# A COMPARISON BETWEEN PRESCRIPTIVE APPROACH AND PERFORMANCE BASED APPROACH ON DAYLIGHT FOR HONG KONG

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**Abstract**

The desirability of a high-rise and high-density approach to urban planning is challenged by an outbreak of SARS in 2003 in a number of populated and densely developed cities. In Hong Kong, awareness to inherent environmental issues such as poor daylight for domestic kitchens in high-rise towers is taken up by a government initiative to introduce a performance based design method to supplement a prescriptive design method Rectangular Horizontal Plane (RHP). Vertical Daylight Factor (VDF) has been proposed as the performance based method. However, this design approach raises critical concerns of its pros and cons. This paper makes a technical comparison of the two methods based on their variables and methodology to improve daylight access for domestic kitchens in a compact city. The study found that as VDF gives more area of light coming from surrounding of the building, it would enhance the provision of daylight in the high-rise residential building in densely urban conditions. As a result, this method may provide better daylight to the domestic kitchen.

**Keywords :** Daylight access, Rectangular horizontal plane, Vertical Daylight Factor.

## 1. Introduction

From the 1960s to 2003, local building codes that govern daylight for residential buildings were based on a mandatory and prescriptive approach that guaranteed a minimum external area of un-obstruction for daylight admittance for specified habitable spaces on the lowest floor of a tall building. This minimum area was based on a horizontal plane with depth derived from a predetermined ratio of total building height multiplied by a nominal width of 2300mm. This approach is named the RHP (rectangular horizontal plane) calculation method for daylight design, introduced to architects and building developers since 1959 (HKSAR, 1959).

Recent decade (1990s) shows a tendency of ever-increasing number of stories and building height. The prevailing number of story goes from 30, 40 to 60 floors or more during 1980s to 2000s. Recent field measurements of domestic kitchens in these three generations of towers depict a down drop of daylight level at kitchen worktop as a result of increased stories and height (Lau et. al, 2004).

In 2000, the building controls authority commissioned a consultancy study to review existing byelaws concerning building hygiene and safety for residents (Ng , 2004). The result of this study has been published in the proceeding of Eighth International IBPSA Conference (Ng, 2003). The opinion of the consultancy study was that existing building code that was simply a prescriptive approach was insufficient to guarantee good quantity of daylight especially for domestic kitchens as towers increase their height. It was recommended to adopt a performance-based design approach for daylight design.

The performance-based approach was based upon a daylight factor theory widely accepted by most countries. The consultancy study recommends a Vertical Daylight Factor (VDF) Method as a performance based design approach. In December 2003, the building authority introduced the VDF method as a supplement to the prescriptive method (Building Department, 2003).

