Appendix B
(PNAP APP-130)

GUIDANCE NOTES ON VALIDATION OF LIGHTING SIMULATION SOFTWARE

1. Introduction

These notes give guidance on the validation of lighting simulation software for assessing the performance of natural lighting in buildings. As computational lighting simulation is a complicated science, APs may wish to consult a specialist in lighting design.

2. Computational Lighting Simulation

2.1 The BA accepts computational lighting simulation for the assessment of the performance of natural lighting in buildings. The BA will accept such a proposal provided that the software is validated and the simulation is properly conducted. For avoidance of doubt, the currently accepted amenity features including drying racks, small air-conditioner platforms or hoods and window eaves protruding onto the unobstructed vision area may be disregarded if the size of these features is not excessive.

2.2 APs should attend to the following 4 important criteria in carrying out a lighting simulation test:

(i) The accuracy of the Global Illumination Model of the software, which determines how well the software cater for the characteristics of the sky.

(ii) The accuracy of the Local Illumination Model of the software, which determines how well the software cater for inter-reflections between objects in the model.

(iii) The accuracy of the Geometric description of the simulated scenes, which requires the geometric input to the simulation software, is representative of the scenes to be test.

(iv) The accuracy of the Material description of the simulated scenes, which requires the material reflectance of the surfaces of the geometry, is appropriately set.

3. Approach of Validation – Standard 3D Model and Datum

3.1 For the purpose of validating the software, a Standard 3D model is built as the geometrical input of the test and 62 selected points are defined on the model, which together form the Datum of the validation test. Details of the assembly are provided at Annex 1. An overview of the Standard 3D model and the distribution of Datum points on the Standard 3D model are at Figure 1 and Figure 2 of Annex 1 respectively.

3.2 Up to 2 different materials reflectance may be set, one for ALL vertical surfaces and another for ALL horizontal surfaces. Alternatively, a single setting of reflectance may be used for all surfaces. As part of the submission, the material reflectance(s) set should be reported.

3.3 There are total 62 points (23 on horizontal surfaces and 39 on vertical surfaces) where the simulated results of the Standard 3D model should be reported and compared with the Datum. Using the software to be validated with particular settings, the results of all the 62 points on the Standard 3D model must not be more than the Datum. Simulated results of the Daylight Factor (DF) and Vertical Daylight Factor (VDF) of say 12.459% could be rounded off to whole number (i.e.12%). Likewise, 12.501% should be rounded off to 13%. Details of the Datum values are provided at Annex 2.

4. Validation Test

To demonstrate that the software is validated for use, the APs should submit the following document to BA for approval:

(i) The name and version of the software to be validated. The name, country of origin and contact details of the vendor including mail address, telephone number, fax number, email and website address must be attached.

(ii) A folder containing the generic simulation file(s) with the 3D model, and all files and detail settings necessary to reproduce the simulation results independently and without making reference to the APs.

(iii) A note stating the Material Reflectance of the Standard 3D model used. Only up to 2 material reflectance settings may be used: one for the ground horizontal surface, the other for all vertical surfaces.

(iv) A print out of DF and VDF of ALL 62 points as defined in The Datum that are generated by the software to be validated. And a statement that the 62 values obtained with the software to be validated, using the settings and geometry as defined, is UNDER the respective values of the Datum.

5. Guide on creating an Accurate Geometric Model

5.1 Once the software is validated for use, the AP should ensure the accurate building of the geometry file of the design. An example is shown in Annex 3. Apart from the building to be tested, the surrounding wall should be constructed according to the following guidelines (refer to Annex 3 for reference):-

(i) The building to be tested and all buildings within the same site must be accurately modeled.

(ii) A "closed" surrounding wall is to be built surrounding the site, in such a way that no gap is possible. This surrounding wall should be made up of two parts: from ground to height W and from height W to height H. This wall is to represent reasonably the surrounding conditions of the test site.

(iii) Height W is the equivalent height of the façade area of all immediate buildings when compressed to fill the entire length of the site boundary. The surrounding wall up to this height W is solid. This portion of the wall represents the main bulk of the buildings on the test site.

(iv) Height H will be the average height of buildings used to work out height W. The wall between W and H should be perforated with slots. Vertical slots equal to 1/5 (or 20%) the area of the surrounding wall W to H may be inserted. The void portions of the slots are to be between 10 to 15 meters wide – exact dimension to be worked out evenly across the boundary. The slotted wall represents closely the cityscape immediately in front and beyond the test site. This portion of the wall captures the gaps of tower buildings around the site.

