DAYLIGHTING SIMULATION AS MEANS FOR CONFIGURING HOSPITAL INTENSIVE CARE UNIT WINDOWS UNDER THE DESERT CLEAR SKIES

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ABSTRACT

This paper reports on a research that aims at identifying acceptable window configurations that suit the requirements of hospital Intensive Care Units located in the desert. It aims at achieving daylight adequacy and visual comfort in a typical assumed ICU space, in Cairo, Egypt. Annual simulations were conducted using Diva-for-Rhino, a plug-in for Rhinoceros modeling software that was used to interface Radiance and Daysim. Six window-to-wall ratios were investigated; in addition the effect of adding shading and daylighting systems was examined. Successful window configurations were recommended for the different window to wall ratios, for each of the four main orientations.

INTRODUCTION

Most healthcare design guidelines stipulate the existence of windows in hospital Intensive Care Units (FGI, 2010). Access to external view and natural light in healthcare facilities were found to have an important stress-reducing effect, where they can reduce pain and length of stay at hospitals. It provides the patient with a sense of time and connects him to the environment.

Ulrich (1991) found that access to views and natural light in healthcare facilities could have important stress-reducing effects. They could also reduce pain and the length of stay at the hospital. In another research, Ulrich et al. (2004) analyzed more than 600 primarily peer-reviewed studies and found associations between the physical environment, patient and staff outcomes in four areas: reduced staff stress and fatigue and increased effectiveness in delivering care; improved patient safety; reduced patient stress and improved health outcomes; and enhanced overall healthcare quality. Walch, et al. (2005) compared the amount of pain medications used by patients who stayed on the bright side of a hospital and those of the dim parts. Those on the bright side were exposed to 46% higher sun intensity and perceived less stress and less pain and took fewer analgesics.

To investigate the effect of daylight on the length of stay at hospitals, an experiment took place in a cardiac intensive care unit (Beauchemin & Hays, 1998). The hypothesis was that sunny rooms would be conducive to better outcomes built on reports in the psychiatric unit that depressed cardiac patients did less well than those in normal mood. It was found that patients stayed a shorter time in the sunny rooms. In another research, Choi et al. (2012) investigated how day-lit indoor environments affect patients' average length of stay (ALOS) in a general hospital in Incheon, Korea. The variables considered in this study were: each patient's ALOS as an index of health outcome, and the differences in environments during daylight hours, including illuminance, luminance ratio. It was found that there is a significant relationship between indoor daylight environments and a patient's ALOS. 25% of the comparison sets showed that, in the brighter orientations, as in rooms located in the SE area, the ALOS by patients was shorter than that in the NW area by 16% - 41%.

The impact of daylight and window views on patient pain levels, length of stay, staff errors, absenteeism, and vacancy rates were examined (Shepley, et al. 2012). ICU patients were randomly selected from two ICUs; one was operational until 2007, the second opened in 2007. Comparing light levels independent of ICU assignment supported the hypothesis that increased light levels reduce pain perception and length of stay, but the relationship was not statistically significant. However, the research found that high levels of natural light and window views might positively affect staff absenteeism and staff vacancy.

In one of the rare studies related to this paper Pechacek, et al. (2008) studied the positive correlation between lighting, human health and performance in a patient room located in Boston, USA. Daylight Autonomy (DA) was used to simulate the hospital room orientation. The glazing factor was addressed in this research. The results demonstrated that modest amounts of glazing could provide a high degree of circadian stimulus in certain orientations.

PROBLEM DEFINITION

Although there is an abundance of evidence to the positive effect of daylighting on the health and pain relief of patients, very few publications addressed the qualitative and quantitative aspects of providing daylight in the Intensive Care Units, especially under the desert sunny clear-sky conditions. Unplanned window configurations could result in unsuitable daylighting distribution and/or visual discomfort due to the harsh desert sun. A wide range of shading solutions for the control and distribution of natural light could be utilized to respond to the needs of the users of these critical spaces.

OBJECTIVE

This paper utilized simulation tools to investigate the impact of using solar control methods and daylighting systems -such as sun breakers, solar screens and light shelves-on the daylight availability and glare probability in a typical hospital Intensive Care Unit room. The daylight availability and visual comfort all-year-round at different window-to-wall-ratios (WWR) was analyzed, taking into account the recommended illuminance levels at two reference planes: at the level of the patient bed and at the surrounding floor. The larger aim was to arrive at satisfactory window configurations that achieve daylighting adequacy and visual comfort in Intensive Care Unit settings, thus help improve the delivery of healthcare.

