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Developing a simplified parameter for assessing view obstruction in high-rise high-density urban environment

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Abstract

View is a key factor that influences property price. Previous studies represent view either by simple pictorial description of a scene, or by rather sophisticated mathematical methods. Both hinder proper allocation of a premium for different view obstruction levels for high-rise high-density urban environments. View obstruction level and the applicable premium are useful information for stakeholders of the property market for making optimum decisions. Accordingly, there is a need to develop a simple parameter for assessing view obstruction level. While view is difficult to define, reference is made to law cases which often settle view disputes by the extent of daylight obstruction. Shading mask is typically used to assess availability of daylight outside a residential unit and hence is an ideal parameter for assessing view obstruction. Computation of shading mask values (SMK) is a very complex task that needs meticulous site surveys, 3D drafting skills, and computer simulations. They are too effort intensive for stakeholders. This paper summarizes the relevant considerations and the case studies conducted to establish the average angle of unobstructed sky (θ) as a simple parameter to represent mean SMK for assessing view obstruction. Correlation analysis of mean SMK of 708 case study residential units determined by the detailed computer simulation method and the corresponding angle of unobstructed sky showed that the latter can be used to assess view obstruction adequately close to simulation predictions. Given average angle of unobstructed sky can easily be determined based on the geometrical primitives of a residential unit, this can enable future allocation of a premium for different view obstruction levels for stakeholders.

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Introduction

Prices of residential property are affected by a set of locational and environmental features and qualities (Mahan, Polasky, & Adams, 2000). Influence of these factors has been subject to much study. One important factor, particularly in high priced dwellings in cities like Hong Kong (Kalra, Mihaljek, & Duenwald, 2000), is the view that can be seen from a residential unit. It has been accepted that homebuyers are willing to pay more for a scenic view; a good view can increase the market price of an apartment by anywhere between 8% and 60%. However, most studies represent views by pictorial description of a scene, such as landscape, lake, and ocean views (Rodriguez & Sirmans, 1994; Tse & Lovem, 2000). Only some have carefully defined the quality of view to allocate a premium on value. Brown and Pollakowski (1977) found that a shorter distance from the waterfront significantly increased house price in Seattle. Benson, Hansen, Schwartz, and Smersh (1998) made an attempt to classify sea views into 4 performance levels ranging from full sea view to poorer partial sea view.

A view is a single view even if broken into segments by obstructing structures or other objects. The placement and significance of the obstructions, which are inherent parts of the view, affect view quality. It is, therefore, difficult to simply rely on pictorial description to define a view. Reference can be made to a law case in Texas where a dispute on view was settled by estimating the extent of obstructions (ARC, 2007). A study has investigated the impact of view obstruction on residential apartment prices (Yu, 2007). It can be seen that view obstruction is considered the key information to supplement a view description.

Recent advances in laser ranging combined with Geographic Information Systems (GIS) facilitate the use of viewshed analysis for a more precise and objective measure of view obstruction for each property to circumvent previous view classifications (Hamilton & Morgan, 2010). In constructing viewshed variables, information of the built landscape features of the subject property is required. This is less of a problem for a new development, or for urban and natural resource planning. It is difficult to capture a residential unit's view...
obstruction due to poor availability of high resolution spatial data for buildings, especially their locations and heights, which are rarely reflected in commonly available maps; collecting these data can be complicated because of the time, effort and expense involved (Sander & Manson, 2007). Furthermore, a viewed analysis basically assesses the visibility of a viewpoint for an area of interest (view). A value of unity indicates that the viewpoint is visible, while a value of zero indicates that the viewpoint is not visible (Kim, Rana, & Wise, 2004). In high-density urban developments like Hong Kong, uniform high-rise buildings are closely packed to create a solid wall-effect that blocks the view (Giridhara, Ganesan, & Lau, 2004). As such, even when spending is allowed, the variation in viewed value will be too small to provide a precise measure of view obstruction. This explains why viewed analysis, if conducted to measure a property’s views, is confined to property developments where there is an unobstructed distinguished view nearby (Germino, Reiners, Blasko, McLeod, & Bastian, 2001).

View obstruction and daylight are closely linked with one another. It is noted that most building environmental assessment schemes in use nowadays combine views and overshadowing performance as a single assessment criterion to assess impact of neighbouring buildings in respect of access to daylight and views (HK-Beam, 2004; LEED, 2008). Several lawsuits have also confirmed the obstruction of view and light by neighbouring obstacles as into one single complaint (CPC, 2010; Law Letter, 1995). In Hong Kong, site planners and architects adopt a simplified method called the unobstructed vision area (UVA) method, originally developed for quantifying the visible sky area (Ng, 2003), to demonstrate compliance with performance-based requirements of daylight availability in buildings (BD, 2010), though proper application of the UVA method is subject to many constraints (Cheung & Chung, 2007; Chung & Cheung, 2006). Nevertheless, it can be seen that assessing availability of daylight is widely accepted as an alternative means for assessing view obstruction.