(v) The minimum perpendicular dimension from own site boundary to the edge of all the 'immediate tower blocks' facing the same boundary on its own site should be defined. Assume the average dimension be A meter. For example, if there are 3 immediate tower blocks, A will be the average of their minimum distance from the boundary. The minimum distance should be taken from the walls of the buildings.

(vi) The surrounding wall towards that boundary could be positioned A into the neighbour's boundary. This literally assumes that if the test building is set back from its own site boundary, a mutually respected situation could be established from the surrounding buildings on the other side of the boundary.

(vii) The design could also take advantage of 'long and straight' roads leading out of the test site. The open end of roads leading out could be capped (closed) reasonably at a distance 5 times the height of the surrounding walls.

5.2 The surrounding walls proposed here is a simplified method to re-create reasonable surroundings for the test site. The heights and positions of the surrounding wall facing various orientations of the test site are to be determined independently.

6. Guide on Material Description

The AP should use the reflectance they had set when the software was originally validated for the scene they are going to test. Only 2 reflectance should be used, one for all ground horizontal surfaces and another for all building vertical surfaces including the top horizontal surfaces of any podium.

7. Performance Standard for Natural Lighting

7.1 No window in a building shall be take into account unless:

(i) it faces into a space which is uncovered and not bounded on the side opposite the window by any obstruction of the building; and

(ii) the top of the window is at least 2m above the floor level.

7.2 Under PNAP APP-130, 8% VDF and 4% VDF should be made available on the vertical surface of the windows of habitable room and kitchen respectively when the aggregate superficial area of glass in a window (i.e. actual glazing area excluding window frames) is 10% of the usable floor area of the room. If larger window size is used, the following table could be used for the purpose of simulation:-

Required VDF / **Glazing area (% of UFA)**	**VDF 8% or more**	**VDF 6% or more**	**VDF 5% or more**	**VDF 4% or more**	**VDF 3% or more**
Habitable room	10%	15%	20%		
Kitchen				10%	15%

7.3 The maximum glazing area is limited to 20% and 15% for habitable room and kitchen respectively. Therefore, for example, VDF of habitable room cannot be less than 5%. Extrapolation beyond the limit (VDF 5% for habitable room or VDF 3% for kitchen) is not possible.

7.4 The required glazing area could be interpolated from the table. For example, the simulation results show that the window is receiving 7.5% VDF. The glazing area needed is therefore 11.25% or larger.

8. Daylight Software

Some software are currently available in the market for daylight studies. Details are provided at Annex 4 for reference.

Annex 1
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Standard 3D Model

1. The Standard 3D model is assembled with 1 unit by 1 unit cube. It is therefore 34 units wide, 44 units high and 8 units deep.

