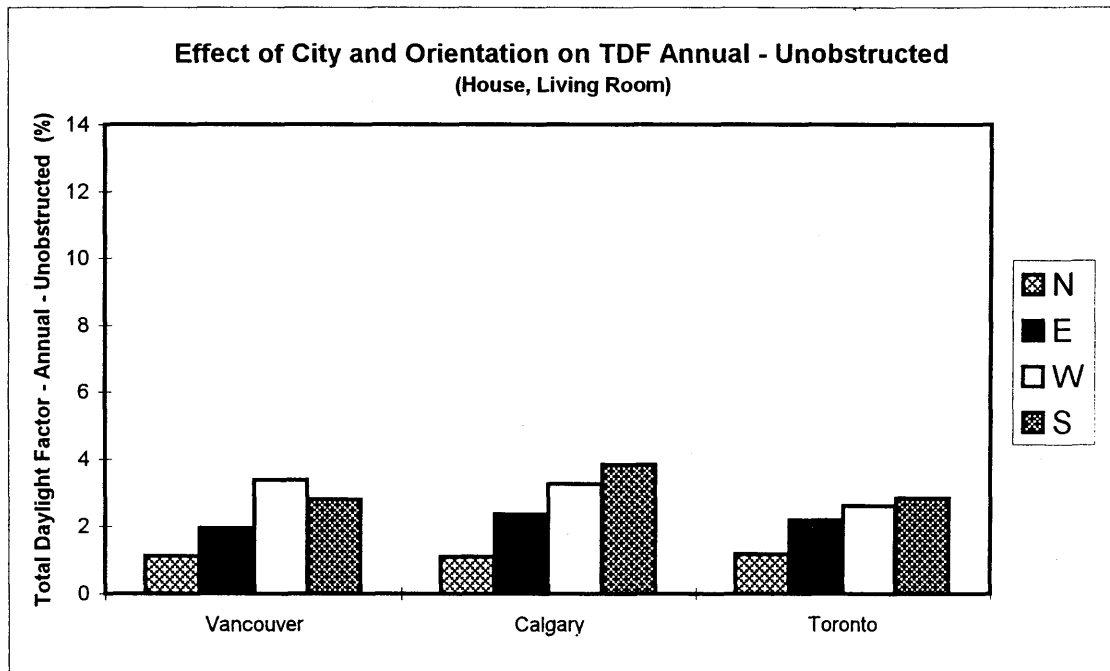
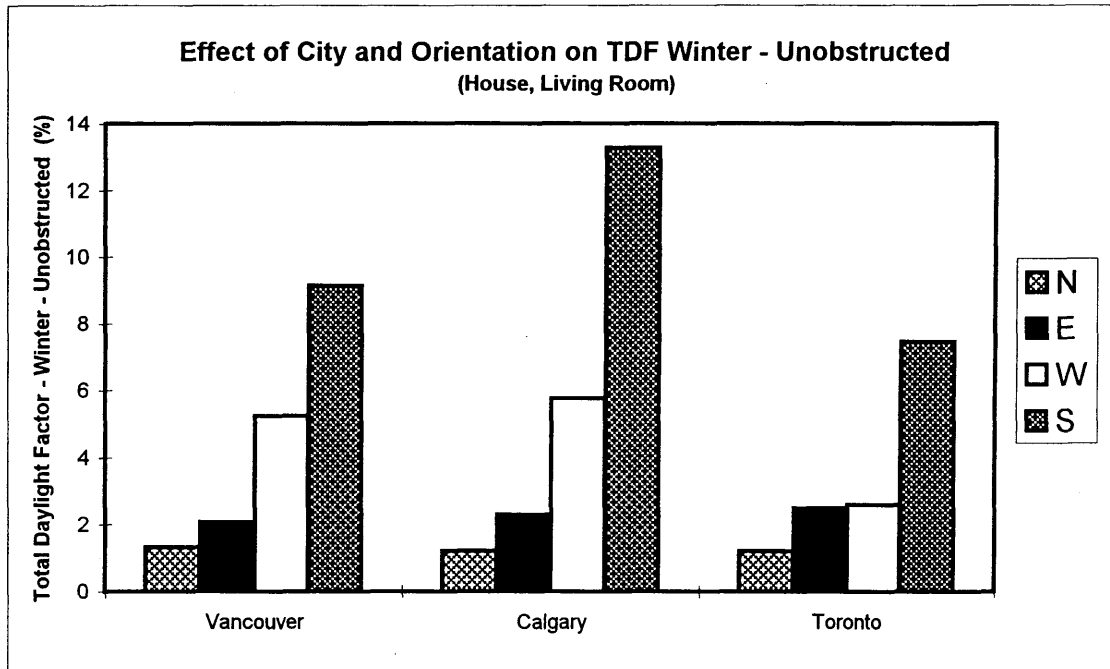
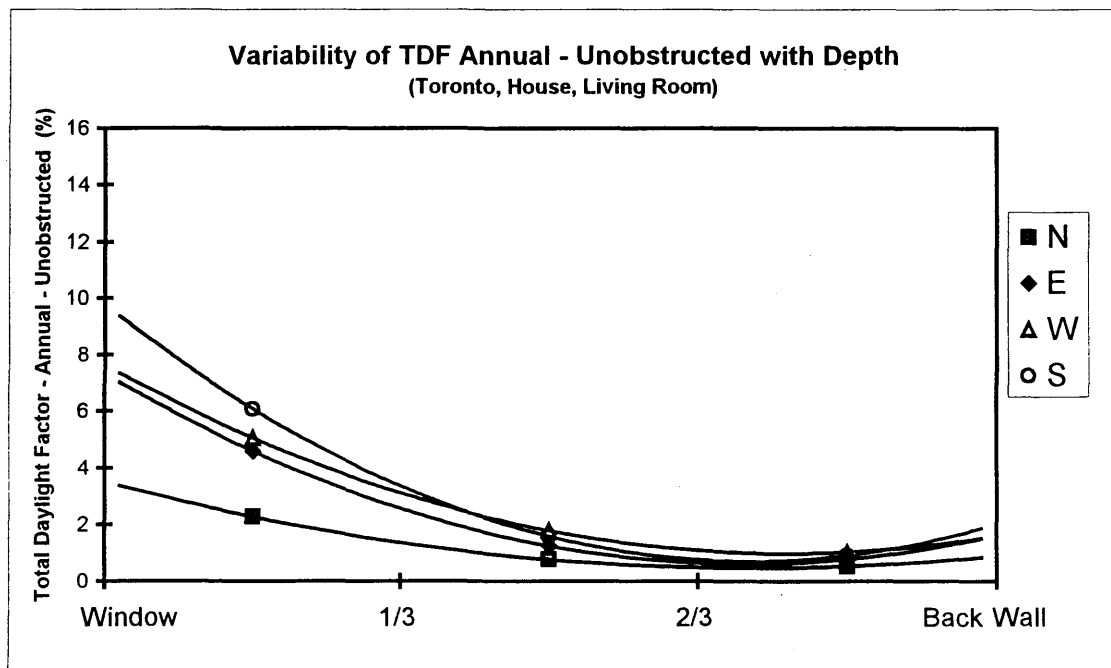
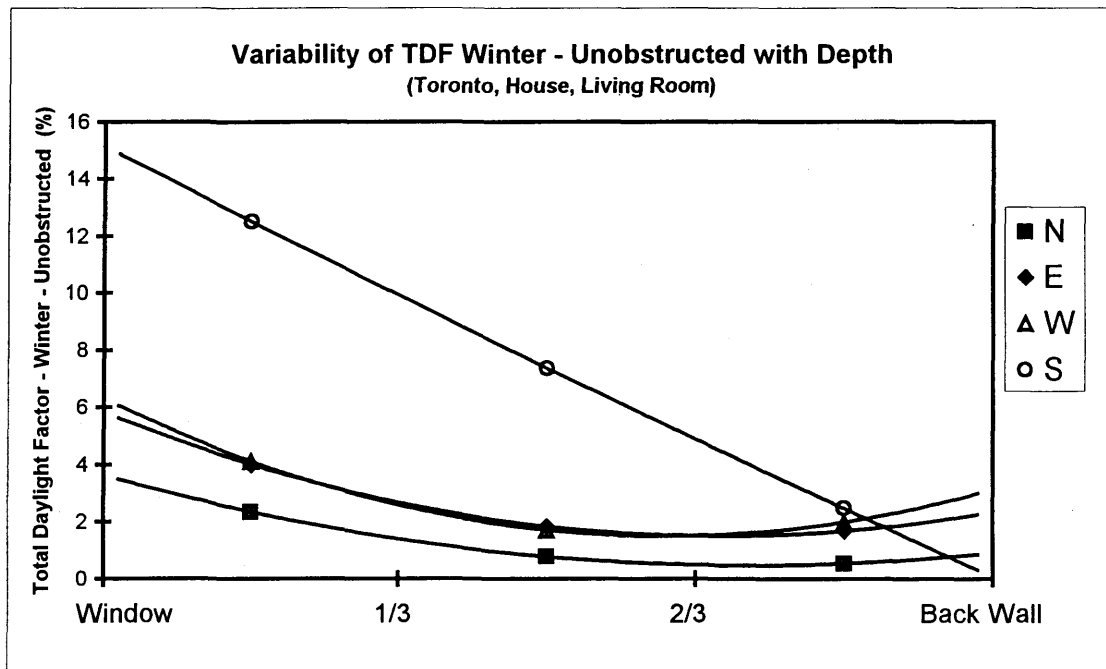


Figure 5.6:

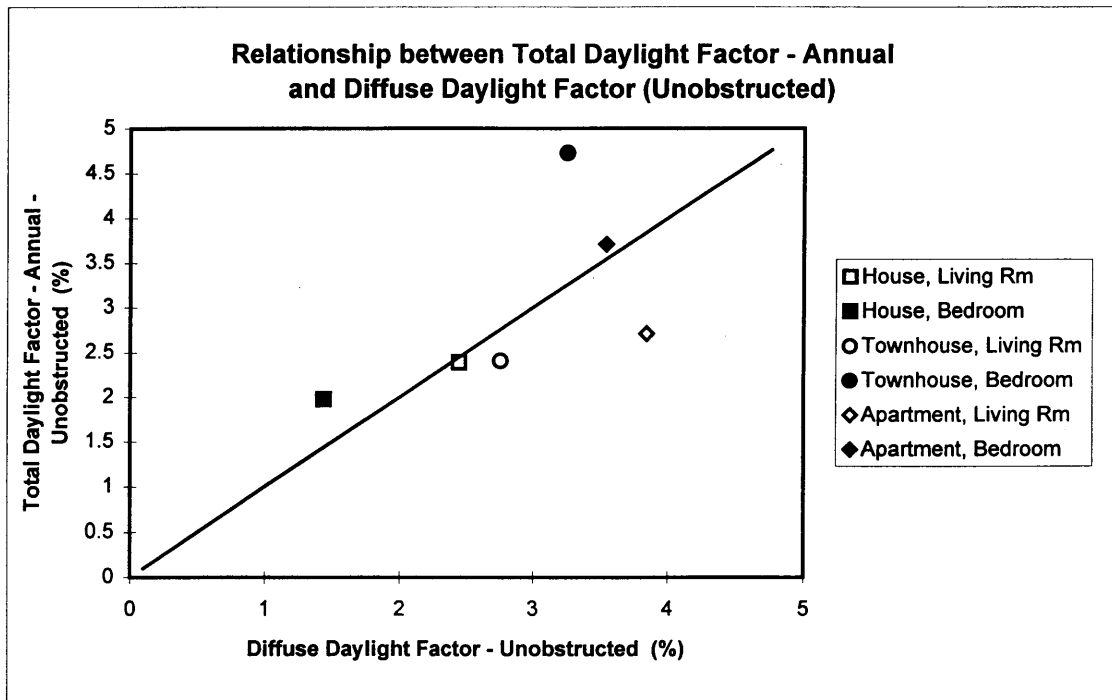


In Table 5.4, annual values of unobstructed Total Daylight Factor (averaged over the room, the four orientations and the three cities) are compared to the Diffuse Daylight Factor (fully diffuse sky model). The two sets of numbers are reasonably close to one another, and there appears to be a one-to-one correlation (see Figure 5.7). Although the unobstructed Total Daylight Factor includes beam (or direct) light, averaging the values over the year and orientation yields a value that is close to a fully diffuse value. Thus, the Diffuse Daylight Factor (which is easy to calculate) appears to be a reasonable approximation to the unobstructed Total Daylight Factor.

Table 5.4: Comparison of Diffuse Daylight Factor and TDF-unobstructed

House, Room	Diffuse Daylight Factor (diffuse sky model) (%)	Total Daylight Factor Annual - Unobstructed (%)
House, Living Room	2.5	2.4
House, Bedroom	1.4	2.0
Townhouse, Living Room	2.8	2.4
Townhouse, Bedroom	3.3	4.7
Apartment, Living Room	3.8	2.7
Apartment, Bedroom	3.5	3.7

Figure 5.7:



5.5 Total Daylight Availability

The total daylight available is the product of the available outdoor illuminance (Section 5.2), the Overhang and Density Obstruction Factor (Section 5.3), and the Total Daylight Factor - unobstructed (Section 5.4). The Total Daylight Factor - obstructed is the product of the last two quantities. Figure 5.8 shows the variation of TDF - obstructed for the six rooms studied. Annual values of TDF - obstructed range from 0.5 to almost 3%, for the winter season, whereas south-facing TDF - obstructed values can go as high as 6%. The lowest daylight values are for the apartment building, even though they had high values of unobstructed TDF. The daylight blockage (ODOF) had a major impact on apartment buildings. On an annual basis, the house living room TDF - obstructed values are 4 to 5 times higher than the apartment living room values.

Figure 5.9 shows the variation of TDF - obstructed by city. Because of offsetting effects the three cities have very similar results. Calgary had the lowest values of ODOF (largest blockage) during the winter because of its high latitude. This same high latitude resulted in high unobstructed TDF values. When these two effects are combined, Calgary TDF - obstructed values are similar to Toronto TDF values - obstructed.

In Section 5.4, it was shown that there was reasonable agreement between the TDF - unobstructed and the Diffuse Daylight Factor. Table 5.5 shows the same comparison with both values adjusted to include obstructions. The correction for Daylight Factor is simply the % of the sky that is visible. In this case there is poor agreement (especially in percentage terms) between the two sets of numbers. For the apartment living room, the Diffuse Daylight Factor is zero, whereas the actual value is 7.7 %. It would seem that the daylight blockage effects are too complicated to be adjusted by the total blockage angle alone. (Section 5.6 presents a more comprehensive approach.)