METHODOLOGY

The Daylight Dynamic Performance Metrics (DDPMs) was used for simulation. A typical ICU patient space was selected for investigations. Its layout, dimensions and parameters were based on standard ICU space requirements (FGI, 2010). These are illustrated in Figure1 and Table 1. The space was assumed to be located on the first floor level of a hospital building in the desert outskirts of the city of Cairo, Egypt (30° N- 31° E) which enjoys a typical desert clear-sky. Six values of window-to-wall ratios (WWR= 8, 16, 24, 32, 40 and 48%) were investigated (Figure 2).

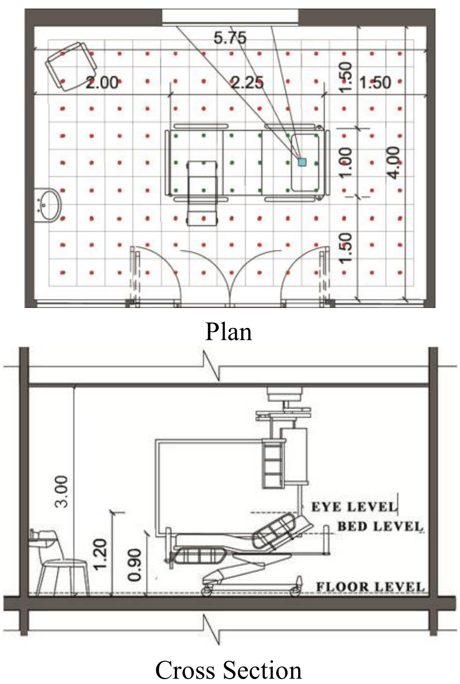


Figure 1:The tested ICU space.

Table 1: Parameters of the tested ICU space.

Indoor Space Parameters		
Floor level		*First Floor (+4.00 m)*
Dimensions (m)		*5.75 * 4.00 * 3.00*
Internal Surfaces Materials		
Walls	*Reflectance*	*50% (Medium Colored Internal-walls Off-White)*
Ceiling	*Reflectance*	*80.0% (White Colored Ceiling)*
Floor	*Reflectance*	*20.0% (Wooden Floor)*
Glazing		*Double glazing clear (VT= 65%)*

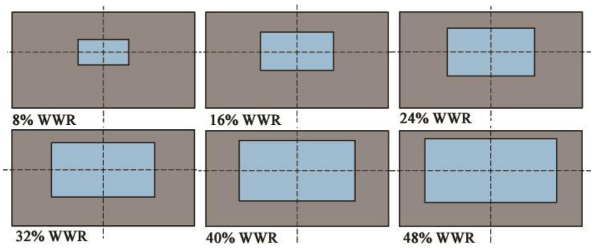
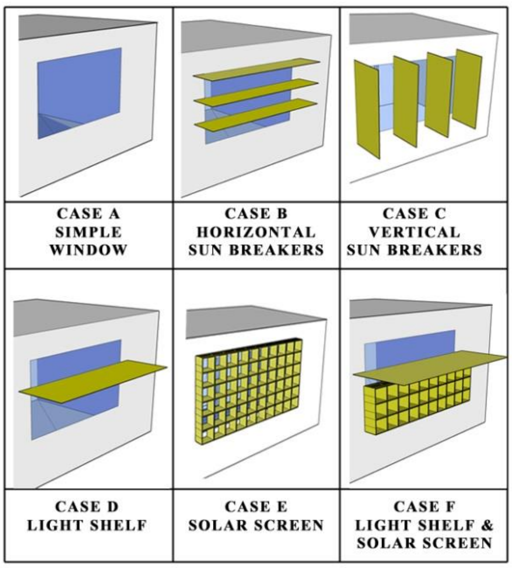


Figure 2: The tested window to wall ratios

Six window configuration cases (Table 2) were tested for each of the above WWRs, in each of the four main orientations (N, E, S, W). Their parameters were based on previous research by the authors. These were as follows:

- Case A: A Simple unprotected window.
- Cases B: An External horizontal sun breakers spaced to provide a 45° cut-off sun shading angle (reflectance = 50%).
- Cases C: An External vertical sun breakers spaced to provide a 45° cut-off sun shading angle (reflectance = 50%).
- Case D: An External light shelf located at the 2/3 of window height (upper surface reflectance = 90%).
- Case E: An External perforated solar screen with 1:1 aspect ratio and 90% perforation rate (reflectance = 50%).
- Case F: A combination of cases D and E.