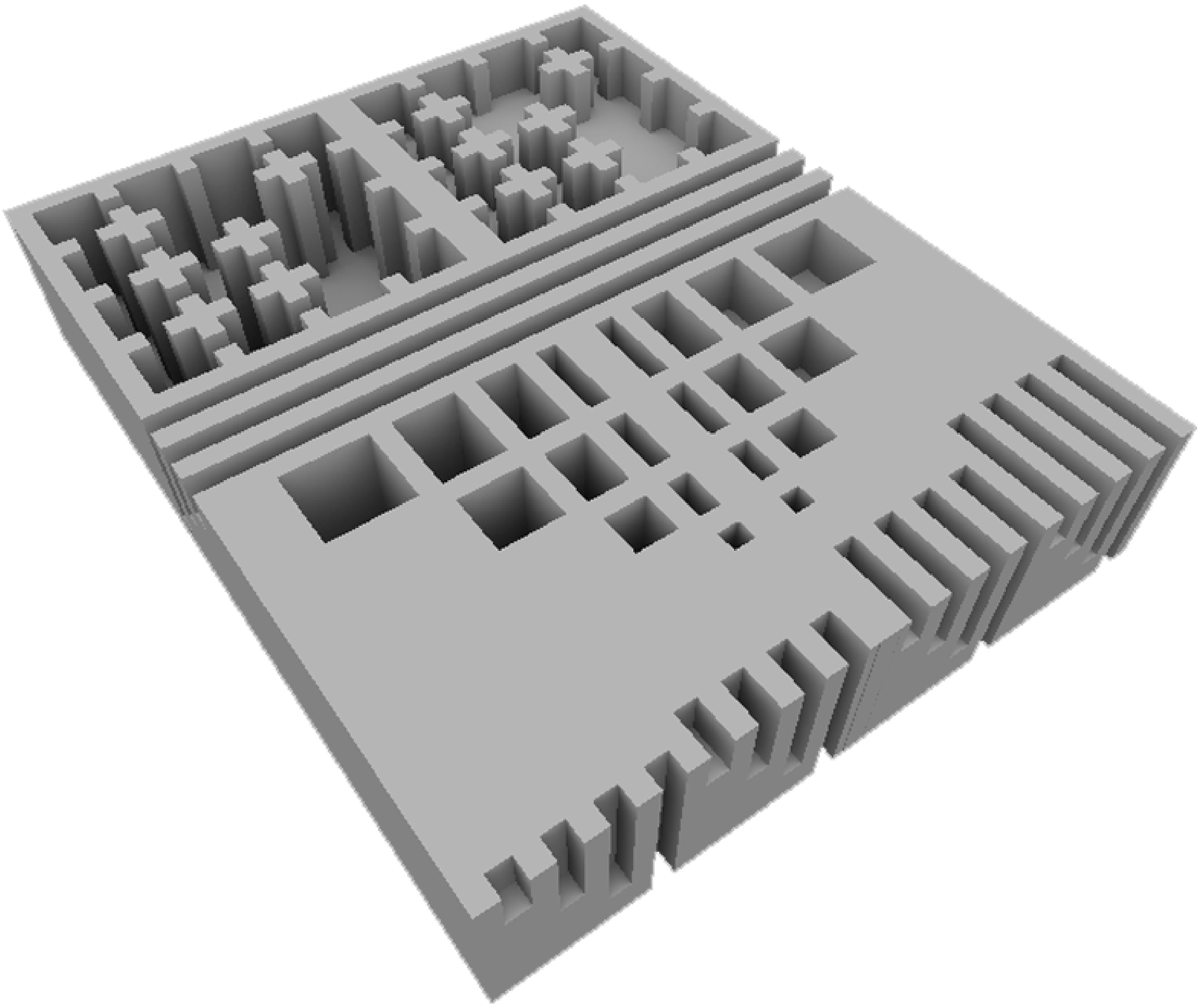

Figure 1: An overview of the Standard 3D model

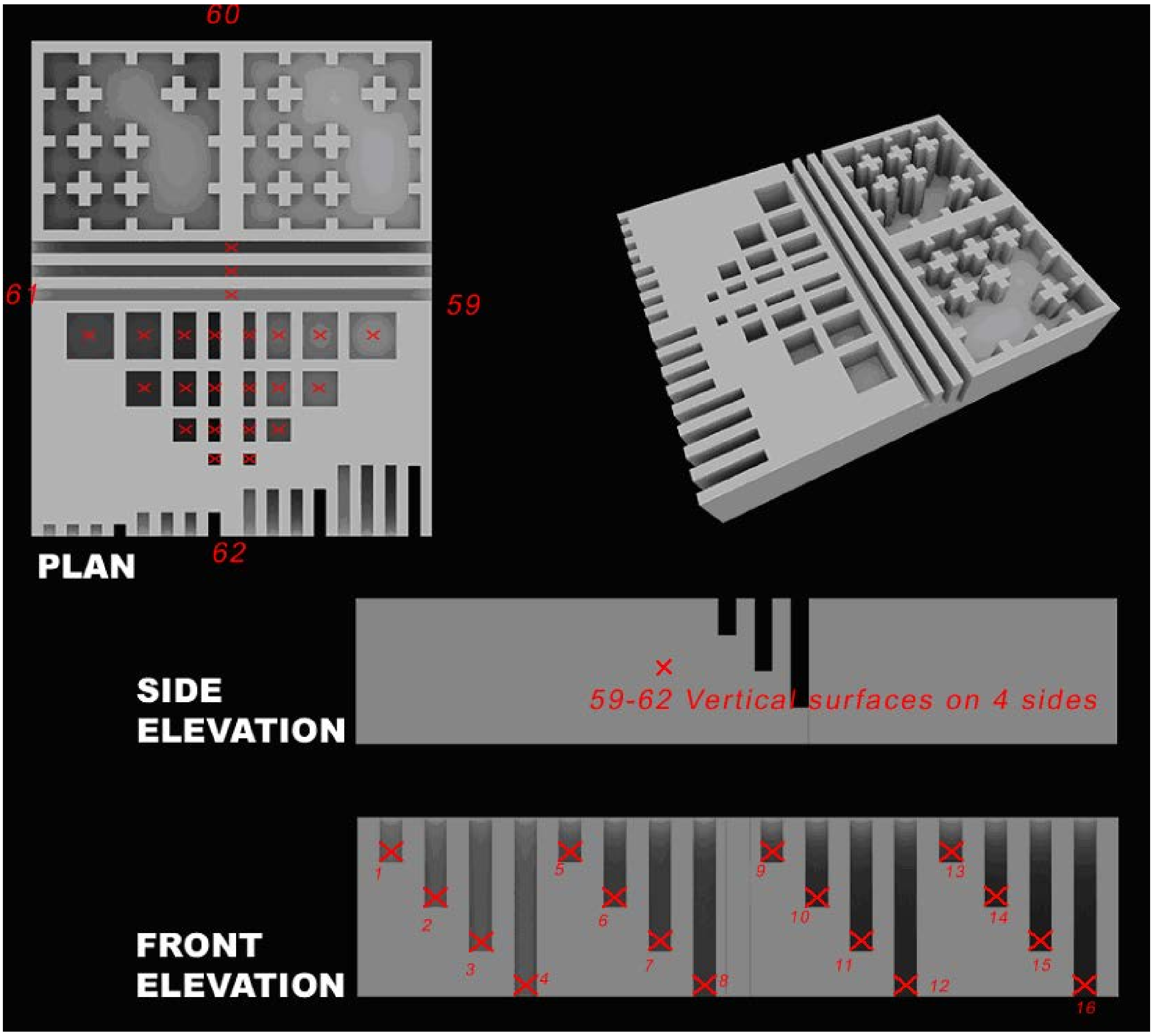

Figure 2: Distribution of Datum points on the Standard 3D model

2. Figure 2 shows distribution of datum points on the Standard 3D model:

   (i) Datum points 1-16: Within it there are 16 slots at the bottom (Front Elevation in Figure 2). They are 1 unit wide, 2, 4, 6 and 8 units high, and 2, 4, 6 and 8 units deep. The 4 deepest slots (8 unit deep) puncture the base of the overall model and thus could be seen from below.