Figure 5.8:

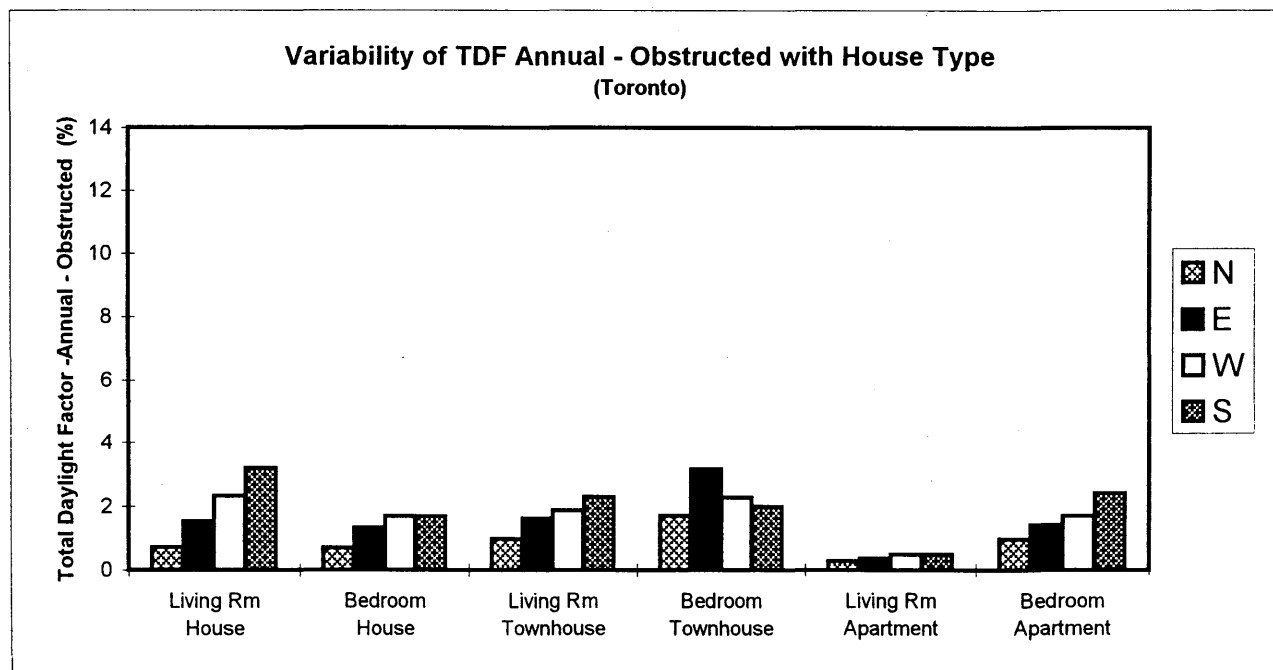
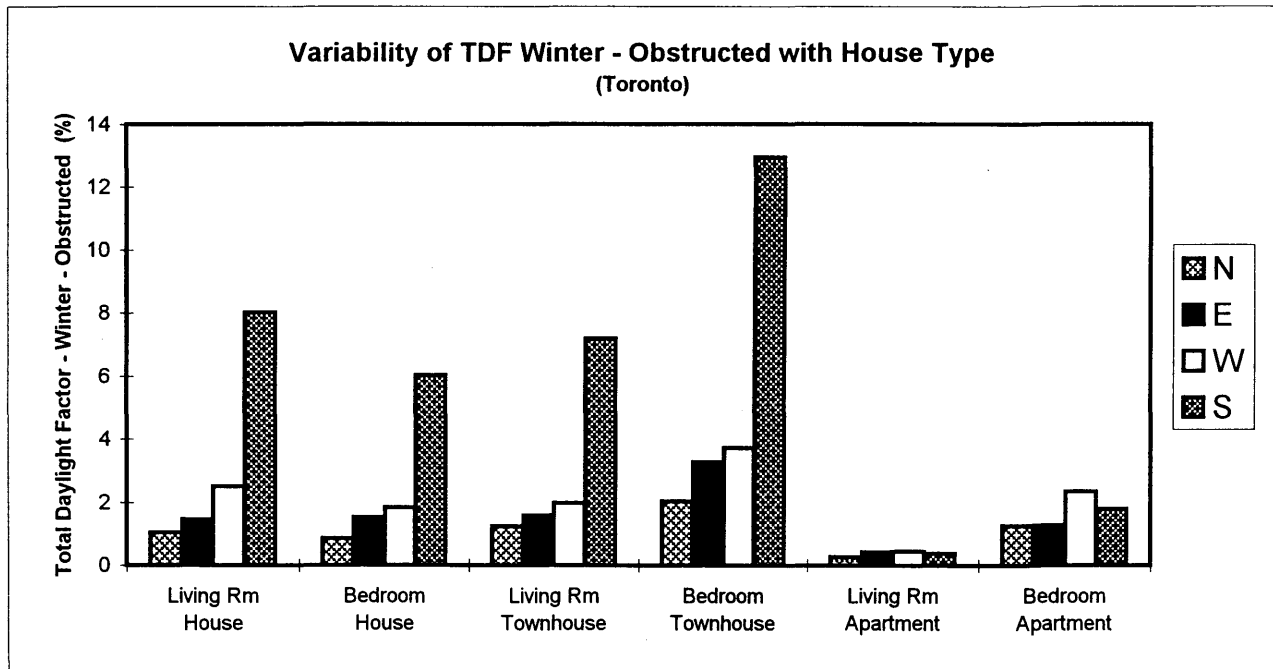


Figure 5.9:

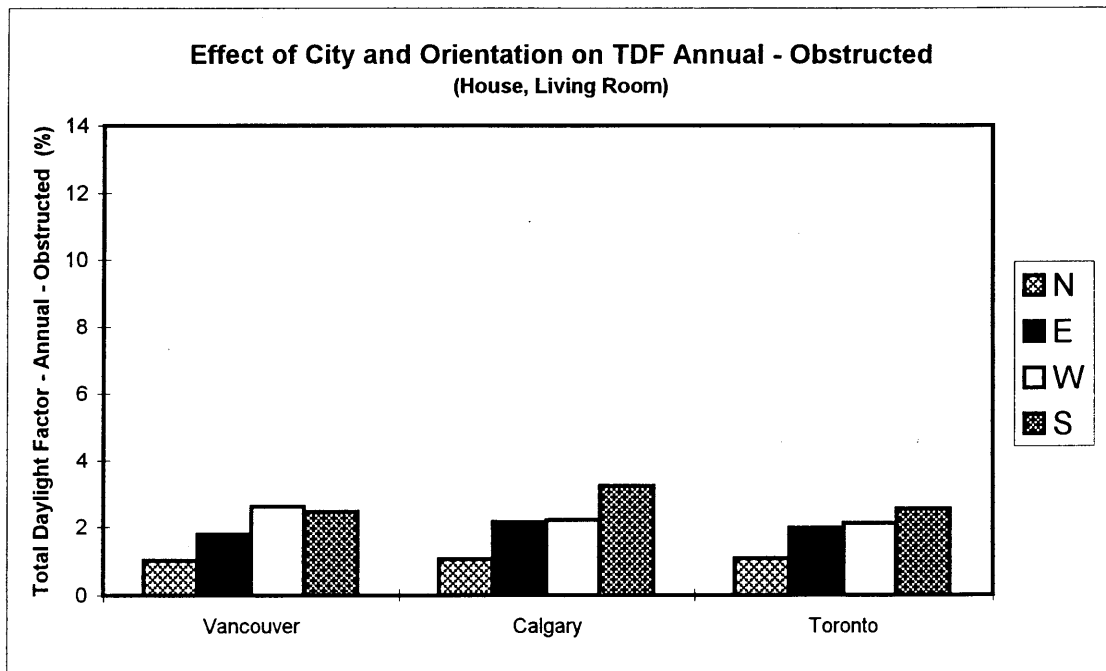
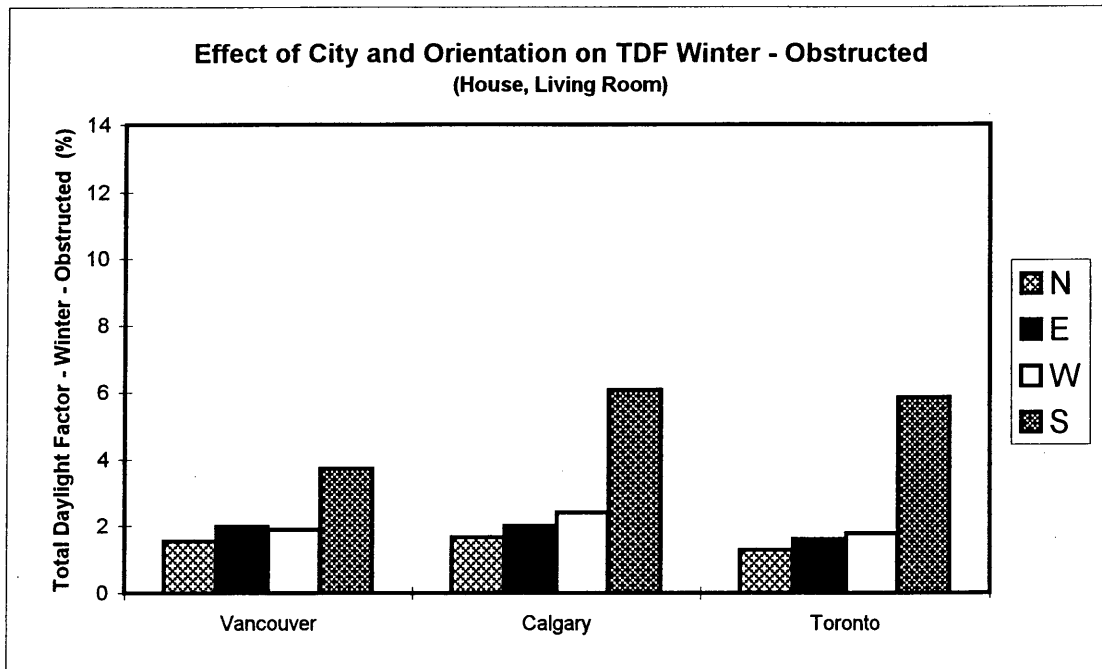


Table 5.5: Comparison of Diffuse Daylight Factor and TDF- obstructed

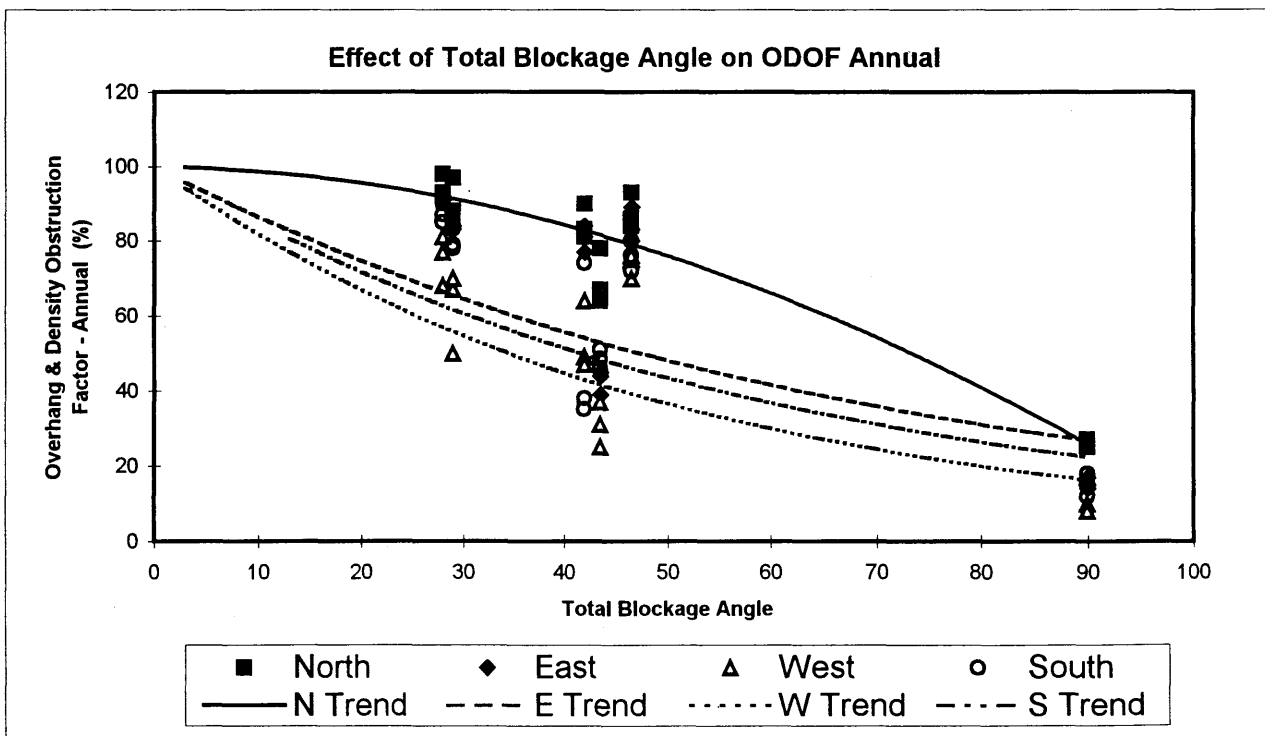
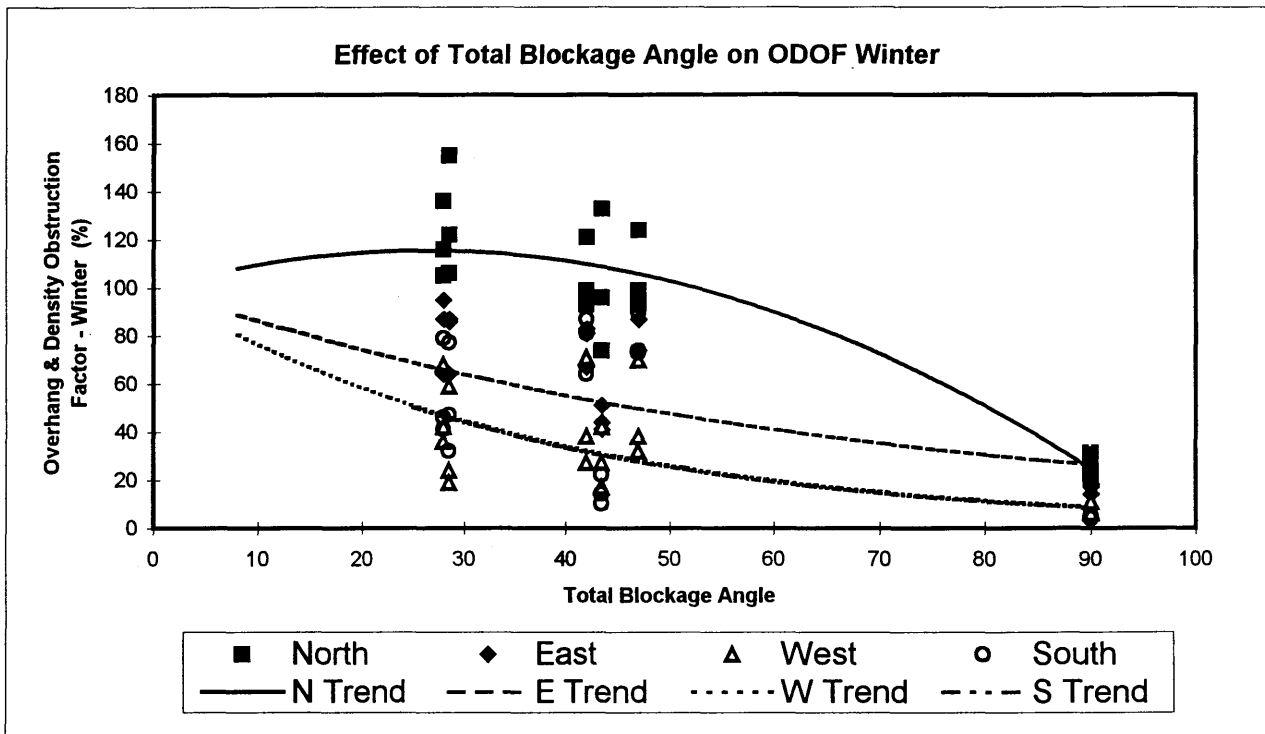
House, Room	Diffuse Daylight Factor (diffuse sky model) (%)	Total Daylight Factor Annual - obstructed (%)
House, Living Room	1.7	4.0
House, Bedroom	0.7	4.5
Townhouse, Living Room	1.9	5.9
Townhouse, Bedroom	1.7	9.0
Apartment, Living Room	0.0	7.7
Apartment, Bedroom	1.8	6.0

5.6 Synthesis of Results

The previous sections presented the daylighting results for six rooms in three cities. The purpose of this section is to determine if there are any trends to data and whether generalizations can be made about daylighting performance. This information could then be used to predict daylight levels in rooms and cities not studied. The reader is cautioned that the generalizations made in this section are based on a small data set. Additional cases should be studied to see if the trends identified are universal.

