DAYLIGHT SIMULATION FOR CODE COMPLIANCE: CREATING A DECISION TOOL

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ABSTRACT

The minimum illuminance requirement for New Zealand Building Code (NZBC) Clause G7 – Natural Light is currently not being met in some new apartments. Daylight simulation is the most effective method of predicting the performance of daylight in apartments, but due to the complexity and time required to gain accurate results, these simulations are not routinely done. This paper discusses an investigation into whether a tool could be created that will identify when daylight simulations may be required to prove compliance with NZBC G7. A tool was created by simulating the effects of various building design and environmental factors on the illuminance levels in a set of hypothetical apartments. Calibration tests were carried out for three typical apartments in Wellington. This research demonstrated that a tool can be created that determines when apartment buildings may required daylight simulations as proof of compliance with NZBC G7.

KEYWORDS

Daylight Simulation, Regualtion of Daylight, Daylight in Apartments, New Zealand Building Code

INTRODUCTION

All new residential buildings in New Zealand are required to comply with the minimum natural light levels specified in the New Zealand Building Code (NZBC) for Natural Light – Clause G7. Research has shown that this requirement is not always being met. A major reason for this is the difficulty of assessing accurately the natural light levels during the consent process. The purpose of this research project was to determine whether a tool can be created that will identify when simulations are needed to prove that a building will meet the minimum requirement. Such a tool would allow Territorial Authorities to easily identify whether a building will meet the Code requirement, consequently preventing 'borderline' buildings from gaining consent if proof of compliance is not provided.

This research project resulted from speculation that the minimum Building Code requirement for daylight illumination was not always being met in apartments. This speculation was based on an understanding of the factors such as overshadowing likely to affect daylight access in apartments in downtown areas of New Zealand's major cities. In a separate investigation these speculations were proven to be well-founded, as four out of five apartments tested did not reach the minimum requirement post-construction (Stewart 2006). This investigation also concluded that a major reason for consent being given to buildings that do not meet the minimum requirement is that it is difficult to determine, pre-construction, if a building will meet this requirement. It was also noted that Territorial Authorities (TAs) consider it unreasonable to request complex, time consuming, and hence costly daylight simulations for all new apartments, as these are often not necessary.

The aim of this research was to determine if a tool can be created that will address the current issues in the regulation of natural light levels in new apartment buildings. The specifications for this tool were that it was to be: simple and easy to use, reasonably accurate and easily implemented. This tool was based on the format of the NZBC E2 Risk Matrix (DBH, 2007), however this was modified to suit the project. The tool was created to determine when simulations are needed to prove compliance with the NZBC minimum requirement for natural light. This tool was to be representative of typical New Zealand apartments and environmental parameters.

BACKGROUND

New Zealand Building Code Clause G7 – Natural Light

The NZBC Clause G7 – Natural Light has been created to satisfy the aims of the Building Act 2004, to 'encourage better practices, in building design and construction' (DBH, 2007). This clause relates only to housing, which includes all houses, apartments and other dwellings. The performance criteria for natural light are that a minimum illuminance of 30 lux at floor level for 75% of the standard year is provided in all habitable space, and that openings are provided to give visual awareness to the outside (DBH 2001). These requirements are implemented to 'safeguard people against illness or loss of amenity due to isolation from natural light and view to the outside environment' (DBH, 2001).

Definitions (DBH, 2001):

- A **habitable space** is defined as a space used for activities associated with domestic living, but excludes any utility areas such as bathrooms and laundries.

- A **standard year**, for the purpose of these regulations is between 8am and 5pm for 365 days of the year.

This research was only concerned with the illuminance requirement.

Daylight Simulation

The best method of determining, pre-construction, what the illuminance in a space will be is through daylight simulation. These simulations, up until recently, have been complex and expensive to conduct, and very time consuming, especially if they are to be representative of illuminance for all 365 days in a year. They are therefore rarely done.

Recent developments in the area of daylight simulation have meant that it is now feasible for daylight simulations to be used regularly to examine all the hours of the standard daylight year (8am – 5pm) for proof of code compliance. The daylight simulation software, DAYSIM (NRC, 2007), has been developed that will produce relatively quick results and provides more relevant information than has previously been available.

This program utilizes annual weather data to calculate the annual profiles of daylight in the space. This process allows a more direct calculation of the percent of the year that a certain illuminance is exceeded at specified points. The program uses only one simulation to calculate the contribution of each part of the sky (including those where the sun is located) to the light at each virtual light sensor in a room. The program then uses hour by hour weather (solar radiation) data to calculate the amount of light at each virtual light sensor point. The simulation time is dramatically cut down, as only one simulation needs to be run to provide the required annual light availability information.