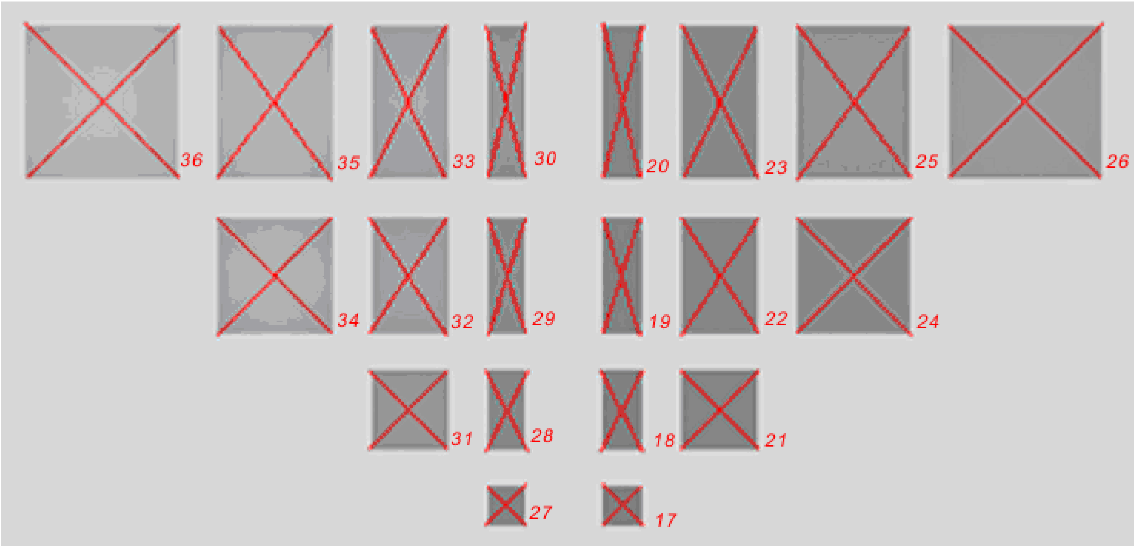

Figure 3: Holes of the Standard 3D model

(ii) Datum points 17-36: On top of the slots, there are 20 holes (Figure 3 refers). The holes on the right are 3 units deep, whilst the ones on the left are 6 units deep. The largest hole is 4x4 unit in size, whilst the smallest hole is 1x1 unit in size. The rest of the holes follow the logic ranging from 1x1 to 1x4, and 1x4 to 4x4.