To determine daylight levels for a specific room, it is necessary to know the Overhang and Density Obstruction Factor and the Total Daylight Factor-unobstructed. The TDF-obstructed is the product of these two parameters. Figure 5.10 shows the relationship between ODOF and the blockage angle for all the rooms and cities studied. The winter values of ODOF are plotted as a function of the Total Blockage Angle (adjacent buildings and overhangs). Although there is considerable scatter in the points especially in winter ($R^2 = 0.63$), some conclusions can be made about the impact of external blockages on daylight availability. The ODOF is a strong function of orientation because of the different sun angles. North-facing rooms have the highest values of ODOF (in some cases going above 100%) and south-facing rooms have the lowest values. In the winter, the value of ODOF drops off quickly with blockage angle, north-facing rooms excepted. At high Density Blockage Angles (greater than about 30 degrees), the daylight availability is cut in half by external obstructions. A similar but less dramatic situation is seen on an annual basis ($R^2 = 0.72$).

Figure 5.10:



In Section 5.3, it was shown that the Total Daylight Factor-unobstructed averaged over the four orientation can be approximated by the Diffuse Daylight Factor. The designer, however, needs to know the TDF for a particular orientation. To adjust the TDF for orientation, an Orientation Factor is defined as the ratio of TDF for a particular orientation (and season) to the annual TDF averaged over the four orientations. Figure 5.11 presents values for the Orientation Factor for all the rooms and cities studied. Although there is considerable scatter in the data, the results do fall into bands of similar orientation, especially for the annual case. Thus, the Orientation Factor appears to be relatively constant for the cases studied. The average Orientation Factors are summarized in Table 5.6. The Orientation Factor can be thought of as the fractional adjustment to the Diffuse Daylight Factor to account for season and orientation.

Table 5.6: Orientation Factors for Total Daylight Factors

Orientation	Winter Orientation Factor	Annual Orientation Factor
North	0.21	0.41
East	0.51	0.91
West	1.11	1.41
South	2.11	1.31

Using the graphs and tables presented in this Section, it is possible to predict the Total Daylight Factor for any room (provided the room, urban density and geographic location are not outside the range studied). The TDF for the winter and on an annual basis can be estimated as follows.

$TDF_{Winter} = ODOF_{Winter} * DDF * OF_{Winter}$

$TDF_{Annual} = ODOF_{Annual} * DDF * OF_{Annual}$

where

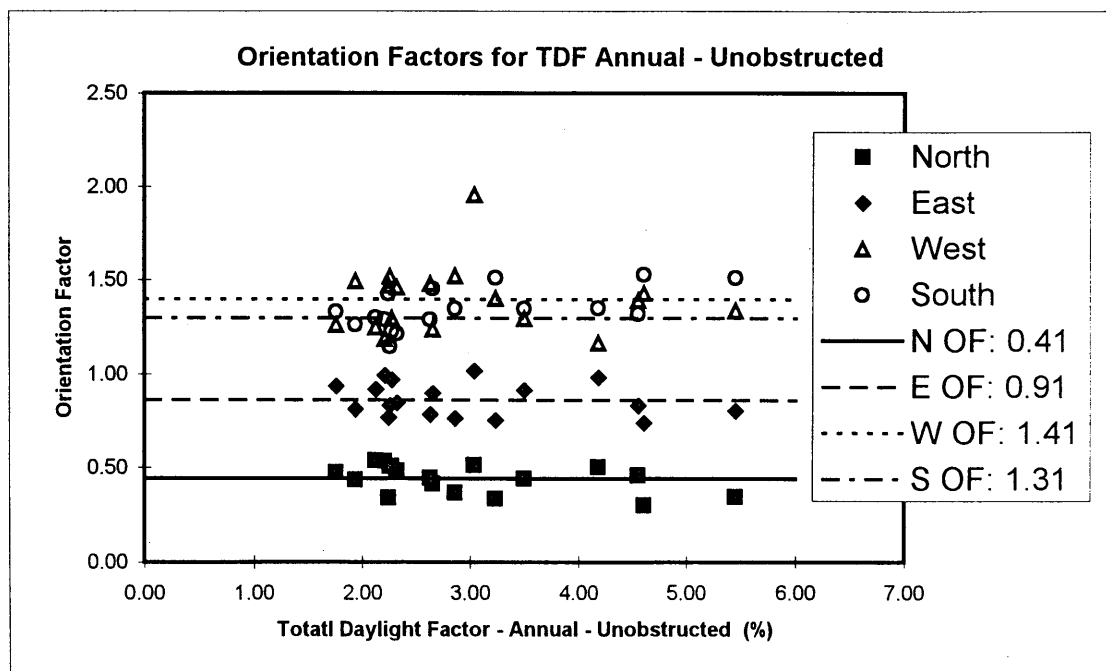
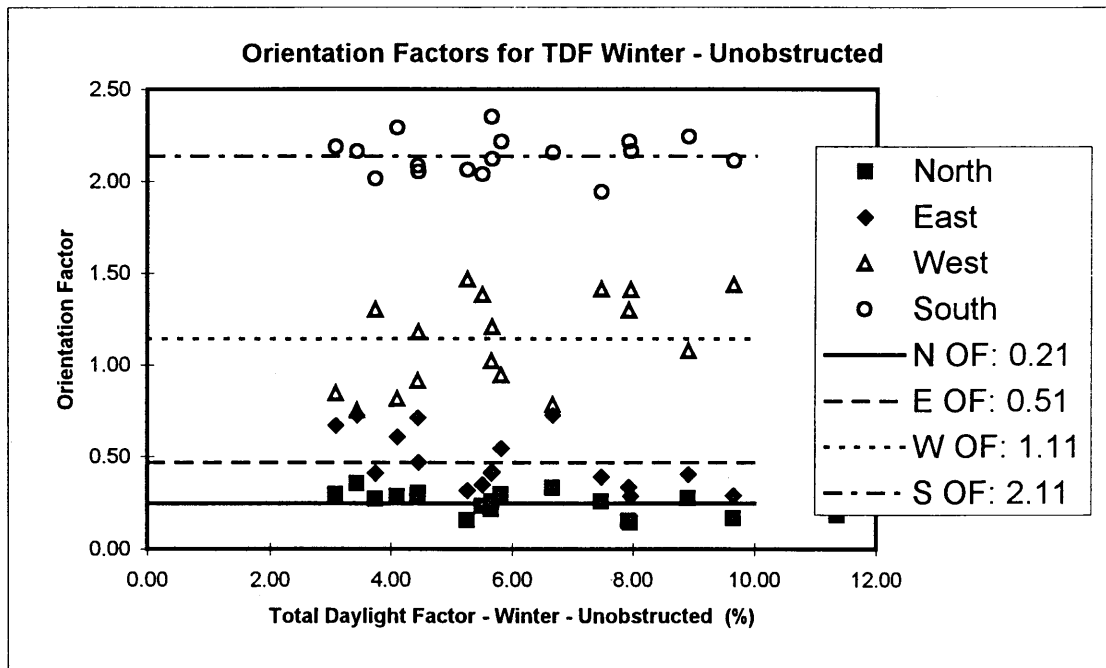
ODOF is the Overhang and Density Obstruction Factor taken from Figure 5.10 (upper graph for winter, lower graph for the year)

DDF is the Diffuse Daylight Factor (from the equation in Section 5.2, with no obstructions)

OF is the Orientation Factor taken from Figure 5.11 (upper graph for winter, lower graph for the year)

The daylight available over the winter or annual period can be found by multiplying the TDF by the illuminance totals given in Section 5.2.

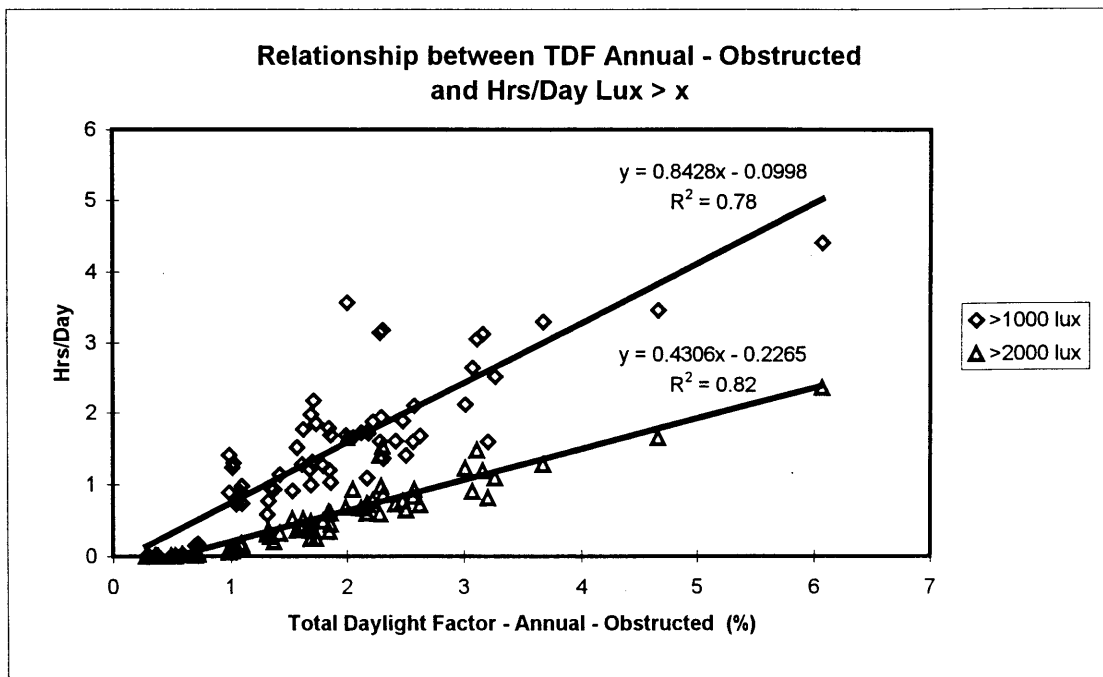
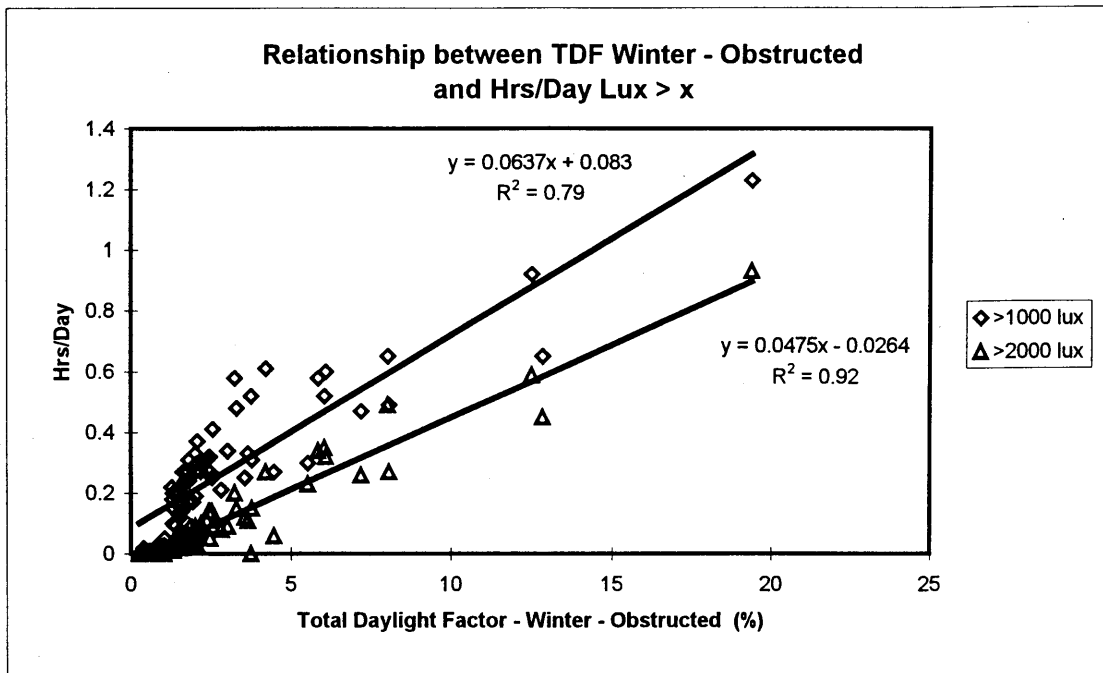
Figure 5.11:



As discussed in Section 2, there may be cases when the designer needs to know the frequency of high light levels. Figure 5.12 compares the TDF-obstructed to the number of hours per day that the light level is above 1000 and 2000 lux (averaged over the room). For the winter only period, there appears to be a reasonable straight line fit to the data ($R^2 = 0.79$ & 0.92). On an annual basis, the straight-line fit is not as good, although the trend is the same. Thus, knowing the TDF (as calculated above), the number of hours above these two thresholds can be estimated. The graphs are not orientation dependent because the orientation dependency is accounted for in the TDF.

These graphs can be used to provide guidance on daylighting design for buildings. If an average of 2 to 3 hours per day of bright sunlight is desirable then Figure 5.12 shows that this is difficult to achieve in winter. On an annual basis, however, this period of bright light could be achieved in a room with a TDF of over 6%. In Toronto, such a room would receive an average of 15,600 lux-hours per day (23.4 from Table 5.3 * $1000 / 90$ days * 6%).

Figure 5.12:



5.7 Characterizing Canadian Housing and Urban Densities

The methodology described in Section 5.6 is a first step in developing a tool to evaluate the potential of Canadian housing to gather daylight. In this section, the hand calculation procedures described in Section 5.6 are applied to the three buildings studied to estimate building-average values of TDF. Further work is needed to refine the methodology, but this section shows how it could be applied.

The building-average TDF was estimated by calculating the values of TDF for each room (using the equations in Section 5.6) and weighting each TDF value by the area of each room. It was assumed that the living room faced south and all other orientations were determined from the typical floor plans illustrated in Section 3.3 (except for apartment north-facing case). Corridors, entrance ways, and window-less bathrooms were assumed to have a TDF of zero. While these rooms would get some daylight from adjacent rooms, this light was already accounted for in the TDF value for the other rooms. The basement was excluded from the study. The building average ODOF is the ratio of the TDF with obstructions to the TDF without obstructions.