Property purchase is an important decision for most people. The economic theory suggests that individuals seek to maximize utility. Assuming homebuyers are willing to pay a premium for a better view, site planners and architects, while designing the building configuration to maximize positive views, need to have broad estimates of the premium of different types of views can command. In other words, while they can calculate the cost, they need to know the likely revenue. Considering that most stakeholders in the property market do not have the technical background to conduct theoretical modeling and simulations, or a meticulous site survey to ascertain the view obstruction of a residential unit, the objective of this study is to formulate a simple, and yet scientific method based only on geometrical primitives of a residential unit, for assessing view obstruction. In formulating the simplified method, reference is made to previous studies on the impact of view on property price by 6.7%. Street and building views also suppressed housing price, with street affecting it more significantly. Street scene reduces property price by 3.7%, while the influence of building view was insignificant.

It is apparent from the above that there is a premium for different views in Hong Kong. However, among the views that have been studied, it is noted that the effect of obstructions on the quality of view has not been taken into account.

Accordingly, a preliminary study on the influence of obstructions on property price was conducted. Reference was made to government statistics for identifying a period of time when property prices were relatively stable, and were not affected by intervention events such as policy changes, strikes, environmental regulations, and economic conditions. Table 1 provides monthly price indices for the period 2000–2005 (RVD, 2010). It can be seen that the variation in price indices is the smallest in 2003 (9.146). The small variation in price indices in 2003 was the effect of SARS, leading to a substantial drop in property price by 6.7%. Street and building views also suppressed property price by 2.97% to property price while a broad mountain view depressed property price by 5.957. Street and building views also suppressed property price by 3.217.

| Month | Year | Price Index |
|-------|------|-------------|
| Jan   | 2000 | 73.9        |
| Feb   | 2000 | 80.7        |
| Mar   | 2000 | 74.1        |
| Apr   | 2000 | 63.6        |
| May   | 2000 | 69.5        |
| Jun   | 2000 | 85.7        |
| Jul   | 2000 | 73.9        |
| Aug   | 2000 | 82.2        |
| Sep   | 2000 | 73.6        |
| Oct   | 2000 | 65.4        |
| Nov   | 2000 | 64.3        |
| Dec   | 2000 | 95.4        |
| Max   | 2000 | 92.9        |
| Min   | 2000 | 58.4        |
| Var   | 2000 | 30.2        |

Hedonic pricing method. It was concluded that full sea view added 2.57% to property price while a broad mountain view depressed property price by 6.7%. Street and building views also suppressed housing price, with street affecting it more significantly. Street scene reduces property price by 3.7%, while the influence of building view was insignificant.

Hong Kong situation

Hong Kong is characterized by the high-rise high-density environment and the sky view factor is low in most residential developments. Owning a residential unit without external obstacles is a luxury to most Hong Kong people. As such, it is worthwhile to review if there is a premium available for a slightly better view in Hong Kong.

Reference is made to previous studies on the impact of view on prices of private housing in Hong Kong. Tse and Lovem (2000) found that a cemetery view depressed property price because the Chinese culture associates graveyards with ill fortune. Jim and Chen (2009) conducted a detailed study of the value of views by the