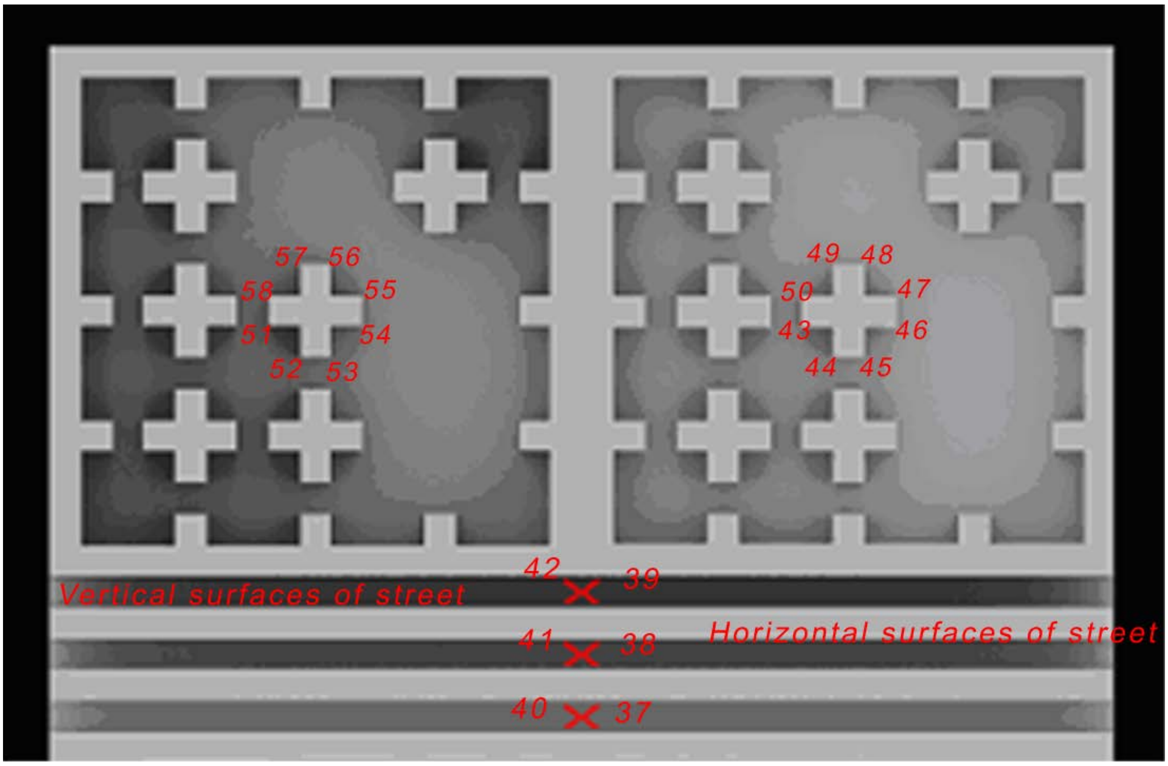

Figure 4: Streets and Buildings of the Standard 3D model

(iii) Datum points 37-42: There are three horizontal slots on top of the holes (Figure 4 refers). They represent street conditions. They are all 1 unit high, and 2, 4 and 6 unit deep respectively.

(iv) Datum points 43-58: On top of the slots are 2 housing layouts (Figure 4 refers). The one on the right is 3 units deep, and the one on the left is 6 units deep. The cruciform blocks are all 1+1+1 unit in plan.

(v) Datum points 59-62: The four vertical external surfaces of the model (Plan and Side Elevation in Figure 2).

3. The Standard 3D should ideally have all the surfaces join perfectly (that is to say, there is no gap between the surfaces used to build the model). Typically the use of solid model is the best way to guarantee that. If surface CAD modeler is used (e.g. AutoCAD), the operator must exercise extra care in building the model. The reason for perfectly aligned model is to prevent light leak through the gaps. Moreover, some software is known to behave strangely when surfaces intercept each other.