RESEARCH DESIGN

This research involved the simulation of typical apartment and site variations that may affect the availability of natural light. It was not necessary to investigate all apartment situations, as it was the main objective of this research to determine if a tool can be created, rather than creating a finalised tool. The information from the simulations was analysed and was used to form the basis of the ‘decision tool’. Calibration tests were conducted to ensure the tool was accurate and met the specified criteria for the tool.

A set of criteria were outlined to ensure the tool was practical and effective. These criteria were based on those identified by Professor Edward Ng (2001). Ng created a design tool that allows architects to estimate daylight performance of high-rise residential buildings in high-density urban sites. The criteria outlined by Ng were that the tool must be: reasonably accurate, easy and straightforward to use. These criteria are also relevant to the creation of a tool to determine when daylight simulations are required for New Zealand apartment buildings.

Ng also suggested that it was necessary that it be clear that the use of the tool is enforceable. In the context of this project, which sought to make a positive addition to the New Zealand Building Code, the third criterion became that the tool was to be easily implemented.

SIMULATIONS

Wellington City, a mid-latitude city in New Zealand, and the capital, was chosen as a representative location for this study. Daylight simulations were produced for typical apartment building situations in Wellington, with the intention that these could easily be adapted to the situation found in other New Zealand Cities. Daylight simulations were produced for buildings which varied systematically in the values of the factors that affect the availability of daylight in apartments:

- Six hypothetical apartments were modelled representative of the range found in Wellington.
- Three streets were chosen that represented the range of streets found in Wellington.
- A building on each of these streets was selected.
- Two apartment types were then added to each of the three buildings.

A selection of factors was chosen for the simulations, with the intention of representing the range of potential factors experienced at the site. These factors were separated into two sections based on hierarchy of importance, these were Primary Factors, highly influential, and Secondary Factors, less influential.

Factors

The separation into primary and secondary factors was a means of managing the number of simulations to be run. The primary factors were simulated for every apartment type in the list above, but the secondary factors were only simulated for four out of the six situations. The primary factors are the aspects of the building and environment that have been acknowledged in the literature as having a large effect on the availability of daylight in urban environments. The secondary factors are aspects that may have an effect on the availability of daylight and therefore need to be tested, but are likely to be of less importance. This process necessitated a number of *a priori* assumptions in relation to the apartments and their surroundings: interior colour scheme; apartment layout, dimensions and location; glazing type; and placement of measurement points were standardized.

The primary factors considered for the tool were Building Heights (Opposite Building and Proposed Building), Street Width and Apartment Type. Apartment Type was derived from the work of Roger Sherwood (1978). He defined apartments as belonging to three types: single wall to the outside; opposite walls to the outside; adjacent walls to the outside. The other factors were identified by both the IEA (2001) and Ng (2001), and are commonly recognised in the field as aspects that affect the performance of daylight in urban environments.

The secondary factors simulated were: Location, Building Colour, Building Materials, Apartment Orientation, Internal Rooms, and Glazed Area.

11 factors were identified for simulation, with 59 apartment building situations being simulated to provide the data for the tool.

CREATING THE TOOL

There were two steps involved in the creation of the tool, analysis of the simulation results and formulation of the tool.

Analysis

A categorisation method was adopted for this stage of the research. Clear mathematical relationships could not be established with the planned limited number of simulations. The factors were categorised depending on the effect they had on the illuminance levels in the apartments. The table below shows how the data was categorised to formulate the tool. The variation referred to in this table is the amount of deviation from the 30 lux target in the Code.

Table 1 – Categorisation Table

CATEGORY	VARIATION
Large	> 25%
Medium	15 – 25 %
Small	5 – 14 %
Minimal	< 5 %

Figure 1 shows a comparison of the effects of the height on daylight levels for each apartment. It compares the effects against the minimum NZBC G7 compliance level for each measurement point. Data like this was used to calculate the average increase for each factor used for the categorisation of the variation.