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1 SARS stands for Severe Acute Respiratory Syndrome. SARS in Hong Kong killed almost 300 people over a four month period.
views. In de
unobstructed, good partially obstructed, and poor obstructed
views (point of interest) into three performance levels, namely,
the window (the use of 50 degrees and 500 m are explained in
a later section). While good partially obstructed view means facing
a roughly equal area (solid angle) for each segment while others
apply a simpler latitude/longitude or equal angle approach. The
equal angle approach uses altitude and azimuth values to index
the shading mask, which is often considered a simpler method (Marsh,
2005). Obviously, the smaller the size of each segment, the greater
will be the accuracy of calculations. CIE (1994) suggested that for
daylight calculations, segments with a solid angle of approximately
0.2 radians, i.e. 11.5 degrees, are small enough to be considered as
top points without significant error. Reference is also made to
a computer simulation package HTB2 adopting the shading mask
concept to estimate the inter-shadowing effect on solar heat gain
through windows and on conduction heat transfer through enve-
lope (Alexander, 1994). In HTB2, 10 degree segments are used. This
corresponds to the 324 equal area segments (i.e. 0–360° from
azimuth, and 0–90° horizon to zenith). For a given surface and any
given set of obstructions, the shading mask can be recorded in
a shading mask table comprising 36 rows and 9 columns.
Of the 324 shading mask figures in the shading mask table, 50%
can be ignored because they belong to sky vault positions at the
back of the window surface. In summing up the remaining 162
shading mask figures, it can be assumed that the figures are inde-
dependent, and are of equal importance because they are from equal
sky segments. It is therefore acceptable to use simple arithmetic
mean of the figures to devise the mean shading mask for a specific
surface (SMK) (Watson, Billingsley, Croft, & Huntsberger, 1996,
chap. 3; Scheaffer, Mendenhall, & Ott, 1996, chap. 5). Higher values
represent smaller view obstructions.
In this study, Ecotect computer software was used to generate
the shading mask table. The overshadowing accuracy and the azi-
muth and altitude increment were set at medium and 2.0,
respectively. It was determined after trial simulations with changed
settings, in order to observe the influence on shading mask values.
Detailed description of Ecotect simulation can be found on the
product website (Marsh, 2010). In preparation for the simulation,
a scaled three-dimensional (3D) model of the target building,
together with the neighboring buildings and other external objects
and structures within a circumference of 500 m were drawn by
using AutoCAD. AutoCAD was used because it is popular in the
construction industry, and is compatible with Ecotect. The site
boundary was determined based on findings of Chau, Wong, and
Yiu (2005), indicating that a view with a premium refers to the
panoramic view within 500 m of the living This is consistent with
distance zone suggested by other studies (Bishop & Hulseb, 1994;
Leeds et al., 2008). As for the target unit, the apertures and the
fenestration details including fins and canopy were precisely drawn
(Fig. 1), while other surfaces were modeled as flat planes. On
exporting the AutoCAD files to Ecotect, a shading mask table for
each window surface is generated. In this study, window pane
position was assumed the standing position for a specific view.

### Table 2

| Region       | No. of units | No. of transactions | Unobstructed view | Good partial obstructed view | Poor obstructed view |
|--------------|--------------|---------------------|-------------------|-----------------------------|---------------------|
|              | A, H         | B, G                | 5032–8624         | 4672–7492                   | 4004–6825           |
| HK Island    | 1328         | 15                   | 6427 (+14.8%)     | 3655 (+13.5%)               | 5601                |
| Kowloon      | 1684         | 91                   | 4609 (+9.1%)      | –                           | 4225                |
| New Territories | 1224   | 67                   | 5730 (+14.3%)     | –                           | 5011                |
| New Territories | 1535   | 138                  | 3598 (+11.2%)     | 3546 (+10.5%)               | 3208                |

Quantifying view obstruction

Owing to the interactive characteristics of view obstruction and
daylight availability, the shading mask (a mechanism that records
which parts of the sky are obstructed from a particular point in
a building) is selected to represent view obstruction level for con-
ducting a detailed study. It was selected because it is often used to
determine the actual contribution of sky to daylight, and is typically
adopted to quantify the availability of daylight outside a residential
unit and it enables accurate estimation of the fraction of unob-
structured sky as seen from the center of a window (Gupta, 1985;
Kensek, Noble, Schiler, & Setiadarma, 1996; Tahbaz, 2007;
Tregenza, 1995). The obstructing objects include all external
obstacles in front of the window.

For a given set of obstacles, the shading mask of a position
(SMK) is the fraction of unshaded area of the sky vault at that
position.

Department. To further enhance the accuracy of the collected
information, site visits were conducted in winter of 2006 to better
appreciate the three-dimensional view of some of the residential
units.

Upon confirming the view of each residential unit, the method
used by Benson et al. (1998) was adopted to classify individual
views (point of interest) into three performance levels, namely,
unobstructed, good partially obstructed, and poor obstructed
views. In defining the different levels of view obstruction, it was
assumed that for 500 m from the living room window, an unob-
structured view means facing to an unobstructed space formed by
two angles of 50 degrees measured horizontally from the center of
the window (the use of 50 degrees and 500 m are explained in
a later section). While good partially obstructed view means facing
an unobstructed space formed by an angle of 50 degrees
determined by the standing position for a speci-
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For a given set of obstacles, the shading mask of a position
(SMK) is the fraction of unshaded area of the sky vault at that
position.

In specifying the sky vault positions, it is common to subdivide
the sky dome into discrete segments. Some seek to achieve
a roughly equal area (solid angle) for each segment while others
apply a simpler latitude/longitude or equal angle approach. The
equal angle approach uses altitude and azimuth values to index
the shading mask, which is often considered a simpler method (Marsh,
2005). Obviously, the smaller the size of each segment, the greater
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Leeds et al., 2008). As for the target unit, the apertures and the
fenestration details including fins and canopy were precisely drawn
(Fig. 1), while other surfaces were modeled as flat planes. On
exporting the AutoCAD files to Ecotect, a shading mask table for
each window surface is generated. In this study, window pane
position was assumed the standing position for a specific view.
SMK values and transaction prices is signiﬁcant, and subjective view obstruction level, and transaction price. Reference was made to transaction records of Royal Ascot (Table 2).