4. The plan, sections and elevations of the Standard 3D model is shown in Figure 5.

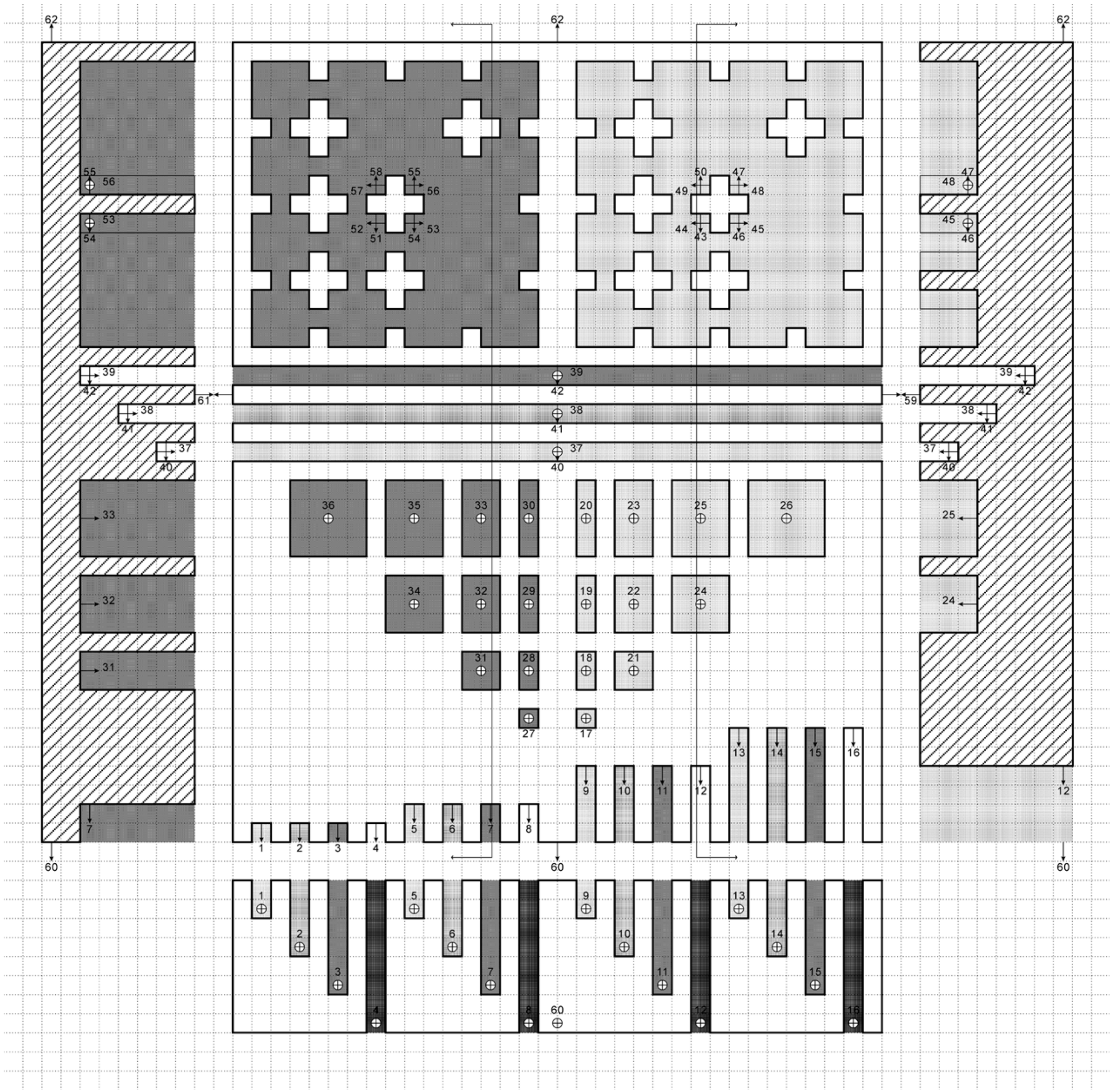

Figure 5: Plan and Sections and elevation of the Standard 3D model

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Annex 2
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Datum Values

The Datum values are shown in the following table:

Datum point	**Key description**	**Detail description**	**DF or VDF**	**Datum (%)**
1	Slot	1x1x 2 deep	VDF	**22**
2		1x1x 4 deep	VDF	**21**
3		1x1x 6 deep	VDF	**21**
4		1x1x 8 deep	VDF	**20**
5	Slot	1x2x 2 deep	VDF	**14**
6		1x2x 4 deep	VDF	**12**
7		1x2x 6 deep	VDF	**12**
8		1x2x 8 deep	VDF	**11**
9	Slot	1x4x 2 deep	VDF	**12**
10		1x4x 4 deep	VDF	**8**
11		1x4x 6 deep	VDF	**8**
12		1x4x 8 deep	VDF	**7**
13	Slot	1x6x 2 deep	VDF	**10**
14		1x6x 4 deep	VDF	**6**
15		1x6x 6 deep	VDF	**5**
16		1x6x 8 deep	VDF	**5**
17	Hole	1x1x3 deep	DF	**6**
18		1x2x3 deep	DF	**10**
19		1x3x3 deep	DF	**13**
20		1x4x3 deep	DF	**15**
21		2x2x3 deep	DF	**18**
22		2x3x3 deep	DF	**24**
23		2x4x3 deep	DF	**28**
24		3x3x3 deep	DF	**32**
25		3x4x3 deep	DF	**38**
26		4x4x3 deep	DF	**45**
27	Hole	1x1x6 deep	DF	**2**
28		1x2x6 deep	DF	**4**
29		1x3x6 deep	DF	**5**
30		1x4x6 deep	DF	**6**
31		2x2x6 deep	DF	**7**