Formulation of Tool

This categorisation method was used in the creation of the decision tool. Each category had a weighting applied, following the style of the NZBC E2 Weathertightness risk matrix, to represent the degree each factor affected the daylight access. The weighting was distributed proportionally between the aspects tested for each factor. The worst condition for each factor received the maximum value, with the other condition given a proportion of the maximum weighting related to the number of conditions tested and the effect they had. In a situation where there were three conditions tested, the worst situation received the full value, the middle condition received two thirds of the full value, and the best condition received one third of the full value. An example of this is shown in the table below, where the maximum weighting is 30.

The weighting values for each factor were added together to receive a ‘final value’ (see table 3). From this final value the threshold value can be determined.

This was found by applying the decision tool which determined the final value for each apartment situation simulated. The simulation results for each situation were also noted, specifying whether the apartment complied. The ‘final value’ that provided the highest level of accuracy was selected, which became the threshold value for the tool.

The method used for delivering the tool was an automated spreadsheet. This meant that the appropriate information could be entered without requiring any calculation by the users, eliminating the chance of miscalculations. This also meant an answer could be provided quickly and involving little effort.

Figure 2 shows the format of the Decision Tool before being applied to an apartment building.

Table 2 – Distribution of Weightings

	8m-14m (Worst)	15m-27m (Medium)	28m or Greater (Best)
Street Width	30	20	10

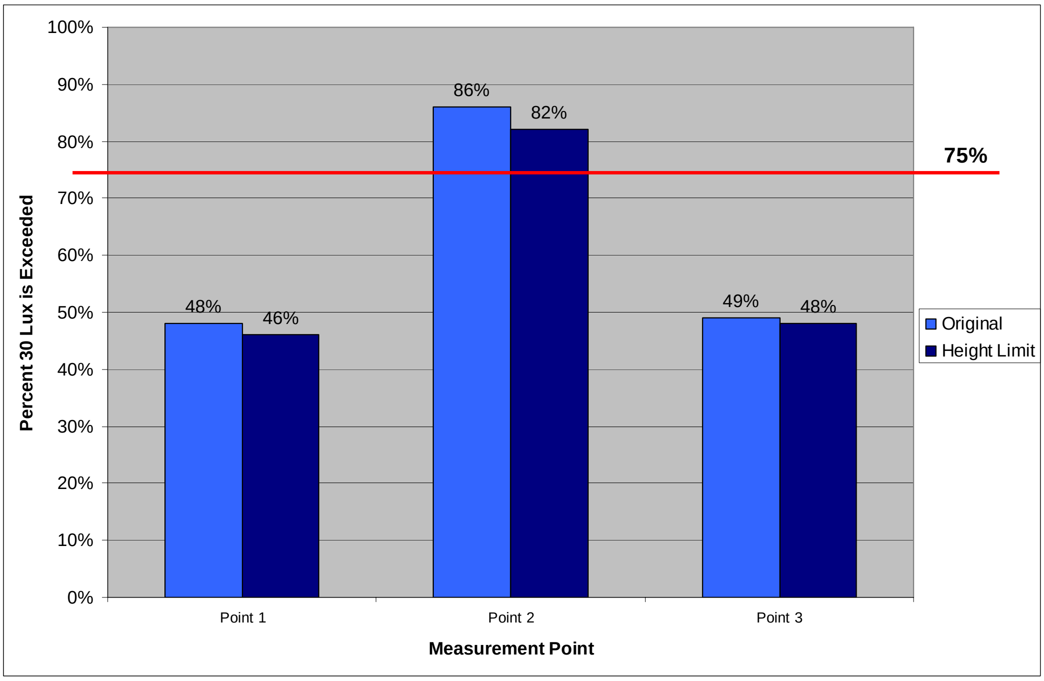

Figure 1 – Analysis of Building Heights

Table 3 – Calculating Final Value

Tennyson Street Deep Original	**Final Value**
Apartment Type	30
Street Width	30
Height Limit	5
Proposed Building Height	1
Opposite Building Height	5
Internal Room	1
Location	5
Orientation	5
Glazed Area	20
Colour	3
Construction Material	10
Total	115

Table 4 – Comparison of Final Values

Factors	**Simulations Result**	**Final Value**
Tennyson Street Deep Apartment		
Original	Fail	115
Opposite at Height Limit	Fail	119
Proposed at Height Limit	Fail	120
Glazed	Fail	104
Stone	Fail	124
Victoria Street Wide		
Original	Pass	74
Internal Room	Fail	103

NZBC G7 - Decision Tool

To determine if daylight simulations will be required to prove the proposed building will meet NZBC G7 the following questions should be answered.

Enter the number 1 in the cell that corresponds with the conditions present for the proposed building.