Pearson correlation result (−0.564) indicates that correlation between SMK values and transaction prices is significant at the 0.01 level (2-tailed). Cluster analysis results are shown in Table 3. It can be seen that with the exception of two cases, the clustered group number based on the transaction prices and SMK values aligned with the subjective view obstruction levels. The SMK values and transaction prices are also comparable to confirm the link.

For further ascertaining feasibility of the mean shading mask (SMK) to assess view obstructions, a residential development in Shatin, New Territories of Hong Kong was chosen as the case study development for evaluation.

Case study development

The case study development is a high-rise residential estate consisting of 10 blocks of around 2500 units in total. It was chosen because the authors were familiar with the views available in the estate, and could gain access to a number of households residing there. As can be seen from the site layout in Fig. 2, there is a racecourse 70 m from the southeastern side of the development. To the northwestern side, there is a small hill 50 m apart, of 150 m height. Other orientations are bounded by the neighboring buildings 10–40 m apart. Given the precise view obstruction for this estate can be ascertained, Benson et al. (1998) method was adopted to classify the residential units into four subjective levels of view as described below:

1. Unobstructed view (Level 1): facing to an unobstructed hill/racecourse view within 500 m from the living room window formed by two angles of 50 degrees measured horizontally from the center of the window.
2. Good partially obstructed view (Level 2): facing to an unobstructed hill/racecourse view within 50 m from the living room window formed by two angles of 50 degrees measured horizontally from the center of the window. 50 m was assumed because the small hill is 50 m apart.
3. Partially obstructed view (Level 3): facing to an unobstructed hill/racecourse view within 50 m from the living room window formed by an angle of 50 degrees measured horizontally from one side of the center of the window.
4. Poor obstructed view (Level 4): facing a building within 50 m from the living room window formed by an angle of 50 degrees measured horizontally from both sides of the center of the window.

Amongst the 10 housing blocks, Block 11 was chosen for detailed evaluation because it typically consists of all four levels of view. The target block is 40-story, and 8 units per story. It is 10-story taller than Blocks 1 and 2, which are in the front. The block’s plans, together with neighboring features, are shown in Fig. 2. On the basis of the above four subjective levels of view, it can be seen that the topmost floors of Units A through H are higher than the small hill and the other blocks, resulting in an unobstructed hill/racecourse view within 500 m to conclude Level 1 view; Units C and D are facing to the small hill 50 m apart, and thus have Level 2 view; Units A and B have Level 3 view because part of the hill view is blocked by the adjacent blocks 30 m apart; and lower floors of Units E and F are completely blocked by adjacent buildings to conclude Level 4 view (Table 4).

Views of lower floors of Units G and H (Levels 3 or 4) cannot be ascertained from the block plan because there is an observation tower at the racecourse that possibly blocks the racecourse view. Similarly, the racecourse view of upper floors of E, F, G and H (Levels 2 or 3) cannot be ascertained because Blocks 1 and 2 are in the front. Site visits were therefore made by the authors to units in the 17th, 27th and 35th floors in January 2008 through personal contacts and the local property agent, Midland Realty. Subjective levels of view obstruction of the units concerned were then conﬁrmed by visual inspection, while visual qualities due to different distances and angles were not considered.

Relating SMK and subjective view

In this study, SMK of the window surface of the living room of 48 case study units were calculated to determine the corresponding view obstructions. The units are on the 1st, 11th, 21st, 31st, 35th and the topmost (40th) floors of the target block. The calculations were on every 10th floor basis because view obstruction of lower floors does not vary signiﬁcantly, and the influence of neighboring obstacles is mainly on views of upper floors. Hence, the 35th and the topmost ﬂoors were included in calculations. The calculation results are compared with subjective view levels determined in the previous section (Table 4), which indicates that:

| Description     | Cluster group number | Subjective view obstruction level |
|-----------------|----------------------|----------------------------------|
| Number of cases | 51                   | 16                               | 50                               | 17                               |
| Unit price (HKD)| 5024.2               | 5011                             | 5730                             |
| SMK             | 0.554715             | 0.5434                           | 0.9019                           |
| Number of cases | 51                   | 16                               | 50                               | 17                               |
- For Units A through D and lower floors of Units E through H, the rate of increase in SMK is driven basically by an increase in floor levels, indicating a decrease in view obstruction;
- For upper floors of Units E through H, there is a substantial increase in SMK to reflect a less obstructed view in comparison to the lower floors; and
- For the topmost floor, SMK are comparable for the 8 units because there are no external structures and objects to block the view.