Table 5.7 summarizes the building average values of ODOF and TDF for the three house types studied. The TDF values are the average indoor illuminance relative to the average outdoor illuminance. The ODOF is the reduction in interior light levels due to exterior obstructions. The building average TDF values could serve as a means of comparing house designs on their availability of daylight. Table 5.8 shows how the TDF values for the individual rooms and total house were determined; tables for the other rooms are in Appendix A.

Table 5.7: Building Average Density Obstruction and Total Daylight Factors

Building Type	Winter Results		Annual Results	
	Building Average ODOF	Building Average TDF	Building Average ODOF	Building Average TDF
House	40%	1.10%	52%	1.12%
Townhouse	42%	1.29%	64%	1.45%
Apartment (south-facing)	14%	0.87%	30%	1.13%
Apartment (north-facing)	54%	0.32%	45%	0.52%

The house has an annual ODOF value of 52%. Although the south-facing living room has an ODOF value of 80%, the blockage due to sideyard buildings and eaves over second-floor windows, reduce the total house value to 52%. The townhouse ODOF value, at 64%, is slightly higher than the house because there are no townhouse sideyard windows. The south-facing apartment ODOF is very low, especially in winter, because the sun never rises above the adjacent building to the south. The north-facing apartment has a higher ODOF because of daylight reflection off the building to the north.

The townhouse has the highest value of TDF. The townhouse has large south-facing windows and modest floor areas without windows. The building average TDF for the house is lower than that of the townhouse because the house has a dining room and a bedroom facing west. The daylight blockage from adjacent buildings reduces the ODOF for the house and, therefore, the building average TDF.

Despite the large window areas in the apartment, the building average TDF is lower than for the house and townhouse. The low TDF value is a result of daylight blockage caused by adjacent buildings and the balcony. The TDF values for the north-facing apartment are approximately half those of a south-facing apartment.

In summary, the calculation of TDF is relatively simple and provides a single number to rate the daylight availability of housing. The TDF accounts for urban density, building orientation and window/room size.

Table 5.8: Calculation of Building Average TDF for the House - Annual

Average TDF Annual - House

* Living Includes Kitchen & Nook

Room	Floor Area (m2)	Window Area (m2)	Density Blockage Angle (Degrees)	Overhang Blockage Angle (Degrees)	DDF (%)	ODOF (%)	TDF (%)
Living	39.06	3.69	10.2	13.0	2.45	70	2.15
Great Rm	16.93	1.85	10.1	12.6	2.37	95	1.06
Dining	12.74	1.85	60.6	12.6	2.95	23	0.95
Bedroom 1	20.76	4.66	7.4	38.7	5.22	47	3.07
Bedroom 2	10.22	1.04	4.9	38.7	1.99	48	0.45
Bedroom 3	12.14	0.85	40.8	39.3	1.44	19	0.38
Bedroom 4	12.66	1.04	7.4	38.7	1.71	47	1.00
Family Rm	28.94	4.09	5.4	34.6	3.65	84	1.44
Laundry	12.00	0.49	60.6	14.0	0.81	20	0.23
Foyer/Stair	24.92	1.20	10.8	38.7	1.08	44	0.59
Ensuite/Walk-in	12.95	0.00					0.00
Hall/Stair	21.84	0.00					0.00
Bath	8.97	0.49	40.7	38.7	1.03	19	0.28
Building Average TDF Annual							1.12

6. CONCLUSIONS

Daylight levels in three housing types (single detached, townhouse and apartment) for three cities (Toronto, Calgary and Vancouver) were predicted using a modified version of the SUPERLITE computer program. The accuracy of the predictions were checked by comparing program predictions to measurements made in three buildings. There was reasonable agreement for the house and office building, but only fair agreement for the apartment building. The variation in the apartment building results is attributed to the combined shading impacts of trees, balcony railings, overhangs and sidewalls.

The results of the simulations were used to determine Overhang and Density Obstruction Factor (a measure of daylight blockage from obstructions) and Total Daylight Factor (a measure of the light level in the room to the exterior light level).

The Overhang and Density Obstruction Factors (ODOF) for rooms in the house and townhouse are typically above 80%, indicating only a modest loss in daylight due to exterior obstructions. It is possible that the ODOF for north-facing rooms can be above 100%. North-facing rooms benefit from light bouncing off adjacent buildings to the north. The ODOF for apartment suites with balconies can be much lower; an average of 16% for the case studied. This reduction can be attributed to a low Density Obstruction Factor (caused by blockage from adjacent buildings) of 45% and a low Overhang Obstruction Factor (caused by blockage from the balcony) of 35%.

Unobstructed values of TDF vary considerably with orientation and the time period considered (e.g., winter versus annual). TDF values are higher in the winter because of the low sun angle (light is more normal to the window). Winter values for south-facing rooms are six times higher than for north-facing rooms. On an annual basis, the difference between north- and south-facing rooms is reduced to 2.5 times. The Diffuse Daylight Factor is a reasonable approximation of the Annual Total Daylight Factor (without obstructions) averaged for the four orientations.

The daylight availability of the three housing types was compared by combining room design and urban density effects. The Annual Total Daylight Factor for individual rooms ranged from 0.5 to 3%. The house and townhouse rooms had similar TDF values whereas the apartment rooms were significantly lower especially when facing north. TDF values for entire buildings were determined by area-weighting the individual room values of TDF.

A simple methodology can be developed based on the detailed simulations to assess the daylight acceptance of buildings. This methodology could be used as an evaluation

tool to compare building and urban designs for daylight design. Further validation and simulation work is needed to refine the predictions and extended the results to a wider range in building designs and climates.

7. REFERENCES

Begemann, S., G. van den Beld and A. Tenner, 1996. Daylight and Artificial Light and People: Part 3, Visual and Biological Responses, CIBSE National Lighting Conference

Johnson, R., D. Arasteh, D. Connell and S. Selkowitz, 1985. The Effect of Daylighting Strategies on Building Cooling Load and Overall Energy Performance, Thermal Performance of the Exterior Envelopes of Buildings III, Clearwater Beach, FL

Rusak, B., G. Eskes and S. Shaw, 1995. Lighting and Human Health: A Review of the Literature, report prepared for Canada Mortgage and Housing Corporation, Ottawa, ON

University College Dublin, 1994. Daylighting in Buildings, report produced by the Energy Research Group, University College Dublin for the European Commission Directorate-General for Energy.

APPENDIX A:
RESULTS OF COMPUTER SIMULATIONS

Summary of Superlite Input Data for Office For Comparison to Monitored Data							
Line 1 Input/Output Options							
	Input Description	Short					
	Weather Input Type	Solar Data from CWEC					
	Number of Iterations	3.00					
	Output Type	Work Surface Illuminance & Daylight Factors					
Line 2 Room Dimensions							
	Room Width	3.79					
	Room Depth	4.04					
	Room Height	2.70					
Line 3 Room Elevation & Orientation							
	Room Elevation	0.00					
	Room Orientation	90.00					
Line 4 Number & Location of Windows							
	Number of Windows	2					
	Location of Windows	Front Wall					
Line 5 Window Data							
	Window Width	Window 1	Window 2	Window 3			
	Window Height	1.30	1.3	N/A			
	Horizontal Displacement from Wall Centre	1.39	1.39	N/A			
	Vertical Displacement from Wall Centre	-1.16	0.93	N/A			
	# of Nodes in Width	1.70	1.7	N/A			
	# of Nodes in Height	5	5	N/A			
	Reflectance of Inside Surface of Window	5	5	N/A			
		0.10	0.1	N/A			
Line 6 Window Type							
	Type of Window	Clear Window	Clear Window	N/A			
	Maintenance Factor	0.95	0.95	N/A			
	Normal Transmittance	0.53	0.53	N/A			
	Thickenss of Opening	0.15	0.15	N/A			
	Overhang Type	Above Window	Above Window	N/A			
Line 7 Overhang Data							
	Width of Overhang	0.30	0.30	N/A			
	Dist from Window Edge	1.22	1.22	N/A			
	Overhang Reflectance	0.40	0.40	N/A			
	Transmittance Identifier	Opaque	Opaque	N/A			
	Overhang Transmittance	0.00	0.00	N/A			
Line 8 Sheer Curtain Data							
	Line 8 Does not Apply						
Line 9 Indoor Surface Data							
		Front Wall	Left Wall	Rear Wall	Right Wall	Ceiling	Floor
	# of Nodes in Horizontal (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	# of Nodes in Vertical (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	Surface Reflectance	0.60	0.50	0.50	0.50	0.70	0.30
Line 10 Work Surface Data							
	# of Nodes Parallel to Front Wall	5					
	# of Nodes Perpendicular to Front Wall	3					
	Elevation of Work Surface Above Floor	1.07					
Line 11 Outdoor Surrounding Data							
	Obstructions Considered	No Obstruction, Only Ground Reflectance					
Line 12 Outdoor Obstruction							
	Height of Obstruction	N/A					
	Width of Obstruction	N/A					
	Horizontal Displacement from Wall Centre	N/A					
	Distance to Obstruction	N/A					
	Obstruction Reflectance	N/A					
Line 13 Subject Building Data							
	Height of Outdoor Wall that Contains Windows	8.84					
	Width of Outdoor Wall that Contains Windows	36.23					
	Horizontal Displacement of Outdoor Wall form Centre of Room Wall that Contains Windows	0.00					
	Outdoor Wall Reflectance	0.20					

**Summary of Superlite Input Data for House Living Room
For Comparison to Monitored Data**

Line 1	Input/Output Options						
	Input Description	Short					
	Weather Input Type	Solar Data from CWEC					
	Number of Iterations	3.00					
	Output Type	Work Surface Illuminance & Daylight Factors					
Line 2	Room Dimensions						
	Room Width	9.55					
	Room Depth	4.09					
	Room Height	2.44					
Line 3	Room Elevation & Orientation						
	Room Elevation	0.30					
	Room Orientation	-43.00					
Line 4	Number & Location of Windows						
	Number of Windows	4					
	Location of Windows	Front Wall					
Line 5	Window Data						
		Window 1	Windows 2 & 3	Window 4			
	Window Width	0.66	0.69	0.66			
	Window Height	1.17	1.85	0.56			
	Horizontal Displacement from Wall Centre	3.80	0.68 & -0.18	-3.10			
	Vertical Displacement from Wall Centre	1.38	1.08	1.66			
	# of Nodes in Width	5	5	5			
	# of Nodes in Height	5	5	5			
	Reflectance of Inside Surface of Window	0.10	0.10	0.10			
Line 6	Window Type						
	Type of Window	Clear Window	Clear Window	Clear Window			
	Maintenance Factor	0.95	0.95	0.95			
	Normal Transmittance	0.80	0.80	0.80			
	Thickenss of Opening	0.09	0.09	0.09			
	Overhang Type	Above Window	Above Window	Above Window			
Line 7	Overhang Data						
	Width of Overhang	0.91	0.91	0.91			
	Dist from Window Edge	3.30	3.26	3.32			
	Overhang Reflectance	0.70	0.70	0.70			
	Transmittance Identifier	Opaque	Opaque	Opaque			
	Overhang Transmittance	0.00	0.00	0.00			
Line 8	Sheer Curtain Data						
	Line 8 Does not Apply						
Line 9	Indoor Surface Data						
		Front Wall	Left Wall	Rear Wall	Right Wall	Ceiling	Floor
	# of Nodes in Horizontal (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	# of Nodes in Vertical (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	Surface Reflectance	0.45	0.55	0.40	0.40	0.70	0.30
Line 10	Work Surface Data						
	# of Nodes Parallel to Front Wall	5					
	# of Nodes Perpendicular to Front Wall	3					
	Elevation of Work Surface Above Floor	1.04					
Line 11	Outdoor Surrounding Data						
	Obstructions Considered	One Obstruction and Ground Reflectance					
Line 12	Outdoor Obstruction						
	Height of Obstruction	2.13					
	Width of Obstruction	50.00					
	Horizontal Displacement from Wall Centre	0.00					
	Distance to Obstruction	12.00					
	Obstruction Reflectance	0.30					
Line 13	Subject Building Data						
	Height of Outdoor Wall that Contains Windows	5.57					
	Width of Outdoor Wall that Contains Windows	10.03					
	Horizontal Displacement of Outdoor Wall form Centre of Room Wall that Contains Windows	0.00					
	Outdoor Wall Reflectance	0.20					

**Summary of Superlite Input Data for Apartment Living Room
For Comparison to Monitored Data**

Line 1	Input/Output Options						
	Input Description	Short					
	Weather Input Type	Solar Data from CWEC					
	Number of Iterations	3.00					
	Output Type	Work Surface Illuminance & Daylight Factors					
Line 2	Room Dimensions						
	Room Width	5.96					
	Room Depth	4.03					
	Room Height	2.44					
Line 3	Room Elevation & Orientation						
	Room Elevation	0.00					
	Room Orientation	-23.00					
Line 4	Number & Location of Windows						
	Number of Windows	1					
	Location of Windows	Front Wall					
Line 5	Window Data						
		Window 1	Window 2	Window 3			
	Window Width	2.50	N/A	N/A			
	Window Height	1.55	N/A	N/A			
	Horizontal Displacement from Wall Centre	-0.11	N/A	N/A			
	Vertical Displacement from Wall Centre	1.01	N/A	N/A			
	# of Nodes in Width	5	N/A	N/A			
	# of Nodes in Height	5	N/A	N/A			
	Reflectance of Inside Surface of Window	0.10	N/A	N/A			
Line 6	Window Type						
	Type of Window	Clear Window	N/A	N/A			
	Maintenance Factor	0.95	N/A	N/A			
	Normal Transmittance	0.80	N/A	N/A			
	Thickenss of Opening	0.09	N/A	N/A			
	Overhang Type	On all 4 Sides	N/A	N/A			
Line 7	Overhang Data						
	Width of Overhang	3.02	N/A	N/A			
	Dist from Window Edge	0.06	N/A	N/A			
	Overhang Reflectance	0.30	N/A	N/A			
	Transmittance Identifier	Opaque	N/A	N/A			
	Overhang Transmittance	0.00	N/A	N/A			
Line 8	Sheer Curtain Data						
	Line 8 Does not Apply						
Line 9	Indoor Surface Data						
		Front Wall	Left Wall	Rear Wall	Right Wall	Ceiling	Floor
	# of Nodes in Horizontal (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	# of Nodes in Vertical (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	Surface Reflectance	0.60	0.50	0.30	0.60	0.70	0.20
Line 10	Work Surface Data						
	# of Nodes Parallel to Front Wall	5					
	# of Nodes Perpendicular to Front Wall	3					
	Elevation of Work Surface Above Floor	1.04					
Line 11	Outdoor Surrounding Data						
	Obstructions Considered	One Obstruction and Ground Reflectance					
Line 12	Outdoor Obstruction						
	Height of Obstruction	1.09					
	Width of Obstruction	8.92					
	Horizontal Displacement from Wall Centre	1.48					
	Distance to Obstruction	3.02					
	Obstruction Reflectance	0.30					
Line 13	Subject Building Data						
	Height of Outdoor Wall that Contains Windows	38.22					
	Width of Outdoor Wall that Contains Windows	83.92					
	Horizontal Displacement of Outdoor Wall form Centre of Room Wall that Contains Windows	32.98					
	Outdoor Wall Reflectance	0.20					