Apartment Type	Wide	Deep
What is the typical apartment type for apartments situated on the lower floors?		

Street Width	8m-14m	15m-27m	28m or Greater
The proposed building is situated on a street with a width of			

Building Heights	26m or Less	27m - 42m	43m - 64m	65m or Greater
The proposed building is situated in a Height Limit area of				
The Height of the proposed building is				
The Maximum Height of the opposite Buildings is				

Internal Room	Yes	No
Do any apartments in the proposed building contain internal rooms?		

Site Variables				
	Upper North Is	Lower North Is	South Is	
Where in New Zealand is the site situated?				
	North	East	South	West
What is the orientation of the main facade?				

Glazed Area	10% of Floor Area	Between 10% and Full Façade	Full Facade
What is the area of the main façade that is glazed?			

Qualities of Adjacent Buildings			
	Light	Medium	Dark
What is the main colour of opposite buildings?			
	Fully Glazed	Medium	Stone
What is the façade of the opposite building constructed of?			

Are Simulations Required: **NO**

Figure 2 – Decision Tool

CALIBRATION

To ensure the tool provides accurate results, and that it meets the original criteria, calibration tests were conducted. These tests involved the selection of three distinctly different apartment buildings. The accuracy was tested by applying the decision tool to each apartment to determine if that apartment would require daylight simulations. The results from daylight simulations were then compared with the results from the decision tool results to determine if the tool provided the correct results.

The tool was used to determine if these buildings would have required daylight simulations to receive building consent.

For the first case, the tool determined that daylight simulations would be required. Daylight simulations found that all three measurement points in this apartment did not comply with the NZBC performance criterion. The second case also found that daylight simulations would be required. The daylight simulations conducted for this site supported the findings of the decision tool as only one of the measurement points was found to comply with NZBC G7. The third case found that daylight simulations would not be required for this building. Daylight simulations found that the light levels in the two apartments measured greatly exceeded the minimum requirement for NZBC G7.

At least in this limited calibration the decision tool appears to provide accurate guidance for typical apartment buildings.

CALIBRATION EXAMPLE

To illustrate the application of the tool the following shows the process of calibration for an apartment situated in an area of Wellington popular for the construction of apartment buildings. This building was measured (Stewart 2006) as non compliant. It is made up of nine floors. The ground floor is retail and is therefore not required to comply with NZBC G7. Each of the remaining eight floors contains 12 apartments of varying sizes.

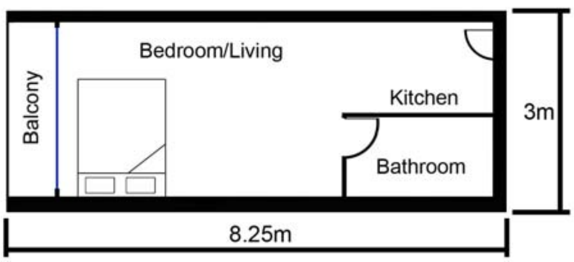

Figure 3 – Typical Apartment Layout

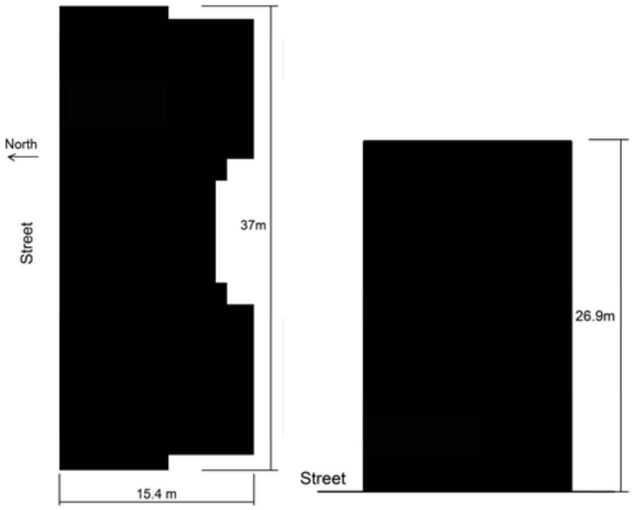

Figure 4 – Building Plan and Elevation

Table 5 shows the information to be entered into the decision tool. The data for this table was drawn from the site and plans of the building. The application of the Decision Tool is shown in Figure 5.