SMK values for the four view levels are compared in Fig. 3. It can be seen that the SMK ranged between 0.127 and 0.37, which

![Fig. 2. Site layout of Royal Ascot. (a) Site plan. (b) Floor layout of block 11.](image)

Table 4
Simulated obstruction levels of different units in Block 11 of Royal Ascot.

| Unit | A        | B        | C        | D        | E         | F         | G         | H         |
|------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|
| Floor| Partially obstructed hill view (level 3) | Good partial obstructed hill/racecourse view (level 2) | Poor obstructed building view (level 4) |
| 1st  | 0.201    | 0.225    | 0.249    | 0.241    | 0.127     | 0.125     | 0.140     | 0.136     |
| 11th | 0.207    | 0.230    | 0.264    | 0.256    | 0.130     | 0.131     | 0.144     | 0.139     |
| 21st | 0.213    | 0.233    | 0.275    | 0.269    | 0.148     | 0.159     | 0.156     | 0.146     |
| 31st | 0.227    | 0.242    | 0.284    | 0.276    | 0.236     | 0.255     | 0.293     | 0.191     |
| 35th | 0.244    | 0.257    | 0.287    | 0.279    | 0.278     | 0.294     | 0.334     | 0.229     |
| Unobstructed hill/racecourse view (level 1) | 0.348    | 0.376    | 0.366    | 0.360    | 0.355     | 0.370     | 0.358     | 0.355     |
correlates well with the subjective view levels; obviously SMK values can be used as an objective indicator of view obstruction, where 0 represents fully obstructed view and 1 represents 100% unobstructed view.

**SMK and angle of unobstructed sky**

Modeling the obstruction situations that arise in a simple building requires preparation of detailed 3D models and interactions with a large number of external structures and objects for Ecotect simulations so as to determine the SMK. This is less of a problem for designers if evaluation of view obstruction is a major design objective. However, if the view obstruction level is only a decision-making information for an existing building, site inspections to confirm building apertures and obstruction details will be difficult and effort intensive. Furthermore, it is not common for stakeholders in the property market to familiarize themselves with 3D drafting skills and Ecotect simulations. Consequently, it is imperative to establish a simple method to assess view obstruction based upon the conceptual background of shading mask.

There are three possible paths along which daylight can reach a point inside a room through glazed windows — the sky component, the external reflected component, and the internally reflected component. However, when view obstruction is concerned, the most significant factor is the availability of daylight at the window, which is the solar component. Thus assessing solar component for a window does provide a quick and simple guide to the potential for daylight to satisfy the intended objectives of this study. Different methods are available for calculating the solar component (Capeluto, 2003; Littlefair, 1995, 2001; Tregenza, 1989) for a point of interest. Angle of unobstructed sky ($\theta$) is often considered the simple design method for architects during initial design stages to assess the daylight potential of a building site (Littlefair, 2001).

In determining the angle of unobstructed sky ($\theta$), some research studies (and also regulatory requirements on daylight availability) simply base on the angle of unobstructed sky perpendicular to the window ($\theta_{90}$) for simplicity (Li, Wong, Tsang, & Cheung, 2006; Yu & Chai, 2004). This however depends only on the height of neighboring obstacles and separations perpendicular (90 degree) to the window; it does not take into account obstacles not blocking the perpendicular line but that still block the view and daylight significantly. Windows facing a narrow street is one typical example.

It is rather obvious from the above discussion that $\theta_{90}$ is not a sufficient base to quantify availability of daylight. However, given its wide adoption in similar studies (Li et al., 2006; Yu & Chai, 2004), to better illustrate if $\theta_{90}$ can be used to gauge daylight availability, an attempt has been made to relate simulated SMK of the 48 case study units (i.e. 8 units in 1st, 11th, 21st, 31st, 35th and 40th floor of Block 11, Royal Ascot) with the corresponding angles of unobstructed sky ($\theta_{90}$) to reveal how well they correlate with each other. The $\theta_{90}$ of the 48 case study units were calculated based on measurements in a 3D model, drawn on the basis of 1:1000 digital maps. The results are shown in Fig. 4. It can be seen that SMK does not correlate significantly with $\theta_{90}$, particularly in units A, B, G and H where the obstacles are not directly blocking the perpendicular view to yield zero in $\theta_{90}$. The results confirm that $\theta_{90}$ is not a sufficient base to quantify availability of daylight.

As the use of $\theta_{90}$ has been shown to be ineffective, an appropriate method for calculating an average angle of unobstructed sky ($\overline{\theta}$) is required to be formulated. According to Littlefair (1988), $\overline{\theta}$ should be calculated based on the average height of external obstacles, but there is no suggestion on the required horizontal angle measured from the center of the window surface. With regard to the angle required, reference is made to Becker and Jürgens’s (1990) study on human vision, as well as the horizontal angle used in calculation of unobstructed vision area (UVA) (BD, 2010). In Becker & Jürgens’s study, it was suggested that the 90–95 degree section of the horizontal monocular field of vision offers the highest resolution to the eye, at any time, to see the view, while the UVA method suggests 100 degree.