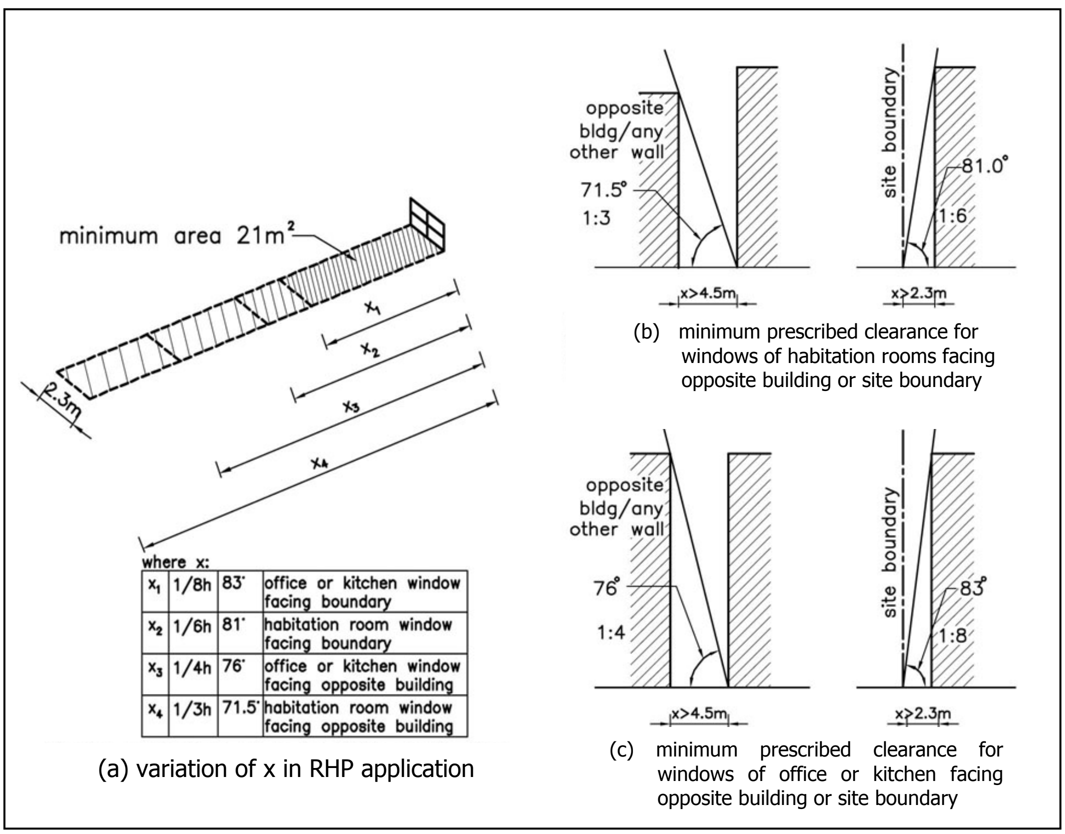
Local practitioners of residential buildings design raised doubts about the benefits and limitations of the newly introduced VDF method because of apparent complexities in the mathematic modeling and site planning implications.

This led the authors to undertake a critical review of the VDF method in terms of its practical value and implications. The review process adopted a comparative approach to evaluate both prescriptive approach of RHP method and the newly introduced performance based VDF method.

## 2. Overview of Building Codes Governing Daylight

### *2.1 Rectangular Horizontal Plane (RHP)*

For the RHP approach, it is stipulated by building regulations of Hong Kong that the minimum distance between building blocks is determined by a minimum prescribed plane of 71.5°, when the window is in a room used for habitation such as a bedroom or living room; or 76° from the horizontal when the window is in a room used as an office or as a kitchen. The minimum clearance of building from boundary is determined by a minimum prescribed plane of 81° when the window is in room used for habitation, or 83° when the window is in a room used as an office or kitchen. This value is obtained by assuming a rectangular horizontal plane, in front of the window, unobstructed and uncovered, and extends from the face of the window such that its length is at least 1/3h, 1/6h (for rooms for habitation) or 1/4h, 1/8h (for rooms as office or kitchen), where h, the height of the building measured from the sill of the of the window concerned (to Fig.1a-c). It is also stipulated that the rectangular horizontal plane should have a minimum width not less than 2.3 m, with an area not less than 21 m$^2$; and the window/ floor ratio of any room should be at least 10%.




(a) variation of x in RHP application

(b) minimum prescribed clearance for windows of habitation rooms facing opposite building or site boundary

(c) minimum prescribed clearance for windows of office or kitchen facing opposite building or site boundary

Fig.1 Principles of RHP application

*2.2 Vertical Daylight Factor (VDF)*

Proposed by the Buildings Department in the end of 2003 (Building Department, 2003), VDF is a new set of standard for the provision of natural lighting in habitable rooms and domestic kitchens described by Building (Planning) Regulations (B (P) Reg.) 30, 31 and 32:

Table 1. Recommended VDF values by the Buildings Department

| Room of domestic building | Vertical Daylight Factor (VDF) (measurement taken on the center-line of window plane) |
|---|---|
| Habitable Room | 8% |
| Kitchen | 4% |

"Vertical Daylight Factor" means a ratio in percentage of the total amount of luminance falling onto a vertical surface of a building to the instantaneous horizontal luminance from a complete hemisphere of sky excluding direct sunlight. In essence, it takes into account light coming from the sky directly and from reflected light of surrounding buildings and the ground both above and below the horizon.