Table 5 – Data for Tool

	Actual	**Decision Tool**
Apartment Type	Deep	Deep
Street Width	9m	8m-14m
Height Limit	27m	27m-42m
Proposed Building Height	26.9m	26m or less
Opposite Building Height	11.4m	26m or less
Internal Room	No	No
Location	Wellington	Lower North Is
Orientation	North	North
Glazed Area	28% of Floor Area	Between 10% and Full Façade
Colour	White	Light
Construction Material	Glass and Concrete	Medium

The daylight simulations measured the percent of the standard year that 30 lux is exceeded at three spots. These show the level of compliance at the back of the apartment at floor level. The results from the daylight simulations are shown in Figure 4.

The decision tool specified that daylight simulations would be required to prove this building would meet the minimum NZBC G7 requirement of 30 lux at floor level for no less than 75% of the standard year. Simulations were conducted for an apartment in this building that was expected to receive the least exposure to daylight. These simulations found that the apartment would not comply with NZBC G7 at the back of the living area.

CONCLUSION

This paper summarises the findings of research on the creating of a decision tool for New Zealand Building Code Clause G7 – Nautral Light. The aim of the project was to determine if it would be possible to create a tool that would specify if apartments should be simulated to prove compliance with NZBC G7.

It was found that it is possible to create such a tool that satisfies two of the three criteria and it is felt that with further developments will satisfy all three. A decision tool was created that is simple and easy to use and is acurate.

There are several steps required before this tool might be able to be applied in practice. The first is to run a significantly larger number of simulations so as to determine a mathematical relationship between the generic properties of apartments and the internal minimum illuminance values. Second is to test the practical application of the tool in compliance offices in Territorial Authorities and in designers' offices. This further development and research is currently under way. Whilst not a cure for bad design, the research should make it easier in apartment buildings to achieve the goals of NZBC Clause G7 Natural Light.

ACKNOWLEDGMENT

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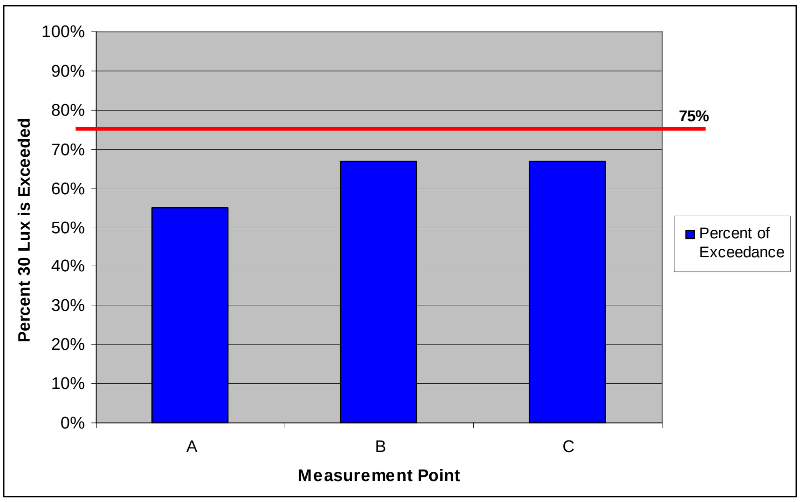

Figure 4 – Simulation Results

NZBC G7 - Decision Tool

To determine if daylight simulations will be required to prove the proposed building will meet NZBC G7 the following questions should be answered.

Enter the number **1** in the cell that corresponds with the conditions present for the proposed building.

Apartment Type	Wide	Deep
What is the typical apartment type for apartments situated on the lower floors?		1

Street Width	8m-14m	15m-27m	28m or Greater
The proposed building is situated on a street with a width of	1		

Building Heights	26m or Less	27m - 42m	43m - 64m	65m or Greater
The proposed building is situated in a Height Limit area of		1		
The Height of the proposed building is		1		
The Maximum Height of the Adjacent Buildings is	1			

Internal Room	Yes	No
Do any apartments in the proposed building contain internal rooms?		1

Site Variables				
	Upper North Is	Lower North Is	South Is	
Where in New Zealand is the site situated?		1		
	North	East	South	West
What is the orientation of the main facade?	1			

Glazed Area	10% of Floor Area	Between 10% and Full Façade	Full Facade
What is the area of the main façade that is glazed?		1	

Qualities of Adjacent Buildings			
	Light	Medium	Dark
What is the main colour of opposite buildings?	1		
	Fully Glazed	Medium	Stone
What is the façade of the opposite building constructed of?		1	

Are Simulations Required: **YES**

Figure 5 – Example Decision Tool