Table 2: Shapes of the tested cases (at 24% WWR).



Phases:

The research was conducted in two phases. These were as follows:

Phase one methodology

The aim of this phase was to investigate the effect of the tested cases on the year-round Daylight Availability. Simulation was conducted using the IWEC weather file of Cairo (ASHRAE, 2001). Diva-for-Rhino, a plug-in for Rhinoceros modeling software, was used to interface Radiance and Daysim for annual simulation and illuminance computation (Rienhart, 2011). The Radiance simulation parameters are: -ab 5 -ad 1000 -as 20 -ar 300 -aa 0.1 All simulations took place on a 2.93 GHz Intel i7 PC (Dell Precision T1500). The execution time of one simulation run was approximately 10 minutes.

The occupied time of the simulations was from sunrise to sunset. The sunset and sunrise times were determined for each day using the sunset calculator for City of Cairo (Time and Date AS, 2012).To meet the IESNA lighting recommendations for Intensive Care Unit spaces (IESNA, 2000), simulations were carried out for two different thresholds and reference planes. These were 100 Lx on the floor plane (at a 0.05 m height) and 300 Lx on patient bed plane (at a 0.9 m height). At each reference plane, measurement was calculated for points spaced at a grid of 0.5m * 0.5 m intervals. The grid is illustrated in the floor plan of Figure 1. Three evaluation criteria were used: “daylit” areas for the areas that received sufficient daylight at least half of the occupied time, year-round; “partially daylit” areas which did not receive sufficient daylight at least half of the year-round occupied time; and “over lit” areas which received an oversupply of daylight, where 10 times the target illuminance was reached for at least 5% of the occupied time year-round (Reinhart & Wienold, 2011). At the time of conducting this research, the development of recommendations for DDPMs criteria to evaluate daylighting performance was not present. Since this is an on-going development, analysis criteria for Daylight Availability adopted in this paper assumed that the cases where the “daylit” areas reached more than or equal to 50% of the tested space were considered “adequate and acceptable”. This criterion was to be satisfied at the two tested reference planes.

Phase two methodology

The aim of this phase was to assure patient visual comfort in the cases that achieved acceptable performance in phase one. Glare probability were analyzed only for the cases that observed “overlit” areas of equal or more than 30% at the patient bed reference plane (1/3 patient bed area). Annual glare predictions were simulated using Daysim, which employs the Daylight Glare Probability (DGP) metric (Wienold, 2009). DGP represents the probability that a person is disturbed by glare and is derived from a subjective user evaluation (Wienold and Christoffersen, 2006). Annual DGP uses a simplified method that calculates the vertical illuminance at the eye level as a parameter which can affect the brightness of the space. In this method, glare was divided into four categories: intolerable glare (DGP ≥ 45%), disturbing glare (45% > DGP ≥ 40%), perceptible glare (40% >DGP ≥ 35%), and imperceptible glare (DGP < 35%). In this paper, fish-eye camera was located at the patient eye level (1.20m) facing the window. Analysis criteria assumed that when the disturbing and intolerable glare combined reach more than or equal 10% of the year-round simulation occupied time, the patient view was considered visually uncomfortable.

SIMULATION RESULTS

South Orientation Results

South Orientation Phase one results

In the South orientation, several cases achieved the required threshold at the two measuring reference planes (Table 3). Window protection measures showed promising results under the harsh desert sun of the city of Cairo.

Use of an unprotected window (Case A) resulted in a very small window size. In this case, the only acceptable solution was for a WWR of 8%. With this very small window, the “daylit” area percentage at the floor and patient bed planes reached 57% and 78% respectively. All larger WWRs failed to provide adequate “daylit” areas either on the bed or the floor or both, since the “overlit” areas dominated the test surfaces reaching up to 100%.

The most promising case in the South orientation was Case E, where an external solar screen was used. This case provided the designer with large windows having a wide range of WWRs to choose from, ranging from 24% to 48%. In these solutions, the “daylit” areas reached impressive results, reaching up to 94% of the area and consistently higher than the threshold of 50% on the two tested planes.