The Unobstructed Vision Area (UVA) calculation has been recommended as a reliable method to calculate VDF. This method is based on simplified design tool for assessment of Daylight Factor, which was proposed by Ng and Tregenza (2001). Two main UVA principles are as follows (Building Department, 2003):

a) Unobstructed vision area of a window is the unobstructed area bounded by a cone with the horizontal angle measuring 100° up to both edges of the window's glazing pane, symmetrical and perpendicular to the window plane (Fig.2a).
b) Maximum length of the cone of the unobstructed vision area is equal to the height of façade in which the window is provided (Fig.2b).

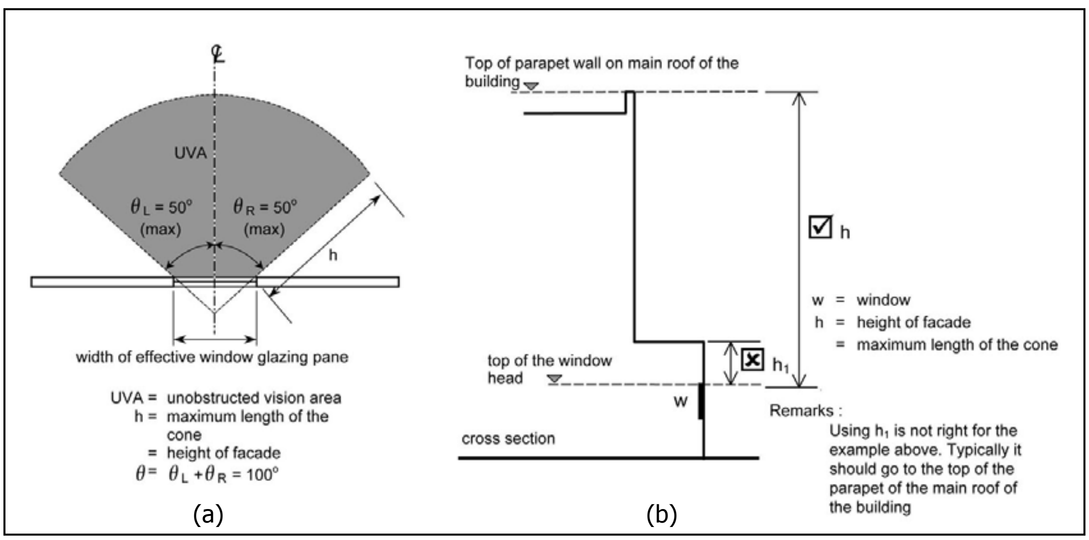



Fig.2 Details of VDF principles

*2.3 Assumption*

In this paper, we pursue a review on the two approaches by comparing their (i) variables in formulation, orientation, sustained angle, percentage of glazing, and (ii) methodology. For standard of comparison, a typical residential tower of building height of 122 m and height of façade of 120 m is taken for consideration unless otherwise stated.

## 3. Comparison between RHP and VDF

### 3.1 Variables

*3.1.1 Formulation.* Both prescriptive method of RHP and performance-based method of VDF contain variables. RHP guaranteed a minimum area of un-obstruction for daylight admittance into the exterior of a window of a habitable space on the lowest floor of the building. The minimum area is based on a horizontal area with its depth derived from a predetermined ratio of total building height and a nominal width of 2300 mm, i.e. RHP = x (2.3), where x = 1/3, 1/4, 1/6, 1/8 of the height of building (Fig.1); while the simplified method of UVA is a sector area calculated as, UVA= πr2θ/360, with variable θ and r. Fig.3a shows, in a most critical case, when $\theta = 100^o$ (max), then r become minimum (UVA_A), or when r becomes maximum, then θ become minimum (UVA_B). Both cases UVA_A and UVA_B are of the same area, but the shape of UVA cone differs from each other. In between these two critical cases lies a lot of possible combinations of r and θ with the same UVA.