Summary of Superlite Input Data for House Living Room

Line 1	Room Detail Options						
	Input Description	Short					
	Weather Input Type	Solar Data from CWECC					
	Number of Iterations	3.00					
	Output Type	Work Surface Illuminance & Daylight Factors					
Line 2	Room Dimensions						
	Room Width	9.55					
	Room Depth	4.09					
	Room Height	2.44					
Line 3	Room Elevation & Orientation						
	Room Elevation	0.30					
	Room Orientation	90.00					
Line 4	Number & Location of Windows						
	Number of Windows	4					
	Location of Windows	Front Wall					
Line 5	Window Data						
		Window 1	Windows 2 & 3	Window 4			
	Window Width	0.66	0.69	0.66			
	Window Height	1.17	1.85	0.56			
	Horizontal Displacement from Wall Centre	3.80	0.68 & -0.18	-3.10			
	Vertical Displacement from Wall Centre	1.38	1.08	1.66			
	# of Nodes in Width	5	5	5			
	# of Nodes in Height	5	5	5			
	Reflectance of Inside Surface of Window	0.10	0.10	0.10			
Line 6	Window Type						
	Type of Window	Clear Window	Clear Window	Clear Window			
	Maintenance Factor	0.95	0.95	0.95			
	Normal Transmittance	0.80	0.80	0.80			
	Thickness of Opening	0.09	0.09	0.09			
	Overhang Type	Above Window	Above Window	Above Window			
Line 7	Overhang Data						
	Width of Overhang	0.91	0.91	0.91			
	Dist from Window Edge	3.30	3.26	3.32			
	Overhang Reflectance	0.70	0.70	0.70			
	Transmittance Identifier	Opaque	Opaque	Opaque			
	Overhang Transmittance	0.00	0.00	0.00			
Line 8	Sheer Curtain Data						
	Line 8 Does not Apply						
Line 9	Indoor Surface Data						
		Front Wall	Left Wall	Rear Wall	Right Wall	Ceiling	Floor
	# of Nodes in Horizontal (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	# of Nodes in Vertical (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	Surface Reflectance	0.50	0.50	0.50	0.50	0.70	0.30
Line 10	Work Surface Data						
	# of Nodes Parallel to Front Wall	5					
	# of Nodes Perpendicular to Front Wall	3					
	Elevation of Work Surface Above Floor	1.04					
Line 11	Outdoor Surrounding Data						
	Obstructions Considered	One Obstruction and Ground Reflectance					
Line 12	Outdoor Obstruction						
	Height of Obstruction	7.01					
	Width of Obstruction	50.00					
	Horizontal Displacement from Wall Centre	0.00					
	Distance to Obstruction	19.80					
	Obstruction Reflectance	0.30					
Line 13	Subject Building Data						
	Height of Outdoor Wall that Contains Windows	5.57					
	Width of Outdoor Wall that Contains Windows	10.03					
	Horizontal Displacement of Outdoor Wall form Centre of Room Wall that Contains Windows	0.00					
	Outdoor Wall Reflectance	0.20					

Summary of Superlite Input Data for House Bed Room

Line 1	Input/Output Options							
	Input Description	Short						
	Weather Input Type	Solar Data from CWEC						
	Number of Iterations	3.00						
	Output Type	Work Surface Illuminance & Daylight Factors						
Line 2	Room Dimensions							
	Room Width	3.70						
	Room Depth	3.28						
	Room Height	2.31						
Line 3	Room Elevation & Orientation							
	Room Elevation	2.97						
	Room Orientation	90.00						
Line 4	Number & Location of Windows							
	Number of Windows	2						
	Location of Windows	Front Wall						
Line 5	Window Data		Window 1	Window 2	Window 3			
	Window Width	0.58	0.47	N/A				
	Window Height	0.85	0.76	N/A				
	Horizontal Displacement from Wall Centre	-0.81	-0.14	N/A				
	Vertical Displacement from Wall Centre	1.45	1.44	N/A				
	# of Nodes in Width	5	5	N/A				
	# of Nodes in Height	5	5	N/A				
	Reflectance of Inside Surface of Window	0.10	0.10	N/A				
Line 6	Window Type							
	Type of Window	Clear Window	Clear Window	N/A				
	Maintenance Factor	0.95	0.95	N/A				
	Normal Transmittance	0.80	0.80	N/A				
	Thickness of Opening	0.05	0.05	N/A				
	Overhang Type	Above Window	Above Window	N/A				
Line 7	Overhang Data							
	Width of Overhang	0.91	0.91	N/A				
	Dist from Window Edge	0.71	0.71	N/A				
	Overhang Reflectance	0.70	0.70	N/A				
	Transmittance Identifier	Opaque	Opaque	N/A				
	Overhang Transmittance	0.00	0.00	N/A				
Line 8	Sheer Curtain Data							
	Line 8 Does not Apply							
Line 9	Indoor Surface Data		Front Wall	Left Wall	Rear Wall	Right Wall	Ceiling	Floor
	# of Nodes in Horizontal (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5	
	# of Nodes in Vertical (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5	
	Surface Reflectance	0.50	0.50	0.50	0.50	0.70	0.30	
Line 10	Work Surface Data							
	# of Nodes Parallel to Front Wall	5						
	# of Nodes Perpendicular to Front Wall	3						
	Elevation of Work Surface Above Floor	1.04						
Line 11	Outdoor Surrounding Data							
	Obstructions Considered	One Obstruction and Ground Reflectance						
Line 12	Outdoor Obstruction							
	Height of Obstruction	7.01						
	Width of Obstruction	50.00						
	Horizontal Displacement from Wall Centre	0.00						
	Distance to Obstruction	19.80						
	Obstruction Reflectance	0.30						
Line 13	Subject Building Data							
	Height of Outdoor Wall that Contains Windows	5.57						
	Width of Outdoor Wall that Contains Windows	10.03						
	Horizontal Displacement of Outdoor Wall form Centre of Room Wall that Contains Windows	-3.17						
	Outdoor Wall Reflectance	0.20						

Summary of Superlite Input Data for Townhouse Living Room							
Line 1 Input/Output Options							
	Input Description	Short					
	Weather Input Type	Solar Data from CWEC					
	Number of Iterations	3.00					
	Output Type	Work Surface Illuminance & Daylight Factors					
Line 2 Room Dimensions							
	Room Width	3.48					
	Room Depth	8.38					
	Room Height	2.31					
Line 3 Room Elevation & Orientation							
	Room Elevation	2.67					
	Room Orientation	90.00					
Line 4 Number & Location of Windows							
	Number of Windows	1					
	Location of Windows	Front Wall					
Line 5 Window Data							
		Window 1	Window 2	Window 3			
	Window Width	1.00	N/A	N/A			
	Window Height	0.95	N/A	N/A			
	Horizontal Displacement from Wall Centre	0.80	N/A	N/A			
	Vertical Displacement from Wall Centre	0.09	N/A	N/A			
	# of Nodes in Width	5	N/A	N/A			
	# of Nodes in Height	5	N/A	N/A			
	Reflectance of Inside Surface of Window	0.10	N/A	N/A			
Line 6 Window Type							
	Type of Window	Clear Window	N/A	N/A			
	Maintenance Factor	0.95	N/A	N/A			
	Normal Transmittance	0.80	N/A	N/A			
	Thickenss of Opening	0.09	N/A	N/A			
	Overhang Type	Above Window	N/A	N/A			
Line 7 Overhang Data							
	Width of Overhang	0.91	N/A	N/A			
	Dist from Window Edge	3.3	N/A	N/A			
	Overhang Reflectance	0.70	N/A	N/A			
	Transmittance Identifier	Opaque	N/A	N/A			
	Overhang Transmittance	0.00	N/A	N/A			
Line 8 Sheer Curtain Data							
	Line 8 Does not Apply						
Line 9 Indoor Surface Data							
		Front Wall	Left Wall	Rear Wall	Right Wall	Ceiling	Floor
	# of Nodes in Horizontal (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	# of Nodes in Vertical (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	Surface Reflectance	0.50	0.50	0.50	0.50	0.70	0.30
Line 10 Work Surface Data							
	# of Nodes Parallel to Front Wall	5					
	# of Nodes Perpendicular to Front Wall	3					
	Elevation of Work Surface Above Floor	1.04					
Line 11 Outdoor Surrounding Data							
	Obstructions Considered	One Obstruction and Ground Reflectance					
Line 12 Outdoor Obstruction							
	Height of Obstruction	9.68					
	Width of Obstruction	50.00					
	Horizontal Displacement from Wall Centre	0.00					
	Distance to Obstruction	19.80					
	Obstruction Reflectance	0.30					
Line 13 Subject Building Data							
	Height of Outdoor Wall that Contains Windows	8.84					
	Width of Outdoor Wall that Contains Windows	36.23					
	Horizontal Displacement of Outdoor Wall form Centre of Room Wall that Contains Windows	0.00					
	Outdoor Wall Reflectance	0.20					

Summary of Superlite Input Data for Townhouse Bed Room							
Line 1 Input/Output Options							
	Input Description	Short					
	Weather Input Type	Solar Data from CWEC					
	Number of Iterations	3.00					
	Output Type	Work Surface Illuminance & Daylight Factors					
Line 2 Room Dimensions							
	Room Width	2.79					
	Room Depth	3.84					
	Room Height	2.31					
Line 3 Room Elevation & Orientation							
	Room Elevation	5.64					
	Room Orientation	90.00					
Line 4 Number & Location of Windows							
	Number of Windows	1					
	Location of Windows	Front Wall					
Line 5 Window Data							
		Window 1	Window 2	Window 3			
	Window Width	1.39	N/A	N/A			
	Window Height	1.18	N/A	N/A			
	Horizontal Displacement from Wall Centre	0.23	N/A	N/A			
	Vertical Displacement from Wall Centre	1.57	N/A	N/A			
	# of Nodes in Width	5	N/A	N/A			
	# of Nodes in Height	5	N/A	N/A			
	Reflectance of Inside Surface of Window	0.10	N/A	N/A			
Line 6 Window Type							
	Type of Window	Clear Window	N/A	N/A			
	Maintenance Factor	0.95	N/A	N/A			
	Normal Transmittance	0.80	N/A	N/A			
	Thickenss of Opening	0.05	N/A	N/A			
	Overhang Type	Above Window	N/A	N/A			
Line 7 Overhang Data							
	Width of Overhang	0.91	N/A	N/A			
	Dist from Window Edge	0.71	N/A	N/A			
	Overhang Reflectance	0.70	N/A	N/A			
	Transmittance Identifier	Opaque	N/A	N/A			
	Overhang Transmittance	0.00	N/A	N/A			
Line 8 Sheer Curtain Data							
	Line 8 Does not Apply						
Line 9 Indoor Surface Data							
		Front Wall	Left Wall	Rear Wall	Right Wall	Ceiling	Floor
	# of Nodes in Horizontal (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	# of Nodes in Vertical (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	Surface Reflectance	0.50	0.50	0.50	0.50	0.70	0.30
Line 10 Work Surface Data							
	# of Nodes Parallel to Front Wall	5					
	# of Nodes Perpendicular to Front Wall	3					
	Elevation of Work Surface Above Floor	1.04					
Line 11 Outdoor Surrounding Data							
	Obstructions Considered	One Obstruction and Ground Reflectance					
Line 12 Outdoor Obstruction							
	Height of Obstruction	9.68					
	Width of Obstruction	50.00					
	Horizontal Displacement from Wall Centre	0.00					
	Distance to Obstruction	19.80					
	Obstruction Reflectance	0.30					
Line 13 Subject Building Data							
	Height of Outdoor Wall that Contains Windows	8.84					
	Width of Outdoor Wall that Contains Windows	36.23					
	Horizontal Displacement of Outdoor Wall form Centre of Room Wall that Contains Windows	0.00					
	Outdoor Wall Reflectance	0.20					

Summary of Superlite Input Data for Apartment Living Room							
Line 1 Input/Output Options							
	Input Description	Short					
	Weather Input Type	Solar Data from CWEC					
	Number of Iterations	3.00					
	Output Type	Work Surface Illuminance & Daylight Factors					
Line 2 Room Dimensions							
	Room Width	5.96					
	Room Depth	4.03					
	Room Height	2.44					
Line 3 Room Elevation & Orientation							
	Room Elevation	0.00					
	Room Orientation	90.00					
Line 4 Number & Location of Windows							
	Number of Windows	1					
	Location of Windows	Front Wall					
Line 5 Window Data							
		Window 1	Window 2	Window 3			
	Window Width	2.50	N/A	N/A			
	Window Height	1.55	N/A	N/A			
	Horizontal Displacement from Wall Centre	-0.11	N/A	N/A			
	Vertical Displacement from Wall Centre	1.01	N/A	N/A			
	# of Nodes in Width	5	N/A	N/A			
	# of Nodes in Height	5	N/A	N/A			
	Reflectance of Inside Surface of Window	0.10	N/A	N/A			
Line 6 Window Type							
	Type of Window	Clear Window	N/A	N/A			
	Maintenance Factor	0.95	N/A	N/A			
	Normal Transmittance	0.80	N/A	N/A			
	Thickenss of Opening	0.09	N/A	N/A			
	Overhang Type	On all 4 Sides	N/A	N/A			
Line 7 Overhang Data							
	Width of Overhang	3.02	N/A	N/A			
	Dist from Window Edge	0.06	N/A	N/A			
	Overhang Reflectance	0.30	N/A	N/A			
	Transmittance Identifier	Opaque	N/A	N/A			
	Overhang Transmittance	0.00	N/A	N/A			
Line 8 Sheer Curtain Data							
	Line 8 Does not Apply						
Line 9 Indoor Surface Data							
		Front Wall	Left Wall	Rear Wall	Right Wall	Ceiling	Floor
	# of Nodes in Horizontal (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	# of Nodes in Vertical (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	Surface Reflectance	0.50	0.50	0.50	0.50	0.70	0.30
Line 10 Work Surface Data							
	# of Nodes Parallel to Front Wall	5					
	# of Nodes Perpendicular to Front Wall	3					
	Elevation of Work Surface Above Floor	1.04					
Line 11 Outdoor Surrounding Data							
	Obstructions Considered	One Obstruction and Ground Reflectance					
Line 12 Outdoor Obstruction							
	Height of Obstruction	34.00					
	Width of Obstruction	85.00					
	Horizontal Displacement from Wall Centre	0.00					
	Distance to Obstruction	34.00					
	Obstruction Reflectance	0.20					
Line 13 Subject Building Data							
	Height of Outdoor Wall that Contains Windows	38.22					
	Width of Outdoor Wall that Contains Windows	83.92					
	Horizontal Displacement of Outdoor Wall form Centre of Room Wall that Contains Windows	32.98					
	Outdoor Wall Reflectance	0.20					