Within 90–100 degrees, obviously, the smaller the angle divisions, the greater is the accuracy of calculations. Considering the size of external obstacles is normally huge, using small divisions to increase the computation time is considered ineffective. Reference is therefore made to the UVA method to base only on two additional angles of unobstructed sky, each measured 50 degree horizontally from center of the window. Accordingly, besides 90 degree ($\theta_{90}$), two other angles of unobstructed sky, i.e. 40 ($\theta_{40}$) and 140 ($\theta_{140}$) degrees, are proposed to be included for calculation of $\overline{\theta}$.

In summing up the three angles of unobstructed sky, as they are considered of equal resolution portion of human eye, the use of simple arithmetic mean is considered acceptable. Hence $\overline{\theta}$ is formulated as:

$$\overline{\theta} = \frac{\sum_{i=1}^{3} \theta_i}{3}$$

where $i = 40, 90$ and 140 degrees.

**The simplified parameter ($\overline{\theta}$)**

Based upon the above discussions, it can be hypothesized that if $\overline{\theta}$ can be developed as a simplified parameter to assess view obstruction, SMK and $\overline{\theta}$ should exhibit a correlation with an interception at zero.
A correlation analysis was conducted based on the calculated $\overline{q}$ and the simulated SMK of representative samples of residential units randomly selected from Royal Ascot and one additional residential development – Taikoo Shing.

Taikoo Shing is a high-rise residential estate comprising 61 blocks developed in 11 phases with a total of around 12,700 residential units. Each phase consists of 2−9 blocks of 20−28 story height. There are 8 units on each floor. As can be seen from the site layout in Fig. 5, Taikoo Shing was built along the seafront, where northern and northeastern sides of the development are facing an ocean and a park. The other orientations are bounded by the neighboring buildings. Taikoo Shing was chosen because the flat sizes (ranging from 55 m² to 110 m²) are comparable to those of Royal Ascot (ranging from 69 m² to 150 m²). As such, the overall block dimensions are similar. Furthermore, Taikoo Shing is equally popular among buyers and speculators. For a significant time in the 1980s and 1990s, Taikoo Shing’s house prices were a general indicator of Hong Kong’s housing market health in general. Its house prices are one of the key constituents of Centa-City Index (CCI), which is a monthly index that reflects the trends in Hong Kong’s property market.

The sample size ($n_0$) was determined based on Equation (2) for achieving a confidence level of 95% based on the probability that 50% of the residential units were picked ($p = 0.5$), and the sampling error ($e$) is ±5% (Franklin, 1999):

$$n_0 = \frac{Z^2 p(1−p)}{e^2}$$  \hspace{1cm} (2)

where

- $n_0$ = the sample size;
- $Z$ = the test statistic which is 1.96 for 95% confidence level;
- $p$ = the estimated proportion of an attribute that is present in the population; and
- $e$ = the desired level of precision.

As populations of the two developments are small, Equation (3) developed by Cochran (1963) was adopted to adjust the sample size:

$$n = \frac{n_0}{1 + \frac{n_0−1}{N}}$$  \hspace{1cm} (3)

where

- $n$ = the corrected sample size; and
- $N$ = the population size.

Incorporating $n_0$ and $N$ of the two developments in Equation (3), the corrected sample size ($n$) required for Royal Ascot and Taikoo Shing was found to be 334 and 374, respectively.

The selection of sample units was again on every 10th floor plus the topmost floor basis. However, the number of specific units selected for the sample differs slightly between Royal Ascot and Taikoo Shing owing to the difference in the scale of the two developments. For Royal Ascot, depending on the number of units on each floor, 5−6 residential units were randomly selected from the 6 target floors of all 10 housing blocks for a sample of 334 units. In case of Taikoo Shing, depending on the total number of blocks for each phase of development, 1−2 constituent blocks were randomly selected. For each target floor of the selected block, all 8 residential units were selected as sample units to meet the sample size of 374 units.

Based on the precisely built 3D models for Royal Ascot and Taikoo Shing, SMK and $\theta$ of the sample units were accurately determined for the correlation analysis.

The simulated SMK and the calculated $\overline{q}$ of the sample units of the two case study developments were correlated, as shown in Fig. 6. They were separately correlated to acknowledge the site specific characteristics of the two developments. It can be seen that they both exhibit a strong linear correlation and the trend lines are intercepted at zero. The $R^2$ for Royal Ascot is 0.83, while that of Taikoo Shing is 0.92. Correlations tend to be stronger for a wider range of values (Hill & Lewicki, 2006, chap. 2). While the site scale of Taikoo Shing is much bigger than that of Royal Ascot, there is a wider range of SMK and $\overline{q}$ (ranging from 0.2 to 0.84 for SMK and 0.2−1.49 for $\overline{q}$), as opposed to a range of 0.1−0.59 for SMK and 0.22−1.39 for $\overline{q}$. Thus, the correlation is weaker in the Royal Ascot case.
The strong correlations between SMK and ̄θ of two residential developments.