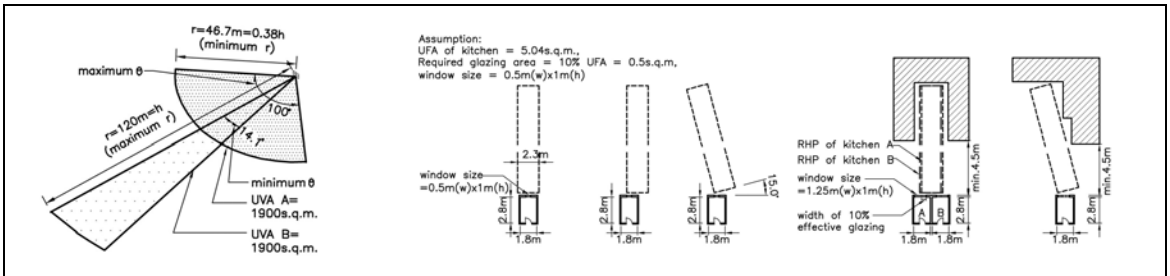
Table 2. Comparison of Variables

| | **Rectangular Horizontal Plane** | **Vertical Daylight Factor** |
|---|---|---|
| a. Area | Rectangular | Sector |
| b. Formulation | x(2.3) | $\pi r^2 \theta / 360$ |
| c. Variables | X | r, θ |

In comparison, the flexibility of variable of RHP is less than that of VDF. As in RHP the length of the unobstructed plane is proportioned by a factor, which only depends on the function of the room, whereas in case of VDF there is lots of variation within the maximum θ and maximum r.

*3.1.2 Orientation.* As stipulated in B(P) Reg31(3), the base of RHP is common with the sill of the window. Further relaxation allows a window not meeting the full requirements of prescribed window under B(P)Reg31(2) would be acceptable if the window when angled at not more than $15^o$ from external wall, meets the prescription requirement. Fig.3b(i) shows the application of RHP by principle. In real situation as in Fig. 3b(ii), the RHP of two kitchens often coincides to minimize the clearance from opposite building.

Whereas in the application of VDF, the orientation of UVA cone has a much greater range of $100^o$. In Fig. 3c, UVA_A, UVA_B, UVA_C & UVA_D could satisfy the required UVA of 1,900 $m^2$. It demonstrates that the orientation of projection of UVA is very flexible, and could be manipulated within the range of $100^o$ according to the location of the obstruction, depending on the design of master layout plan.