The second more promising case was Case B, where horizontal sun breakers were introduced. In this case, several windows showed promising results. Windows having WWRs of 16% and 24% provided acceptable “daylit” areas at both tested planes. These ranged from 50% to 100% on these planes as illustrated in the table. Two other cases -cases D and F- achieved acceptable performance at specific WWRs. These were 16% and 24% WWRs respectively.

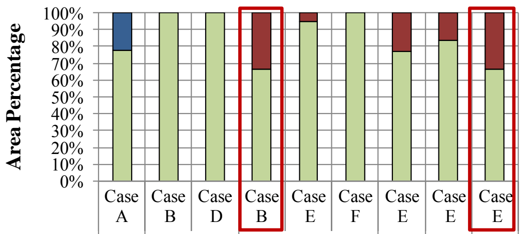
By contrast, adequate daylighting was unattainable in Case C when vertical sun breakers were introduced. The “daylight” areas on the floor plane were short of reaching the threshold of 50% of the total area in all WWRs. The “overlit” areas dominated this case.

Table 3
Percentage of "Daylit" relative to the total area on both measuring reference planes in the South orientation (Lighter shades: Acceptable cases)

Window to Wall Ratio	Daylit Area Percentages at Floor / Bed Reference planes											
	Case A		Case B		Case C		Case D		Case E		Case F	
	Floor	Bed	Floor	Bed	Floor	Bed	Floor	Bed	Floor	Bed	Floor	Bed
8%	57%	78%	37%	0%	42%	22%	70%	0%	1%	0%	2%	0%
16%	18%	94%	84%	100%	48%	100%	76%	100%	56%	33%	89%	17%
24%	2%	39%	50%	67%	23%	72%	23%	67%	84%	78%	86%	67%
32%	2%	0%	21%	61%	4%	39%	5%	33%	77%	94%	43%	33%
40%	0%	0%	5%	50%	0%	6%	1%	28%	79%	83%	11%	28%
48%	0%	0%	2%	44%	0%	0%	0%	0%	56%	67%	2%	0%

South Orientation Phase two results

Two of the nine accepted cases in phase one were identified as having a high potential for glare occurrence and, thus were analyzed in phase two. These were the cases where the "overlit" area percentage exceeded 30% of the bed surface area. These were Case B, at a 24% WWR; and Case E, at a 48% WWR. In these cases the "overlit" area reached 33% of the bed surface area (Figure 3).



	Case A	Case B	Case D	Case B	Case E	Case F	Case E	Case E	Case E
	8%	16%		24%			32%	40%	48%
Overlit	0%	0%	0%	33%	6%	0%	23%	17%	33%
Partialy Daylit	22%	0%	0%	0%	0%	0%	0%	0%	0%
Daylit	78%	100%	100%	67%	94%	100%	77%	83%	67%

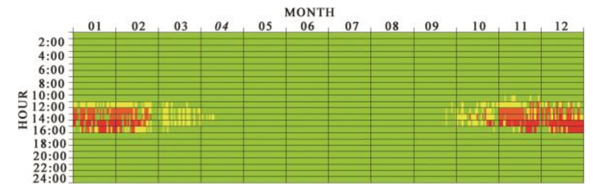
Figure 3: Daylight Distribution for the phase one accepted cases at the patient bed testing plane (South Orientation)

Annual Daylight Glare Probability was acceptable in the two analyzed cases (Figure 4).

In Case B (at a 24% WWR), the disturbing and intolerable glare were only present in only 4% of occupied simulation time collectively. The imperceptible glare was 93% of the occupied simulation time. The percentage of the perceptible glare was found to be only 2%.

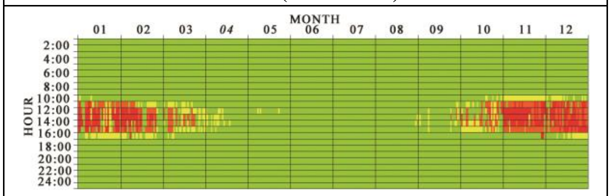
As for Case E (at a 48% WWR), it achieved a slightly lower result. The disturbing and intolerable glare were only present in only 6% of occupied simulation time collectively The imperceptible glare reached 90% while the perceptible glare was found to be 4% of the occupied simulation time.