Summary of Superlite Input Data for Apartment Bed Room							
Line 1 Input/Output Options							
	Input Description	Short					
	Weather Input Type	Solar Data from CWEK					
	Number of Iterations	3.00					
	Output Type	Work Surface Illuminance & Daylight Factors					
Line 2 Room Dimensions							
	Room Width	2.84					
	Room Depth	3.84					
	Room Height	2.44					
Line 3 Room Elevation & Orientation							
	Room Elevation	0.00					
	Room Orientation	90.00					
Line 4 Number & Location of Windows							
	Number of Windows	1					
	Location of Windows	Front Wall					
Line 5 Window Data							
		Window 1	Window 2	Window 3			
	Window Width	1.32	N/A	N/A	N/A		
	Window Height	1.52	N/A	N/A	N/A		
	Horizontal Displacement from Wall Centre	-0.76	N/A	N/A	N/A		
	Vertical Displacement from Wall Centre	1.67	N/A	N/A	N/A		
	# of Nodes in Width	5	N/A	N/A	N/A		
	# of Nodes in Height	5	N/A	N/A	N/A		
	Reflectance of Inside Surface of Window	0.10	N/A	N/A	N/A		
Line 6 Window Type							
	Type of Window	Clear Window	N/A	N/A	N/A		
	Maintenance Factor	0.95	N/A	N/A	N/A		
	Normal Transmittance	0.80	N/A	N/A	N/A		
	Thickenss of Opening	0.09	N/A	N/A	N/A		
	Overhang Type	None	N/A	N/A	N/A		
Line 7 Overhang Data							
	Width of Overhang	N/A	N/A	N/A	N/A		
	Dist from Window Edge	N/A	N/A	N/A	N/A		
	Overhang Reflectance	N/A	N/A	N/A	N/A		
	Transmittance Identifier	N/A	N/A	N/A	N/A		
	Overhang Transmittance	N/A	N/A	N/A	N/A		
Line 8 Sheer Curtain Data							
	Line 8 Does not Apply						
Line 9 Indoor Surface Data							
		Front Wall	Left Wall	Rear Wall	Right Wall	Ceiling	Floor
	# of Nodes in Horizontal (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	# of Nodes in Vertical (or Parallel to Front Wall for Clgs & Flrs)	5	5	5	5	5	5
	Surface Reflectance	0.50	0.50	0.50	0.50	0.70	0.30
Line 10 Work Surface Data							
	# of Nodes Parallel to Front Wall	5					
	# of Nodes Perpendicular to Front Wall	3					
	Elevation of Work Surface Above Floor	1.04					
Line 11 Outdoor Surrounding Data							
	Obstructions Considered	One Obstruction and Ground Reflectance					
Line 12 Outdoor Obstruction							
	Height of Obstruction	34.00					
	Width of Obstruction	85.00					
	Horizontal Displacement from Wall Centre	0.00					
	Distance to Obstruction	34.00					
	Obstruction Reflectance	0.20					
Line 13 Subject Building Data							
	Height of Outdoor Wall that Contains Windows	38.22					
	Width of Outdoor Wall that Contains Windows	83.92					
	Horizontal Displacement of Outdoor Wall form Centre of Room Wall that Contains Windows	32.98					
	Outdoor Wall Reflectance	0.20					

Living Room, Vancouver

City: Vancouver
 Residence Type: House
 Room: Living Room
 Total Available Lux-Hours Whole Year: 138,521,800
 Total Available Lux-Hours Winter: 17,003,100

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	95%	2.09%	1.99%	2.13	0.36
		Centre	92%	0.75%	0.69%	0.03	0.00
		Interior	86%	0.53%	0.45%	0.00	0.00
		Average	93%	1.12%	1.04%	0.72	0.12
	East	Perimeter	95%	3.96%	3.75%	3.36	1.34
		Centre	88%	1.20%	1.05%	0.39	0.14
		Interior	80%	0.73%	0.58%	0.01	0.00
		Average	91%	1.96%	1.79%	1.26	0.49
	West	Perimeter	87%	6.32%	5.52%	3.71	1.74
		Centre	68%	2.45%	1.67%	0.88	0.38
		Interior	47%	1.41%	0.67%	0.46	0.00
		Average	77%	3.39%	2.62%	1.68	0.71
WINTER	North	Perimeter	93%	5.79%	5.39%	4.48	2.11
		Centre	79%	1.67%	1.32%	0.92	0.19
		Interior	69%	1.00%	0.69%	0.26	0.00
		Average	87%	2.82%	2.47%	1.89	0.77
	East	Perimeter	107%	2.60%	2.78%	0.32	0.03
		Centre	124%	0.84%	1.05%	0.05	0.01
		Interior	143%	0.58%	0.82%	0.05	0.02
		Average	116%	1.34%	1.55%	0.14	0.02
	West	Perimeter	97%	3.69%	3.58%	0.44	0.12
		Centre	102%	1.52%	1.56%	0.07	0.04
		Interior	78%	1.05%	0.82%	0.05	0.02
		Average	95%	2.09%	1.98%	0.19	0.06
	South	Perimeter	61%	5.98%	3.62%	0.42	0.10
		Centre	26%	3.95%	1.03%	0.05	0.00
		Interior	18%	5.81%	1.02%	0.04	0.03
		Average	36%	5.25%	1.89%	0.17	0.04

Bedroom, Vancouver

City: Vancouver
 Residence Type: House
 Room: Bedroom
 Total Available Lux-Hours Whole Year: 138,521,800
 Total Available Lux-Hours Winter: 17,003,100

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	79.3%	1.55%	1.23%	0.30	0.07
		Centre	96.5%	0.61%	0.58%	0.04	0.02
		Interior	93.5%	0.37%	0.35%	0.01	0.00
		Average	85.5%	0.84%	0.72%	0.12	0.03
	East	Perimeter	78.7%	3.25%	2.56%	1.39	0.70
		Centre	95.0%	0.96%	0.91%	0.25	0.20
		Interior	90.1%	0.51%	0.46%	0.10	0.03
		Average	83.2%	1.57%	1.31%	0.58	0.31
	West	Perimeter	73.0%	5.71%	4.17%	2.23	1.12
		Centre	86.9%	1.95%	1.70%	0.83	0.55
		Interior	63.8%	1.03%	0.66%	0.22	0.13
		Average	75.1%	2.90%	2.17%	1.09	0.60
	South	Perimeter	72.4%	5.59%	4.05%	2.73	1.09
		Centre	91.1%	1.15%	1.05%	0.31	0.19
		Interior	79.6%	0.60%	0.48%	0.05	0.04
		Average	75.9%	2.45%	1.86%	1.03	0.44
WINTER	North	Perimeter	82.5%	1.99%	1.64%	0.05	0.00
		Centre	118.1%	0.67%	0.79%	0.02	0.00
		Interior	147.5%	0.41%	0.60%	0.03	0.00
		Average	99.0%	1.02%	1.01%	0.03	0.00
	East	Perimeter	78.9%	3.14%	2.47%	0.17	0.08
		Centre	99.6%	0.95%	0.95%	0.06	0.01
		Interior	115.7%	0.52%	0.60%	0.04	0.00
		Average	87.3%	1.54%	1.34%	0.09	0.03
	West	Perimeter	66.7%	4.86%	3.24%	0.16	0.11
		Centre	39.1%	4.20%	1.64%	0.08	0.05
		Interior	12.5%	5.55%	0.70%	0.03	0.02
		Average	38.2%	4.87%	1.86%	0.09	0.06
	South	Perimeter	73.0%	12.44%	9.08%	0.50	0.39
		Centre	73.5%	6.86%	5.04%	0.25	0.21
		Interior	73.2%	3.31%	2.42%	0.15	0.10
		Average	73.2%	7.54%	5.51%	0.30	0.23

Living Room, Calgary

City: Calgary
 Residence Type: House
 Room: Living Room
 Total Available Lux-Hours Whole Year: 154,238,000
 Total Available Lux-Hours Winter: 23,691,600

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	97.6%	2.06%	2.01%	2.57	0.42
		Centre	99.3%	0.73%	0.72%	0.08	0.04
		Interior	98.8%	0.52%	0.51%	0.03	0.02
		Average	98.1%	1.10%	1.08%	0.89	0.16
	East	Perimeter	95.1%	4.86%	4.63%	4.36	1.87
		Centre	87.2%	1.39%	1.21%	0.71	0.30
		Interior	78.4%	0.85%	0.67%	0.13	0.02
		Average	91.6%	2.37%	2.17%	1.73	0.73
	West	Perimeter	80.1%	5.99%	4.80%	4.38	2.04
		Centre	54.5%	2.29%	1.25%	1.02	0.31
		Interior	40.1%	1.55%	0.62%	0.23	0.00
		Average	67.8%	3.28%	2.22%	1.88	0.78
	South	Perimeter	91.1%	7.24%	6.60%	5.59	2.82
		Centre	75.7%	2.52%	1.91%	1.61	0.41
		Interior	71.8%	1.78%	1.28%	0.36	0.04
		Average	84.8%	3.85%	3.26%	2.52	1.09
WINTER	North	Perimeter	116.8%	2.33%	2.72%	0.59	0.08
		Centre	154.7%	0.78%	1.20%	0.06	0.02
		Interior	193.4%	0.54%	1.05%	0.06	0.02
		Average	136.2%	1.22%	1.66%	0.24	0.04
	East	Perimeter	94.8%	3.83%	3.64%	0.73	0.18
		Centre	78.9%	1.68%	1.33%	0.09	0.02
		Interior	74.3%	1.45%	1.08%	0.07	0.02
		Average	86.7%	2.32%	2.01%	0.30	0.07
	West	Perimeter	61.3%	7.05%	4.32%	0.76	0.31
		Centre	39.2%	5.78%	2.27%	0.16	0.12
		Interior	14.4%	4.51%	0.65%	0.04	0.00
		Average	41.8%	5.78%	2.41%	0.32	0.14
	South	Perimeter	54.0%	15.75%	8.51%	1.13	0.62
		Centre	44.1%	12.16%	5.36%	0.56	0.28
		Interior	36.8%	11.91%	4.39%	0.10	0.04
		Average	45.8%	13.27%	6.08%	0.60	0.32

Bedroom, Calgary

City: Calgary
 Residence Type: House
 Room: Bedroom
 Total Available Lux-Hours Whole Year: 154,238,000
 Total Available Lux-Hours Winter: 23,691,600

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	86.2%	1.37%	1.18%	0.45	0.12
		Centre	101.7%	0.56%	0.57%	0.04	0.01
		Interior	105.3%	0.36%	0.38%	0.02	0.02
		Average	92.9%	0.76%	0.71%	0.17	0.05
	East	Perimeter	84.7%	3.53%	2.99%	2.08	1.12
		Centre	97.5%	1.07%	1.04%	0.46	0.32
		Interior	97.2%	0.57%	0.55%	0.18	0.08
		Average	88.7%	1.72%	1.53%	0.91	0.51
	West	Perimeter	83.6%	5.27%	4.41%	2.67	1.59
		Centre	71.3%	2.38%	1.70%	1.10	0.75
		Interior	36.0%	2.26%	0.81%	0.31	0.24
		Average	69.8%	3.30%	2.31%	1.36	0.86
	South	Perimeter	76.1%	6.79%	5.16%	3.77	1.89
		Centre	92.7%	1.97%	1.83%	0.91	0.54
		Interior	81.9%	0.83%	0.68%	0.11	0.06
		Average	80.0%	3.20%	2.56%	1.60	0.83
WINTER	North	Perimeter	100.7%	1.50%	1.51%	0.11	0.02
		Centre	138.4%	0.60%	0.83%	0.02	0.01
		Interior	190.9%	0.39%	0.75%	0.02	0.02
		Average	123.9%	0.83%	1.03%	0.05	0.02
	East	Perimeter	84.4%	3.17%	2.67%	0.33	0.15
		Centre	76.5%	1.23%	0.94%	0.05	0.02
		Interior	123.1%	0.61%	0.75%	0.02	0.02
		Average	87.2%	1.67%	1.46%	0.13	0.06
	West	Perimeter	61.1%	7.28%	4.45%	0.42	0.25
		Centre	34.4%	6.52%	2.25%	0.24	0.14
		Interior	8.5%	9.31%	0.80%	0.08	0.02
		Average	32.4%	7.71%	2.50%	0.25	0.14
	South	Perimeter	76.5%	16.98%	12.99%	1.06	0.82
		Centre	73.7%	12.07%	8.90%	0.65	0.53
		Interior	61.2%	3.53%	2.16%	0.24	0.11
		Average	73.8%	10.86%	8.02%	0.65	0.49

Living Room, Toronto

City: Toronto
 Residence Type: House
 Room: Living Room
 Total Available Lux-Hours Whole Year: 149,097,800
 Total Available Lux-Hours Winter: 23,404,800

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	94%	2.26%	2.13%	2.89	0.52
		Centre	90%	0.76%	0.68%	0.01	0.00
		Interior	83%	0.53%	0.44%	0.00	0.00
		Average	92%	1.18%	1.09%	0.97	0.17
	East	Perimeter	95%	4.58%	4.34%	4.50	1.88
		Centre	86%	1.24%	1.07%	0.50	0.17
		Interior	75%	0.77%	0.57%	0.07	0.00
		Average	91%	2.19%	1.99%	1.69	0.68
	West	Perimeter	88%	5.05%	4.47%	4.26	1.75
		Centre	73%	1.78%	1.31%	0.72	0.25
		Interior	57%	1.03%	0.59%	0.19	0.00
		Average	81%	2.62%	2.12%	1.72	0.67
	South	Perimeter	95%	6.08%	5.76%	5.31	2.59
		Centre	83%	1.58%	1.30%	0.81	0.19
		Interior	71%	0.91%	0.65%	0.18	0.00
		Average	90%	2.85%	2.57%	2.10	0.93
WINTER	North	Perimeter	102%	2.34%	2.37%	0.44	0.02
		Centre	109%	0.78%	0.85%	0.00	0.00
		Interior	116%	0.54%	0.63%	0.01	0.00
		Average	105%	1.22%	1.28%	0.15	0.01
	East	Perimeter	81%	4.00%	3.25%	0.66	0.12
		Centre	53%	1.84%	0.98%	0.04	0.01
		Interior	36%	1.67%	0.61%	0.00	0.00
		Average	64%	2.50%	1.61%	0.23	0.04
	West	Perimeter	85%	4.11%	3.51%	0.64	0.14
		Centre	68%	1.71%	1.16%	0.06	0.03
		Interior	31%	1.98%	0.62%	0.02	0.00
		Average	68%	2.60%	1.77%	0.24	0.06
	South	Perimeter	87%	12.50%	10.87%	1.02	0.65
		Centre	71%	7.38%	5.27%	0.51	0.27
		Interior	58%	2.46%	1.42%	0.22	0.11
		Average	79%	7.45%	5.85%	0.58	0.34

Bedroom, Toronto

City: Toronto
 Residence Type: House
 Room: Bedroom
 Total Available Lux-Hours Whole Year: 149,097,800
 Total Available Lux-Hours Winter: 23,404,800