32		2x3x6 deep	DF	**8**
33		2x4x6 deep	DF	**10**
34		3x3x6 deep	DF	**11**
35		3x4x6 deep	DF	**14**
36		4x4x6 deep	DF	**18**
37	Middle of Street	1x2 deep	DF	**30**
38		1x4 deep	DF	**16**
39		1x6 deep	DF	**11**
40		1x2 deep	VDF	**10**
41		1x4 deep	VDF	**4**
42		1x6 deep	VDF	**2**
43	Building	Surface 1 x 3 deep (H facing 3 blks)	VDF	**13**
44	(anti- clockwise)	Surface 2 x 3 deep (V facing 3 blks)	VDF	**13**
45		Surface 3 x 3 deep	VDF	**22**
46		Surface 4 x 3 deep	VDF	**20**
47		Surface 5 x 3 deep	VDF	**18**
48		Surface 6 x 3 deep	VDF	**19**
49		Surface 7 x 3 deep	VDF	**14**
50		Surface 8 x 3 deep	VDF	**19**
51	Building	Surface 1 x 6 deep (H facing 3 blks)	VDF	**5**
52	(anti-clockwise)	Surface 2 x 6 deep (V facing 3 blks)	VDF	**5**
53		Surface 3 x 6 deep	VDF	**12**
54		Surface 4 x 6 deep	VDF	**8**
55		Surface 5 x 6 deep	VDF	**9**
56		Surface 6 x 6 deep	VDF	**9**
57		Surface 7 x 6 deep	VDF	**5**
58		Surface 8 x 6 deep	VDF	**9**
59	External surfaces	Surface 1	VDF	**40**
60		Surface 2	VDF	**40**
61		Surface 3	VDF	**40**
62		Surface 4	VDF	**40**

Notes : DF – Daylight Factor
VDF – Vertical Daylight Factor

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Annex 3
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Geometric Model – Example to illustrate the construction of surrounding walls

1. To determine the position of the surrounding walls of the test site

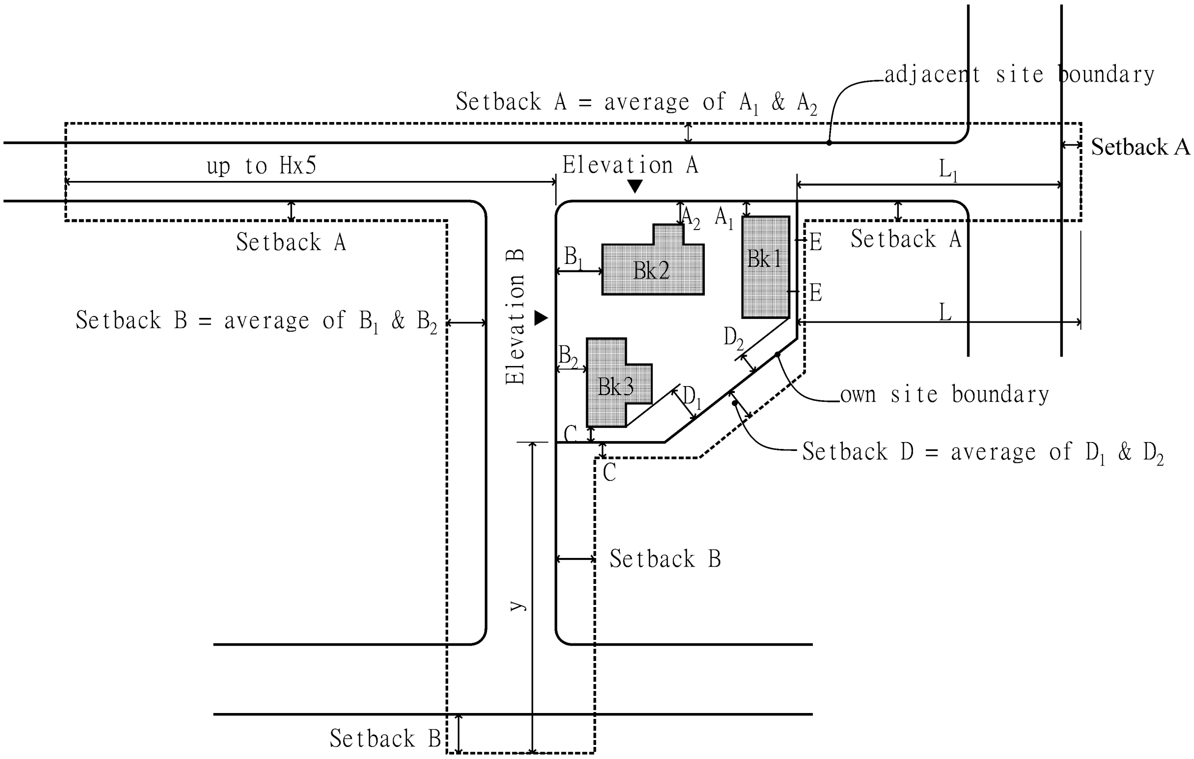

Figure 1: The Setting Out of Surrounding Walls

Setback of surrounding wall (example for elevation A)