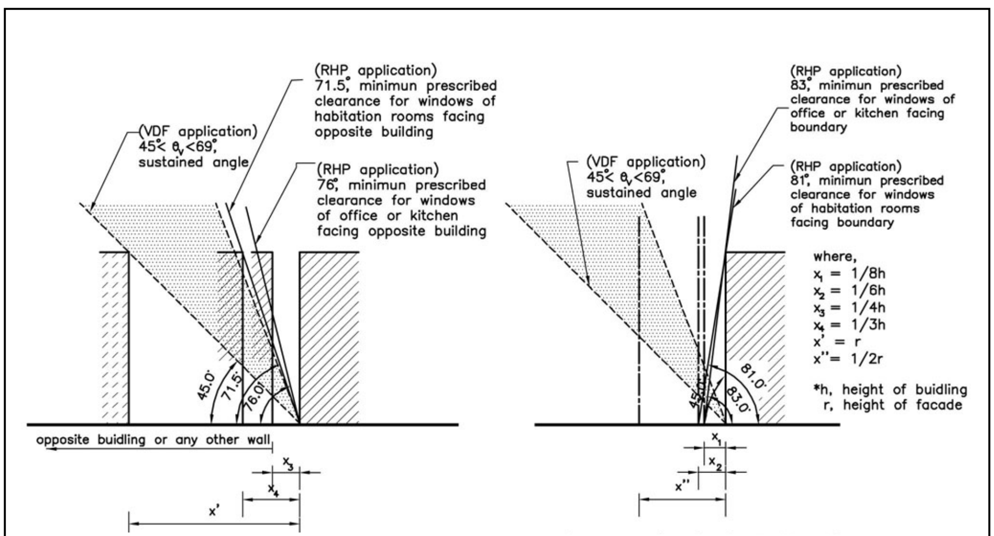



(a) Critical θ and r b(i) Principle of application of RHP for kitchen b(ii) Applicationfor obstructions

(c) Several options that can satisfy UVA requirements

Fig.3 The application of RHP and VDF

*3.1.3 Sustained angle.* As discussed, the RHP inclined at angle of 71.5°, 76°, 81° and 83° with respect to the function of the rooms to determine the minimum distance from its opposite block or boundary (Fig.4). In a VDF application, a sustained angle of $45^o < \theta < 69^o$ is adopted. These sustained angles are, however, below the limitation of the use of UVA method as proposed by Ng (2003). Ng (2003) points out that UVA method is robust when the angle >70°, and should be used within its limitation. The smaller the sustained angle, the more the separation between opposite buildings, i.e. more amount of daylight penetrating into the room.




(a) sustained angle of RHP & VDF facing opposite building

(b) sustained angle of RHP & VDF facing boundary site

Fig.4 Sustained angle of RHP and VDF

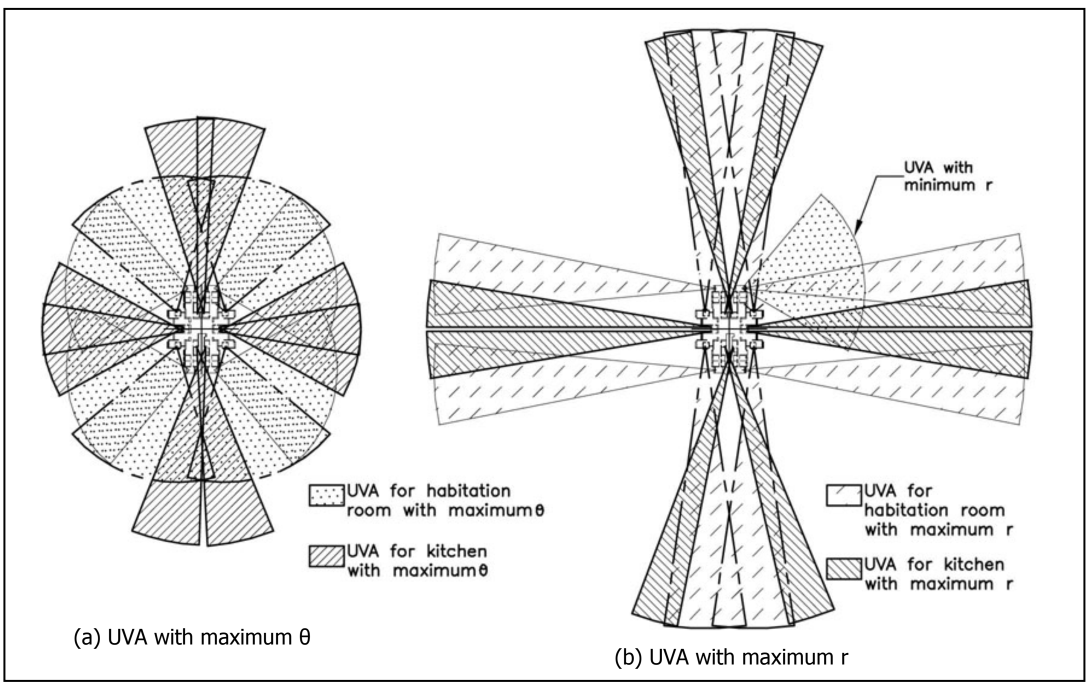
*3.1.4 Percentage of Glazing.* B(P)Reg30 stipulated that the aggregated superficial area of glass in window or window shall not be less than one tenth of the area of the floor of the room. This minimum requirement applies to both RHP and VDF applications. In the provision of VDF it is taken into account that as larger the percentage glazing, the smaller would be the required UVA. This encourages the provision of larger window. However, no such provision is allowed in RHP application.