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	77.3%	1.53%	1.18%	0.42	0.02
		Centre	95.6%	0.58%	0.55%	0.00	0.00
		Interior	91.4%	0.37%	0.34%	0.00	0.00
		Average	83.6%	0.83%	0.69%	0.14	0.01
	East	Perimeter	75.5%	3.43%	2.59%	1.93	0.83
		Centre	93.7%	0.99%	0.93%	0.30	0.22
		Interior	85.9%	0.51%	0.44%	0.07	0.02
		Average	80.2%	1.64%	1.32%	0.77	0.36
	West	Perimeter	73.8%	4.49%	3.32%	2.21	0.99
		Centre	87.4%	1.38%	1.20%	0.57	0.34
		Interior	71.8%	0.78%	0.56%	0.20	0.13
		Average	76.4%	2.22%	1.69%	0.99	0.48
	South	Perimeter	67.1%	5.15%	3.46%	3.11	0.99
		Centre	90.0%	1.28%	1.15%	0.51	0.30
		Interior	74.9%	0.58%	0.43%	0.00	0.00
		Average	71.9%	2.34%	1.68%	1.21	0.43
WINTER	North	Perimeter	80.7%	1.73%	1.39%	0.04	0.00
		Centre	108.4%	0.62%	0.67%	0.00	0.00
		Interior	121.6%	0.39%	0.47%	0.00	0.00
		Average	92.8%	0.91%	0.85%	0.01	0.00
	East	Perimeter	82.3%	3.76%	3.09%	0.27	0.17
		Centre	61.9%	1.56%	0.96%	0.07	0.04
		Interior	58.4%	0.88%	0.51%	0.03	0.00
		Average	73.8%	2.07%	1.52%	0.12	0.07
	West	Perimeter	83.6%	3.86%	3.22%	0.35	0.16
		Centre	61.6%	2.52%	1.55%	0.10	0.09
		Interior	46.7%	1.44%	0.68%	0.07	0.03
		Average	69.7%	2.61%	1.82%	0.17	0.09
	South	Perimeter	88.0%	12.17%	10.71%	0.90	0.65
		Centre	94.6%	6.77%	6.41%	0.48	0.38
		Interior	78.5%	1.29%	1.02%	0.16	0.02
		Average	89.6%	6.74%	6.04%	0.52	0.35

Livingroom, Vancouver

City: Vancouver
 Residence Type: Townhouse
 Room: Livingroom
 Total Available Lux-Hours Whole Year: 138,521,800
 Total Available Lux-Hours Winter: 17,003,100

Season	Orientation	Position	O+D37DOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	90%	2.67%	2.41%	3.71	0.21
		Centre	81%	0.56%	0.45%	0.01	0.00
		Interior	79%	0.21%	0.16%	0.00	0.00
		Average	88%	1.14%	1.01%	1.24	0.07
	East	Perimeter	87%	4.57%	4.00%	4.52	1.08
		Centre	71%	0.76%	0.54%	0.05	0.00
		Interior	67%	0.27%	0.18%	0.00	0.00
		Average	84%	1.87%	1.57%	1.52	0.36
	West	Perimeter	76%	7.82%	5.98%	4.45	1.76
		Centre	36%	1.79%	0.64%	0.34	0.00
		Interior	32%	0.66%	0.21%	0.02	0.00
		Average	67%	3.42%	2.28%	1.60	0.59
WINTER	North	Perimeter	83%	6.38%	5.30%	4.92	2.78
		Centre	64%	1.01%	0.65%	0.07	0.00
		Interior	56%	0.35%	0.19%	0.00	0.00
		Average	79%	2.58%	2.05%	1.66	0.93
	East	Perimeter	115%	3.00%	3.44%	0.42	0.06
		Centre	140%	0.60%	0.84%	0.05	0.02
		Interior	163%	0.23%	0.38%	0.03	0.00
		Average	122%	1.28%	1.55%	0.17	0.03
	West	Perimeter	86%	4.62%	3.99%	0.52	0.11
		Centre	86%	0.84%	0.73%	0.05	0.01
		Interior	88%	0.29%	0.26%	0.00	0.00
		Average	86%	1.92%	1.66%	0.19	0.04
	South	Perimeter	27%	17.87%	4.79%	0.53	0.13
		Centre	14%	3.92%	0.55%	0.02	0.00
		Interior	18%	1.01%	0.18%	0.00	0.00
		Average	24%	7.60%	1.84%	0.18	0.04

Bedroom, Vancouver

City: Vancouver
 Residence Type: Townhouse
 Room: Bedroom
 Total Available Lux-Hours Whole Year: 138,521,800
 Total Available Lux-Hours Winter: 17,003,100

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	77%	3.94%	3.02%	5.04	0.67
		Centre	96%	1.48%	1.41%	0.48	0.04
		Interior	93%	0.81%	0.75%	0.03	0.01
		Average	83%	2.08%	1.73%	1.85	0.24
	East	Perimeter	75%	7.58%	5.66%	5.70	2.08
		Centre	95%	2.63%	2.50%	1.75	0.51
		Interior	89%	1.16%	1.03%	0.46	0.12
		Average	81%	3.79%	3.07%	2.64	0.90
	West	Perimeter	0%	11.45%	0.00%	5.63	2.87
		Centre	88%	4.63%	4.06%	2.37	1.04
		Interior	74%	2.90%	2.16%	1.16	0.55
		Average	49%	6.33%	3.11%	3.05	1.48
	South	Perimeter	0%	12.76%	0.00%	6.08	3.61
		Centre	91%	3.64%	3.30%	2.85	0.75
		Interior	80%	1.63%	1.30%	0.62	0.23
		Average	38%	6.01%	2.30%	3.18	1.53
WINTER	North	Perimeter	83%	4.79%	3.99%	0.63	0.08
		Centre	120%	1.66%	1.98%	0.11	0.03
		Interior	145%	0.90%	1.30%	0.06	0.04
		Average	99%	2.45%	2.43%	0.27	0.05
	East	Perimeter	79%	7.18%	5.64%	0.79	0.21
		Centre	86%	2.47%	2.13%	0.15	0.04
		Interior	104%	1.15%	1.20%	0.08	0.02
		Average	83%	3.60%	2.99%	0.34	0.09
	West	Perimeter	50%	14.85%	7.46%	0.77	0.27
		Centre	23%	10.17%	2.35%	0.16	0.06
		Interior	28%	3.75%	1.07%	0.05	0.00
		Average	38%	9.59%	3.62%	0.33	0.11
	South	Perimeter	65%	26.79%	17.37%	0.98	0.62
		Centre	62%	22.87%	14.13%	0.57	0.47
		Interior	68%	10.29%	7.00%	0.38	0.25
		Average	64%	19.98%	12.84%	0.65	0.45

Livingroom, Calgary

City: Calgary
 Residence Type: Townhouse
 Room: Livingroom
 Total Available Lux-Hours Whole Year: 154,238,000
 Total Available Lux-Hours Winter: 23,691,600

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	97%	2.43%	2.35%	3.85	0.23
		Centre	96%	0.53%	0.51%	0.02	0.02
		Interior	100%	0.20%	0.20%	0.02	0.02
		Average	97%	1.05%	1.02%	1.30	0.09
	East	Perimeter	89%	5.25%	4.67%	5.24	1.81
		Centre	65%	0.96%	0.62%	0.12	0.02
		Interior	67%	0.31%	0.21%	0.01	0.00
		Average	84%	2.18%	1.83%	1.79	0.61
	West	Perimeter	66%	8.68%	5.74%	4.93	2.11
		Centre	17%	3.46%	0.60%	0.21	0.01
		Interior	21%	0.92%	0.20%	0.00	0.00
		Average	50%	4.35%	2.18%	1.71	0.71
WINTER	North	Perimeter	141%	2.60%	3.67%	0.73	0.15
		Centre	193%	0.56%	1.09%	0.06	0.02
		Interior	222%	0.23%	0.50%	0.02	0.02
		Average	155%	1.13%	1.75%	0.27	0.06
	East	Perimeter	87%	5.49%	4.76%	0.90	0.26
		Centre	87%	1.02%	0.89%	0.08	0.02
		Interior	90%	0.34%	0.31%	0.01	0.00
		Average	87%	2.28%	1.98%	0.33	0.09
	West	Perimeter	30%	18.33%	5.54%	0.88	0.29
		Centre	5%	13.27%	0.67%	0.05	0.00
		Interior	11%	2.05%	0.22%	0.00	0.00
		Average	19%	11.22%	2.15%	0.31	0.10
	South	Perimeter	52%	42.09%	21.69%	1.25	0.75
		Centre	25%	7.58%	1.87%	0.18	0.03
		Interior	29%	2.05%	0.60%	0.03	0.02
		Average	47%	17.24%	8.05%	0.49	0.27

Bedroom, Calgary

City: Calgary
 Residence Type: Townhouse
 Room: Bedroom
 Total Available Lux-Hours Whole Year: 154,238,000
 Total Available Lux-Hours Winter: 23,691,600

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	81%	3.51%	2.86%	5.49	0.67
		Centre	102%	1.37%	1.40%	0.43	0.02
		Interior	106%	0.77%	0.82%	0.02	0.02
		Average	90%	1.89%	1.69%	1.98	0.24
	East	Perimeter	78%	8.60%	6.73%	6.88	2.78
		Centre	96%	3.11%	2.98%	2.24	0.79
		Interior	91%	1.43%	1.30%	0.75	0.27
		Average	84%	4.38%	3.67%	3.29	1.28
	West	Perimeter	69%	11.72%	8.12%	6.48	3.26
		Centre	63%	6.39%	4.02%	2.75	1.19
		Interior	49%	3.75%	1.83%	1.16	0.50
		Average	64%	7.29%	4.66%	3.46	1.65
	South	Perimeter	65%	16.43%	10.70%	7.57	4.76
		Centre	93%	5.68%	5.27%	4.03	1.70
		Interior	86%	2.62%	2.26%	1.61	0.63
		Average	74%	8.24%	6.07%	4.40	2.36
WINTER	North	Perimeter	99%	3.88%	3.85%	0.89	0.21
		Centre	141%	1.50%	2.12%	0.26	0.02
		Interior	188%	0.85%	1.59%	0.09	0.02
		Average	121%	2.08%	2.52%	0.41	0.09
	East	Perimeter	81%	7.22%	5.85%	1.23	0.51
		Centre	77%	3.10%	2.38%	0.38	0.07
		Interior	86%	1.58%	1.37%	0.12	0.02
		Average	81%	3.97%	3.20%	0.58	0.20
	West	Perimeter	42%	19.43%	8.12%	1.25	0.58
		Centre	18%	17.47%	3.06%	0.45	0.15
		Interior	15%	9.22%	1.39%	0.12	0.06
		Average	27%	15.37%	4.19%	0.61	0.27
	South	Perimeter	79%	31.09%	24.53%	1.67	1.23
		Centre	80%	26.23%	20.92%	1.21	0.97
		Interior	87%	14.46%	12.65%	0.82	0.59
		Average	81%	23.93%	19.37%	1.23	0.93

Livingroom, Toronto

City: Toronto
 Residence Type: Townhouse
 Room: Livingroom
 Total Available Lux-Hours Whole Year: 149,097,800
 Total Available Lux-Hours Winter: 23,404,800

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	89%	2.65%	2.36%	4.24	0.14
		Centre	77%	0.56%	0.43%	0.00	0.00
		Interior	75%	0.21%	0.16%	0.00	0.00
		Average	86%	1.14%	0.98%	1.41	0.05
	East	Perimeter	87%	4.78%	4.14%	5.28	1.54
		Centre	67%	0.80%	0.54%	0.04	0.00
		Interior	62%	0.29%	0.18%	0.00	0.00
		Average	83%	1.95%	1.62%	1.77	0.51
	West	Perimeter	78%	6.17%	4.81%	4.87	1.80
		Centre	44%	1.29%	0.57%	0.21	0.01
		Interior	38%	0.49%	0.19%	0.00	0.00
		Average	70%	2.65%	1.85%	1.69	0.60
	South	Perimeter	87%	6.96%	6.05%	5.59	2.91
		Centre	64%	0.97%	0.62%	0.23	0.00
		Interior	56%	0.34%	0.19%	0.00	0.00
		Average	83%	2.76%	2.29%	1.94	0.97
WINTER	North	Perimeter	103%	2.71%	2.81%	0.65	0.03
		Centre	114%	0.57%	0.64%	0.01	0.00
		Interior	125%	0.22%	0.28%	0.00	0.00
		Average	106%	1.17%	1.24%	0.22	0.01
	East	Perimeter	67%	5.98%	4.02%	0.80	0.16
		Centre	49%	1.14%	0.56%	0.00	0.00
		Interior	54%	0.36%	0.19%	0.00	0.00
		Average	64%	2.50%	1.59%	0.27	0.05
	West	Perimeter	62%	8.22%	5.11%	0.79	0.25
		Centre	42%	1.40%	0.59%	0.02	0.00
		Interior	46%	0.43%	0.20%	0.00	0.00
		Average	59%	3.35%	1.97%	0.27	0.08
	South	Perimeter	79%	24.96%	19.63%	1.10	0.77
		Centre	62%	2.45%	1.51%	0.28	0.01
		Interior	58%	0.80%	0.46%	0.03	0.00
		Average	77%	9.40%	7.20%	0.47	0.26

Bedroom, Toronto

City: Toronto
 Residence Type: Townhouse
 Room: Bedroom
 Total Available Lux-Hours Whole Year: 149,097,800
 Total Available Lux-Hours Winter: 23,404,800

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	74%	4.01%	2.98%	5.68	1.06
		Centre	95%	1.49%	1.41%	0.84	0.00
		Interior	91%	0.81%	0.74%	0.00	0.00
		Average	81%	2.10%	1.71%	2.17	0.35
	East	Perimeter	71%	8.45%	5.97%	6.45	2.90
		Centre	94%	2.59%	2.42%	2.43	0.50
		Interior	87%	1.25%	1.08%	0.47	0.16
		Average	77%	4.10%	3.16%	3.12	1.19
	West	Perimeter	0%	9.21%	0.00%	6.10	3.06
		Centre	89%	3.48%	3.10%	2.51	0.83
		Interior	76%	1.92%	1.46%	0.82	0.33
		Average	47%	4.87%	2.28%	3.14	1.41
	South	Perimeter	0%	12.33%	0.00%	6.65	4.08
		Centre	90%	3.28%	2.96%	3.19	0.82
		Interior	77%	1.35%	1.04%	0.84	0.04
		Average	35%	5.65%	2.00%	3.56	1.65
WINTER	North	Perimeter	80%	4.21%	3.36%	0.92	0.08
		Centre	111%	1.53%	1.70%	0.15	0.00
		Interior	124%	0.85%	1.05%	0.03	0.00
		Average	93%	2.20%	2.04%	0.37	0.03
	East	Perimeter	76%	8.20%	6.22%	1.11	0.36
		Centre	65%	3.81%	2.48%	0.28	0.06
		Interior	44%	2.53%	1.11%	0.06	0.04
		Average	67%	4.85%	3.27%	0.48	0.15
	West	Perimeter	73%	10.02%	7.30%	1.14	0.44
		Centre	65%	4.02%	2.62%	0.30	0.12
		Interior	74%	1.69%	1.25%	0.11	0.03
		Average	71%	5.24%	3.72%	0.52	0.20
	South	Perimeter	85%	24.92%	21.25%	1.36	0.94
		Centre	91%	14.22%	12.92%	0.87	0.60
		Interior	83%	3.98%	3.31%	0.54	0.24
		Average	87%	14.37%	12.49%	0.92	0.59

Living room, Vancouver

City: Vancouver
 Residence Type: Apartment
 Room: Living Room
 Total Available Lux-Hours Whole Year: 138,521,800
 Total Available Lux-Hours Winter: 17,003,100