- Factor A_1 = setback of tower block 1
- Factor A_2 = setback of tower block 2
- Setback A = average of $A_1 + A_2$

Extent of surrounding wall to close the street (example for elevation A)

- Factor H_1 = height of tower block 1 from street level
- Factor H_2 = height of tower block 2 from street level
- Factor H = average of H_1 & H_2
- Factor L_1 = actual distance from site to cross road
- Extent L = L_1 + setback A, or H x 5, whichever the less

2. To determine the height of the surrounding walls facing the boundary of the test site

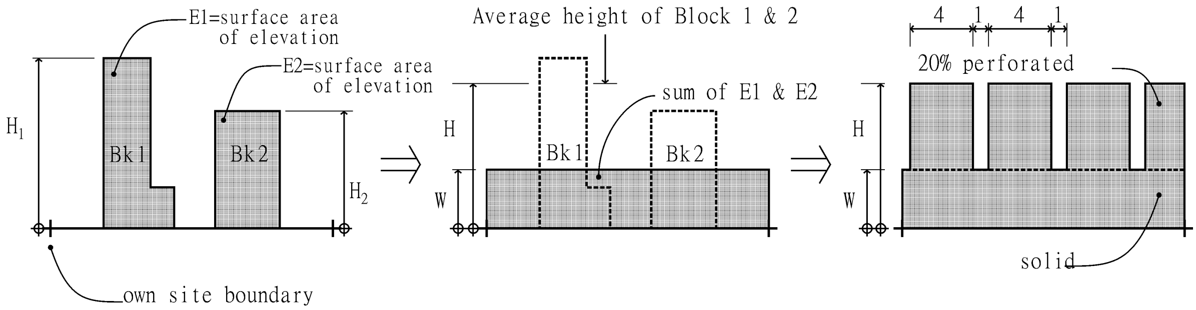

Figure 2: The Height of surrounding walls (Elevation A)

Base of surrounding wall (example for elevation A)

- Height of Podium W = sum of area of elevation of Block 1 and Block 2 divided by width of site
- Height of perforated wall H = average of H_1 & H_2

(Left) Looking at the test site from a certain direction parallel to the boundary, two immediate buildings (including their podiums) are to be taken into account.

(Middle) The elevation areas of the buildings (area of Block 1 and area of Block 2), calculated parallel to the boundary, will be summed. This total area will from the height (W) of an equivalent sized rectangle occupying the whole length of the test site facing that boundary. This represents the 'solid' base of the surrounding walls facing that directing of the boundary. Height W1, W2, W3 and so on for walls facing other directions of the test boundary could be similarly worked out.

(Right) On top of this solid wall should be placed a "slotted wall". This represents possible light from gaps between tower buildings. The slot wall has a rhythm of 1:4:1:4 and so on. When scaled to real dimension, the void portion of the wall should be between 10 to 15 meters. The exact dimension will be worked out evenly across that portion of the boundary. The total height of this wall (W+H) is equal to the average height of the two immediate buildings used to work out H just now.

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Annex 4
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Daylight Software

Some of the currently available software in the market for daylight studies are listed below for reference. Their accuracy should be verified and the software should be validated before adapted for simulation.

ADELINE
Daylighting, lighting, commercial buildings

AG123
Lighting, daylighting, rendering, roadway

BSim2002
Building simulation, energy, daylight, thermal analysis, indoor climate

Building Design Advisor
Design, daylighting, energy performance, prototypes, case studies, commercial buildings

DAYSIM
Annual daylight simulations, electric lighting energy use, lighting controls

Ecotect
Environmental design, environmental analysis, conceptual design, validation; solar control, overshadowing, thermal design and analysis, heating and cooling loads, prevailing winds, natural and artificial lighting, life cycle assessment, life cycle costing, scheduling, geometric and statistical acoustic analysis

FLUCS
Illumination, daylighting

LESODIAL
Daylighting, early design stage, user-friendliness

Lightscape
Daylighting, luminance

LumenMicro
Daylighting, lighting, solar design, luminaries

RADIANCE
Lighting, daylighting, rendering

SKYVISION
Skylight, light well, fenestration, glazing, optical characteristics, daylighting.

SuperLite
Daylighting, lighting, residential and commercial buildings

The Lightswitch Wizard
Annual daylight simulations, electric lighting energy use, lighting controls

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