Conclusion

A review of methods commonly adopted to assess view obstruction was conducted. The properties transaction record of four representative residential developments in Hong Kong in 2005 and the pictorial view of each residential unit in the record were reviewed. It was confirmed that there is a correlation between property price and view obstruction in Hong Kong. On the basis of the findings, it is recommended that for high-rise high-density urban environments like Hong Kong, where the view obstruction level differs only slightly among residential units, view should be represented by daylight obstruction to enable scientific allocation of a premium for view obstruction. Accordingly, shading mask was adopted to assess view obstruction. Case studies were conducted to confirm that the mean shading mask value (SMK) can be effectively used to represent the subjective view obstruction level of a residential unit as checked from 1:1000 digital maps and by site visits. Along the conceptual background of shading mask, a simple parameter, i.e. the average angle of daylighting and geographic information systems. Habitat International, 30, 59–70.

Brown, G. M., & Pollakowski, H. O. (1977). Economic value of shoreline. Review of Economics and Statistics, 59, 272–278.

Buildings Department. (2010). Lighting and ventilation requirements – Performance-based approach. Practice note for authorized persons and registered structural engineers. APP-130. The Government of the Hong Kong Special Administrative Region.

Capeluto, L. G. (2003). The influence of the urban environment on the availability of daylighting in office buildings in Israel. Building and Environment, 38, 745–752.

Centreline Property. (2010). Hong Kong Special Administrative Region. http://hk.centrate.com/icsm/template.aspx?series=211 Accessed on 22.06.10.

Chau, K. W., Wong, S. K., & Yen, C. Y. (2000). Improving the environment with an initial government subsidy. Habitat International, 25, 559–609.

Cheung, H. D., & Chung, T. M. (2007). Analyzing sunlight duration and optimum shading using a sky map. Building and Environment, 42, 3136–3148.

Cheung, T. M., & Cheung, H. D. (2006). Assessing daylighting performance using orthographically projected area of obstructions. Journal of Light & Visual Environment, 30(2), 74–80.

CIE. (1994). Guide to recommended practice of daylight measurement. CIE guideline (CIE 108-1994). Vienna: Commission Internationale de l’Éclairage (CIE).

Cochrane, W. D. (1963). Sampling techniques (2nd ed.). New York: John Wiley and Sons, Inc.

CPC. (2010, March 4). California planning commission. City of Pacific Grove, California, USA.

Franklin, L. A. (1999). Sample size determination for lower confidence limits for estimating process capability indices. Computers and Industrial Engineering, 36(3), 603–614.

Germino, M. J., Reiners, W. A., Blasko, B. J., McLeod, D., & Bastian, C. T. (2001). Estimating visual properties of Rocky Mountain landscapes using GIS. Landscape and Urban Planning, 53(1–4), 71–83.

Giridhara, R., Ganesan, S., & Lau, S. S. Y. (2004). Daytime urban heat island effect in high-rise and high-density residential developments in Hong Kong. Energy and Buildings, 36(6), 525–534.

Gupta, V. (1985). Natural cooling systems of Jaisalmer. Architectural Science Review, September, 58–64.

Hamilton, S. E., & Morgan, A. (2010). Integrating lidar, GIS and hedonic price modeling to measure amenity values in urban beach residential property markets. Computers, Environment and Urban Systems, 34(2), 133–141.

Hill, T., & Lewicki, P. (2006). Statistics: Methods and applications. USA: Statsoft, Inc. HK-BEAM. (2004).

Hill, T., & Lewicki, P. (2004). HK-BEAM – An environment assessment for air conditioned office premises. Version 4.04: New buildings and version 5.04: Existing buildings. Hong Kong: Building Environment Council.

Jin, C. Y., & Chen, W. V. (2009). Value of scenic views: hedonic assessment of private housing in Hong Kong. Landscape and Urban Planning, 91, 226–234.

Kalra, S., Mihaljek, D., & Duenwald, C. (2000). Property prices and speculative bubbles: Evidence from Hong Kong. A working paper of the Internal Monetary Fund. Hong Kong: Asia and Pacific Department.

Kensek, K., Noble, D., Schiler, M., & Settdaruma, E. (1996). Shading mask: a teaching tool for sun shading devices. Automation in Construction, 5, 219–231.