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	18.0%	2.00%	0.36%	0.00	0.00
		Centre	33.0%	0.87%	0.29%	0.00	0.00
		Interior	38.2%	0.63%	0.24%	0.00	0.00
		Average	25.3%	1.17%	0.30%	0.00	0.00
	East	Perimeter	11.0%	3.98%	0.44%	0.00	0.00
		Centre	26.8%	1.31%	0.35%	0.00	0.00
		Interior	31.8%	0.89%	0.28%	0.00	0.00
		Average	17.3%	2.06%	0.36%	0.00	0.00
	West	Perimeter	6.6%	7.01%	0.46%	0.00	0.00
		Centre	14.4%	2.60%	0.37%	0.00	0.00
		Interior	14.9%	2.05%	0.31%	0.00	0.00
		Average	9.8%	3.89%	0.38%	0.00	0.00
	South	Perimeter	8.9%	6.95%	0.62%	0.01	0.00
		Centre	26.4%	1.97%	0.52%	0.01	0.00
		Interior	33.0%	1.26%	0.42%	0.00	0.00
		Average	15.3%	3.39%	0.52%	0.01	0.00
WINTER	North	Perimeter	15.3%	2.55%	0.39%	0.00	0.00
		Centre	35.6%	1.05%	0.38%	0.00	0.00
		Interior	41.3%	0.75%	0.31%	0.00	0.00
		Average	24.7%	1.45%	0.36%	0.00	0.00
	East	Perimeter	12.0%	4.26%	0.51%	0.01	0.00
		Centre	23.8%	1.75%	0.42%	0.00	0.00
		Interior	31.1%	1.08%	0.34%	0.00	0.00
		Average	17.8%	2.36%	0.42%	0.00	0.00
	West	Perimeter	6.0%	8.92%	0.54%	0.02	0.00
		Centre	7.8%	5.84%	0.46%	0.00	0.00
		Interior	6.6%	5.70%	0.38%	0.00	0.00
		Average	6.7%	6.82%	0.46%	0.01	0.00
	South	Perimeter	3.1%	17.67%	0.55%	0.02	0.00
		Centre	3.1%	12.98%	0.40%	0.00	0.00
		Interior	5.9%	5.38%	0.32%	0.00	0.00
		Average	3.5%	12.01%	0.42%	0.01	0.00

Bedroom, Vancouver

City: Vancouver
 Residence Type: Apartment
 Room: Bedroom
 Total Available Lux-Hours Whole Year: 138,521,800
 Total Available Lux-Hours Winter: 17,003,100

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	77.5%	2.75%	2.13%	2.32	0.32
		Centre	53.7%	1.22%	0.65%	0.05	0.02
		Interior	51.6%	0.70%	0.36%	0.01	0.00
		Average	67.4%	1.56%	1.05%	0.80	0.11
	East	Perimeter	54.6%	5.75%	3.14%	2.78	0.61
		Centre	27.3%	2.31%	0.63%	0.01	0.00
		Interior	30.0%	1.17%	0.35%	0.00	0.00
		Average	44.6%	3.08%	1.37%	0.93	0.20
	West	Perimeter	44.0%	10.34%	4.55%	3.44	1.01
		Centre	13.4%	4.81%	0.64%	0.15	0.02
		Interior	13.7%	2.65%	0.36%	0.01	0.00
		Average	31.2%	5.94%	1.85%	1.20	0.34
	South	Perimeter	233.8%	2.75%	6.43%	4.09	1.92
		Centre	55.1%	1.22%	0.67%	0.13	0.00
		Interior	55.4%	0.70%	0.39%	0.00	0.00
		Average	160.4%	1.56%	2.50%	1.41	0.64
WINTER	North	Perimeter	97.2%	3.46%	3.36%	0.35	0.08
		Centre	94.8%	1.48%	1.40%	0.12	0.05
		Interior	92.3%	0.83%	0.76%	0.06	0.04
		Average	95.9%	1.92%	1.84%	0.18	0.06
	East	Perimeter	52.3%	5.48%	2.87%	0.27	0.03
		Centre	30.6%	2.13%	0.65%	0.02	0.00
		Interior	31.5%	1.12%	0.35%	0.00	0.00
		Average	44.4%	2.91%	1.29%	0.10	0.01
	West	Perimeter	47.2%	12.35%	5.83%	0.45	0.16
		Centre	14.9%	12.61%	1.88%	0.11	0.07
		Interior	9.9%	6.68%	0.66%	0.05	0.02
		Average	26.5%	10.55%	2.79%	0.21	0.08
	South	Perimeter	15.1%	22.97%	3.48%	0.49	0.07
		Centre	4.4%	13.30%	0.58%	0.00	0.00
		Interior	4.4%	7.22%	0.32%	0.00	0.00
		Average	10.1%	14.50%	1.46%	0.16	0.02

Living room, Calgary

City: Calgary
 Residence Type: Apartment
 Room: Living Room
 Total Available Lux-Hours Whole Year: 154,238,000
 Total Available Lux-Hours Winter: 23,691,600

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	19.1%	1.81%	0.35%	0.02	0.01
		Centre	35.3%	0.82%	0.29%	0.02	0.01
		Interior	40.6%	0.60%	0.24%	0.02	0.01
		Average	27.2%	1.08%	0.29%	0.02	0.01
	East	Perimeter	9.1%	4.71%	0.43%	0.00	0.00
		Centre	21.9%	1.58%	0.34%	0.00	0.00
		Interior	27.6%	1.01%	0.28%	0.00	0.00
		Average	14.4%	2.43%	0.35%	0.00	0.00
	West	Perimeter	6.2%	7.38%	0.46%	0.01	0.00
		Centre	11.8%	3.20%	0.38%	0.01	0.00
		Interior	10.3%	3.00%	0.31%	0.00	0.00
		Average	8.4%	4.53%	0.38%	0.00	0.00
	South	Perimeter	7.7%	9.02%	0.69%	0.03	0.02
		Centre	15.7%	3.70%	0.58%	0.02	0.02
		Interior	24.0%	1.93%	0.46%	0.02	0.02
		Average	11.8%	4.88%	0.58%	0.03	0.02
WINTER	North	Perimeter	19.5%	2.00%	0.39%	0.02	0.01
		Centre	43.1%	0.96%	0.42%	0.02	0.01
		Interior	49.3%	0.70%	0.34%	0.02	0.01
		Average	31.4%	1.22%	0.38%	0.02	0.01
	East	Perimeter	11.7%	4.56%	0.53%	0.01	0.00
		Centre	21.5%	2.02%	0.43%	0.00	0.00
		Interior	26.5%	1.34%	0.35%	0.00	0.00
		Average	16.7%	2.64%	0.44%	0.00	0.00
	West	Perimeter	6.1%	10.59%	0.65%	0.02	0.00
		Centre	6.6%	8.69%	0.57%	0.01	0.00
		Interior	4.0%	11.54%	0.47%	0.00	0.00
		Average	5.5%	10.28%	0.56%	0.01	0.00
	South	Perimeter	4.4%	23.65%	1.04%	0.03	0.02
		Centre	4.1%	19.94%	0.81%	0.02	0.02
		Interior	7.1%	9.08%	0.64%	0.02	0.02
		Average	4.7%	17.55%	0.83%	0.03	0.02

Bedroom, Calgary

City: Calgary
 Residence Type: Apartment
 Room: Bedroom
 Total Available Lux-Hours Whole Year: 154,238,000
 Total Available Lux-Hours Winter: 23,691,600

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	86.2%	2.37%	2.05%	2.05	0.39
		Centre	69.4%	1.13%	0.79%	0.10	0.04
		Interior	64.0%	0.67%	0.43%	0.02	0.02
		Average	78.1%	1.39%	1.09%	0.73	0.15
	East	Perimeter	49.0%	6.13%	3.00%	2.83	0.81
		Centre	24.7%	2.63%	0.65%	0.02	0.01
		Interior	24.5%	1.44%	0.35%	0.01	0.00
		Average	39.3%	3.40%	1.34%	0.95	0.27
	West	Perimeter	38.3%	9.95%	3.81%	3.71	1.17
		Centre	11.6%	5.68%	0.66%	0.14	0.03
		Interior	9.0%	4.10%	0.37%	0.01	0.00
		Average	24.5%	6.58%	1.61%	1.28	0.40
	South	Perimeter	56.5%	14.37%	8.12%	4.61	2.32
		Centre	21.1%	4.60%	0.97%	0.16	0.07
		Interior	23.9%	2.14%	0.51%	0.04	0.02
		Average	45.5%	7.04%	3.20%	1.60	0.81
WINTER	North	Perimeter	128.0%	2.67%	3.41%	0.52	0.15
		Centre	144.1%	1.33%	1.92%	0.21	0.08
		Interior	132.1%	0.80%	1.05%	0.08	0.02
		Average	133.2%	1.60%	2.13%	0.27	0.08
	East	Perimeter	58.4%	5.15%	3.01%	0.52	0.14
		Centre	40.9%	2.06%	0.84%	0.07	0.02
		Interior	37.6%	1.12%	0.42%	0.01	0.00
		Average	51.3%	2.78%	1.43%	0.20	0.05
	West	Perimeter	42.6%	12.84%	5.47%	0.77	0.34
		Centre	8.0%	14.00%	1.12%	0.11	0.06
		Interior	3.9%	14.76%	0.58%	0.06	0.00
		Average	17.3%	13.87%	2.39%	0.32	0.14
	South	Perimeter	30.6%	32.39%	9.92%	0.73	0.12
		Centre	12.8%	17.89%	2.30%	0.05	0.03
		Interior	10.3%	10.84%	1.12%	0.03	0.02
		Average	21.8%	20.37%	4.45%	0.27	0.06

Living room, Toronto

City: Toronto
 Residence Type: Apartment
 Room: Living Room
 Total Available Lux-Hours Whole Year: 149,097,800
 Total Available Lux-Hours Winter: 23,404,800

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	17.6%	1.96%	0.34%	0.00	0.00
		Centre	32.3%	0.85%	0.28%	0.00	0.00
		Interior	37.0%	0.63%	0.23%	0.00	0.00
		Average	24.8%	1.15%	0.28%	0.00	0.00
	East	Perimeter	10.3%	4.28%	0.44%	0.00	0.00
		Centre	26.3%	1.36%	0.36%	0.00	0.00
		Interior	30.8%	0.94%	0.29%	0.00	0.00
		Average	16.5%	2.20%	0.36%	0.00	0.00
	West	Perimeter	10.6%	5.51%	0.58%	0.00	0.00
		Centre	25.2%	1.96%	0.49%	0.01	0.00
		Interior	29.7%	1.34%	0.40%	0.00	0.00
		Average	16.7%	2.94%	0.49%	0.00	0.00
	South	Perimeter	10.8%	5.42%	0.58%	0.00	0.00
		Centre	28.5%	1.73%	0.49%	0.00	0.00
		Interior	32.7%	1.21%	0.40%	0.00	0.00
		Average	17.6%	2.79%	0.49%	0.00	0.00
WINTER	North	Perimeter	14.4%	2.20%	0.32%	0.00	0.00
		Centre	29.1%	0.94%	0.27%	0.00	0.00
		Interior	33.7%	0.67%	0.23%	0.00	0.00
		Average	21.5%	1.27%	0.27%	0.00	0.00
	East	Perimeter	10.9%	4.85%	0.53%	0.02	0.00
		Centre	17.0%	2.52%	0.43%	0.00	0.00
		Interior	16.0%	2.16%	0.35%	0.00	0.00
		Average	13.7%	3.17%	0.43%	0.01	0.00
	West	Perimeter	7.5%	6.82%	0.51%	0.02	0.00
		Centre	14.5%	3.04%	0.44%	0.01	0.00
		Interior	15.4%	2.36%	0.36%	0.00	0.00
		Average	10.8%	4.07%	0.44%	0.01	0.00
	South	Perimeter	2.7%	18.13%	0.49%	0.01	0.00
		Centre	5.7%	6.59%	0.37%	0.01	0.00
		Interior	9.8%	3.06%	0.30%	0.01	0.00
		Average	4.2%	9.26%	0.39%	0.01	0.00

Bedroom, Toronto

City: Toronto
 Residence Type: Apartment
 Room: Bedroom
 Total Available Lux-Hours Whole Year: 149,097,800
 Total Available Lux-Hours Winter: 23,404,800

Season	Orientation	Position	ODOF	TDF	TDF	Hours/Day	Hours/Day
				Unobstructed	Obstructed	Lux>1000	Lux>2000
WHOLE YEAR	North	Perimeter	74.8%	2.69%	2.01%	2.65	0.30
		Centre	48.5%	1.22%	0.59%	0.01	0.00
		Interior	47.0%	0.71%	0.33%	0.00	0.00
		Average	63.5%	1.54%	0.98%	0.88	0.10
	East	Perimeter	54.2%	6.08%	3.30%	3.41	0.95
		Centre	26.1%	2.34%	0.61%	0.00	0.00
		Interior	29.7%	1.15%	0.34%	0.00	0.00
		Average	44.4%	3.19%	1.42%	1.14	0.32
	West	Perimeter	50.7%	8.06%	4.09%	3.80	1.16
		Centre	18.0%	3.54%	0.64%	0.13	0.02
		Interior	18.1%	2.00%	0.36%	0.02	0.00
		Average	37.4%	4.53%	1.70%	1.32	0.40
	South	Perimeter	63.1%	9.73%	6.14%	4.67	2.16
		Centre	23.0%	2.99%	0.69%	0.15	0.00
		Interior	28.7%	1.41%	0.40%	0.00	0.00
		Average	51.2%	4.71%	2.41%	1.61	0.72
WINTER	North	Perimeter	81.9%	3.02%	2.48%	0.47	0.04
		Centre	63.6%	1.36%	0.86%	0.06	0.00
		Interior	58.3%	0.78%	0.45%	0.01	0.00
		Average	73.5%	1.72%	1.26%	0.18	0.01
	East	Perimeter	47.1%	6.00%	2.82%	0.56	0.11
		Centre	29.2%	2.31%	0.67%	0.03	0.00
		Interior	29.9%	1.21%	0.36%	0.00	0.00
		Average	40.5%	3.17%	1.29%	0.20	0.04
	West	Perimeter	58.3%	9.03%	5.27%	0.74	0.25
		Centre	23.2%	4.89%	1.13%	0.12	0.07
		Interior	22.7%	2.54%	0.58%	0.08	0.01
		Average	42.4%	5.49%	2.33%	0.31	0.11
	South	Perimeter	19.5%	20.21%	3.95%	0.85	0.13
		Centre	7.7%	12.24%	0.94%	0.04	0.03
		Interior	7.3%	6.19%	0.45%	0.03	0.02
		Average	13.8%	12.88%	1.78%	0.31	0.06

*** Living Includes Kitchen & Nook**

[illegible]

Average TDF Winter - House

[illegible]

* Includes Dining Rm

[illegible]

Average TDF Winter - Townhouse

[illegible]

* Service includes Ensuite, Walk-in, Bathroom and Mechanical Rm

Building Average TDF Annual	1.15
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[illegible]

Building Average TDF Winter	0.73
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* Service includes Ensuite, Walk-in, Bathroom and Mechanical Rm

[illegible]

Average TDF Winter - Apartment (North Facing)

[illegible]