*3.2 Methodology*

In the comparison of methodology typical 8 units cruciform plan is employed. As in Hong Kong, there is a high demand for residential units, but with little supple of land, so high-rise and high efficient plan is essential. This compact plan with 8 units per floor is an ultimate solution to cater for the high demand for residential units and regulations. Stipulated in Building Regulations all rooms for habitation expect bathrooms have to be equipped with windows, in planning terms, it virtually means that all rooms would have to face outward for a maximum l orientation in order to attain adequate clearance for each window. The lease important room, being kitchens, are often allocated the worst orientation – a gap on the floor plan, with a limited external view. This narrow gap, called an re-entrant, is usually about 2.3 m wide, i.e. nominal width of the RHP.

In a design application, RHP is considered to be an easy method to use. With known building height and functions of room, the minimum clearance between opposite blocks or boundary could be determined. While in VDF application, more detailed assumptions are required in order to determine the required clearance. Prerequisite information as the height of the façade, function of the room, room size and glazing area are required in order to computer the required UVA of the particular room notwithstanding the fact that such information may be too detailed to be available in an early design stage.

With the above design data, UVA of rooms could be obtained by using the most critical case, maximum θ or maximum r. UVA diagrams of a typical 8-unit plan are obtained as shown in Fig. 5. Not surprisingly, Fig. 5 only shows the possibilities of the two most critical cases, with the manipulation of r and θ, there will be lots of other UVA diagrams for this typical plan.



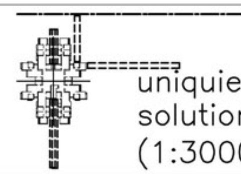
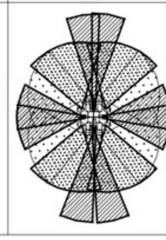

(a) UVA with maximum θ

(b) UVA with maximum r

Fig.5 The methodology of the use of VDF in 8 units flat

In other words, the high flexibility in variation of shape and orientation of the UVA cone also resulted in high complexity in the design application (refers to Table 3).

Table 3. Requirements of the application of RHP and VDF

| Applica –tion | Height of building | Room function | Room size | Glazing area | Result |
|---|---|---|---|---|---|
| RHP | required | required | not required | not required |  uniquie solution (1:3000) |
| VDF | required | required | required | required |  multipule options (1:6000) |

The summary of the comparison between RHP and VDF can be seen in Table 4 below.

Table 4. Summary of Comparison between RHP and VDF

| | Rectangular Horizontal Plane | Vertical Daylight Factor |
|---|---|---|
| 1. Variables: | | |
| a. Formulation | Less flexible | More flexible |
| b. Orientation | Less flexible | More flexible |
| c. Sustained Angle | Smallest of 71.5$^{o}$ | 45$^{o}$<θ<69$^{o}$ , enhanced |
| d. Percentage of glazing | 10% as minimum requirement | Allowance on 10%, 15% and 20%, encourage provision of larger windows |
| 2. Methodology | Easier to use | More difficult to use;<br>As a checking tool rather than a design tool. |

## 4. Conclusion

The comparison of variables and methodology between RHP and VDF has been done. The study found that as VDF gives more area of light coming from surrounding of the building, it would enhance the provision of daylight in the high-rise residential building in densely urban condition. As a result, this method may provide better daylight to the domestic kitchen. However, there should be further research regarding this method in terms of the quantity of daylight in residential building especially the actual benefit for kitchen from both function and habit points of view before it can be accepted as a building code to replace the RHP method.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