Kim, Y. H., Rana, S., & Wise, S. (2004). Exploring multiple viewshed analysis using terrain features and optimisation techniques. Computers & Geosciences, 30, 1039–1032.

Land Registry. (2010). The Government of the Hong Kong Special Administrative Region. http://www.landgovt.gov.hk/en/monthly/gs-primary/10/2.

Law Letter. (1995). Obstruction of view, light or air. Solutions Through Research, 10(1), 1092–1093, Real Estate Centre.

LEED. (2008). LEED for homes rating system. USA: US Green Building Council.

Leeds, S. L., Choper, A., Dougherty, C., Kovach-Orr, C., & Mantell, M. (2008). The Rutgers ecological preserve human aesthetics & recreational analysis. Rutgers report. USA: The Rutgers Ecological Preserve.

Li, D. H. W., Wong, S. L., Tsang, C. L., & Cheung, H. W. C. (2006). A study of the influences of the urban environment on the availability of daylighting in office buildings via computer simulation techniques. Energy and Buildings, 38, 1343–1348.

Littlefair, P. J. (1988). Average daylight factor: A simple basis for daylight design. BRE information paper.

Littlefair, P. J. (1995). Site layout planning for daylight and sunlight: A guide to good practice. Garston, Watford: BRE.

Littlefair, P. J. (2001). Daylight, sunlight and solar gain in the urban environment. SIT Young Energy, 70(3), 57–59.

Mahan, B. L., Polasky, S., & Adams, R. M. (2000). Valuing urban wetlands: a property price approach. Land Economics, 76(1), 100–113.

References

Alexander, D. K. (1994). HTB2 user manual version 2.0. Welsh School of Architecture, University of Wales College of Cardiff.

ARC. (2007, February 2). Standards for determining “view obstruction”. Architectural Review Committee. Monarch Bay Terrace Property Owners Association.

Becker, W., & Jürgens, R. (1990). Human oblique saccades: quantitative analysis of the relation between horizontal and vertical components. Vision Research, 36(6), 893–920.

Benson, E. D., Hansen, J. L., Schwartz, A. L., & Smersh, G. T. (1998). Pricing residential amenities: the value of a view. Journal of Real Estate Finance and Economics, 16(1), 55–73.

Bishop, I. D., & Hulseb, D. W. (1994). Prediction of scenic beauty using mapped data and geographic information systems. Landscape and Urban Planning, 30, 59–70.

Brown, G. M., & Pollakowski, H. O. (1977). Economic value of shoreline. Review of Economics and Statistics, 59, 272–278.
Marsh, A. J. (2005). The application of shading masks in building simulation. In Building simulation 2005. Ninth international IBPSA (the International Building Performance Simulation Association) conference. Montreal, Canada, August 15–18, 2005.

Marsh, A. J. (2010). Ecotect. www.autodesk.com/ecotect-analysis Accessed on 26.01.11.

Midland Realty. (2010). Hong Kong Special Administrative Region. http://www.midland.com.hk/chi/ Accessed on 22.06.10.

Ng, E. (2003). Studies on daylight design and regulation of high-density residential housing in Hong Kong. Lighting Research and Technology, 35(2), 127–139.

Rating and Valuation Department. (2010). The Government of the Hong Kong Special Administrative Region. http://www.rvd.gov.hk/en/home/index.htm Accessed on 22.06.10.

Rodriguez, M., & Sirmans, C. F. (1994). Quantifying the value of a view in single-family housing markets. Appraisal Journal, 62, 600–603.

Sander, H. A., & Manson, S. M. (2007). Heights and locations of artificial structures in viewshed calculation: how close is close enough? Landscape and Urban Planning, 82, 257–270.

Scheaffer, R. L., Mendenhall, W., & Ott, R. L. (1996). Elementary survey sampling. Duxbury Press.

Tahbaz, M. (2007, Fall). Making shadow in open area. Honar-Ha-Ye-Ziba, 31, 27–38.

Tregenza, P. R. (1989). Modification of the split-flux formulae for mean daylight factor and internal reflected component with large external obstructions. Lighting Research & Technology, 21(3), 125–128.

Tregenza, T. (1995). Building on the ideal free distribution. Advances in Ecological Research, 26, 253–302.

Tse, R. Y. C., & Lovem, P. E. D. (2000). Measuring residential property values in Hong Kong. Property Management, 18(5), 366–374.

Watson, C. J., Billingsley, P., Croft, D. J., & Huntsberger, D. V. (1996). Statistics for management and economics. Prentice Hall.

Yu, S. M. (2007, April). What impact does an obstruction of view have on residential apartment prices? Department of Real Estate, National University of Singapore. RICS Research.

Yu, S. M., & Chai, C. H. (2004, August 9–12). Obstruction of view and its impact on house prices. In The ninth Asian Real Estate Society (AsRES) international conference. New Delhi, India.