Case B (24% WWR)



Imperceptible	Perceptible	Disturbing	Intolerable
93%	3%	2%	2%

Case E (48% WWR)



Imperceptible	Perceptible	Disturbing	Intolerable
90%	4%	3%	3%

Figure 4: Annual Daylight Glare Probability percentages for Phase two tested cases

East/West Orientation Results

East/West Orientation Phase one results

Since the sun path is symmetrical, results of daylighting performance in the East and West orientations were found to be almost similar. These are illustrated in Table 4. Results of the East and West orientations were more dramatic than those of the South orientation.

Use of an unprotected window (Case A) did not result in any acceptable solution at any WWR. The "daylit" area ranged between 0% and 6% at the bed surface area at different WWRs. The "overlit" and "partially daylit" were dominant in all WWRs. This was also observed in Case C, where vertical sun breakers were used. The "daylit" area was between 0% and 6 % in all WWRs, except at 16% WWR where it which reached an unacceptable 22% of the bed surface area. Very low unacceptable values (less than 50%) were also observed on the floor plane in these two cases.

Table 4
Percentage of "Daylit" relative to the total area on both measuring reference planes in the East/West orientations.(Lighter shades: Acceptable cases)

Window to Wall Ratio	Daylit Area Percentages at Floor / Bed Reference planes											
	Case A		Case B		Case C		Case D		Case E		Case F	
	Floor	Bed	Floor	Bed	Floor	Bed	Floor	Bed	Floor	Bed	Floor	Bed
8%	48%	0%	5%	0%	24%	6%	33%	0%	0%	0%	0%	0%
16%	31%	6%	62%	50%	42%	22%	62%	50%	23%	0%	42%	0%
24%	8%	0%	48%	33%	30%	0%	32%	39%	48%	0%	72%	56%
32%	3%	0%	26%	33%	9%	0%	9%	0%	66%	50%	47%	56%
40%	1%	0%	10%	0%	3%	0%	2%	0%	56%	72%	19%	28%
48%	0%	0%	3%	0%	0%	0%	0%	0%	27%	39%	4%	22%

The most promising case in the East/West orientations was Case E, where an external solar screen was used. This case provided the designer with large windows having WWRs of 32% and 40%. In these solutions, the "daylit" areas reached reasonable results, between 50% and 72% of the area. Other WWRs failed to provide acceptable performance, where the "daylit" area was below the 50% threshold value.

The other cases (Cases B, D and F) achieved acceptable performance at specific small WWR values. These were 16%, 16% and 24% WWRs respectively. Large windows were not attainable in the East and West orientations, except with the use of solar screens.

It is worth noting that the "daylit" area was as low as 0% at the tested bed surface plane in the majority of solutions. It did not exceed 56% of the area in any WWR. The only exception was Case E (at 40% WWR) where the "daylit" area reached 72%.

East/West Orientation Phase two results

Three of the four accepted cases in phase one were identified as having a high potential for glare occurrence and, thus were analyzed in phase two.

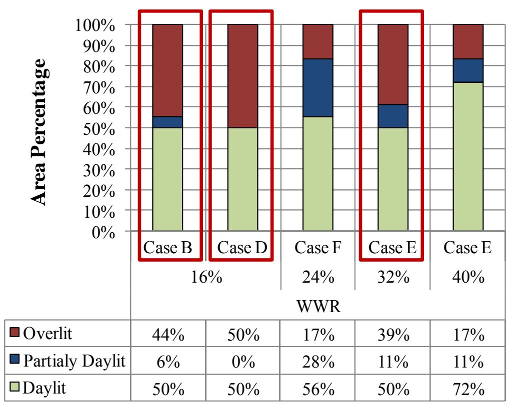


Figure 5: Daylight Distribution for the phase one accepted cases at the patient bed testing plane (East/West Orientation)

These were the cases where the "overlit" area percentage exceeded 30% of the bed surface area. These were: Case B, at a 16% WWR; Case D, at a 16% WWR; and Case E, at a 32% WWR. In these cases the "overlit" area reached 44%, 50% and 39% of the bed surface area respectively (Figure 5).

As a general result, two of the three evaluated cases passed the assumed threshold for visual comfort in the East/West orientation(Figure 6).

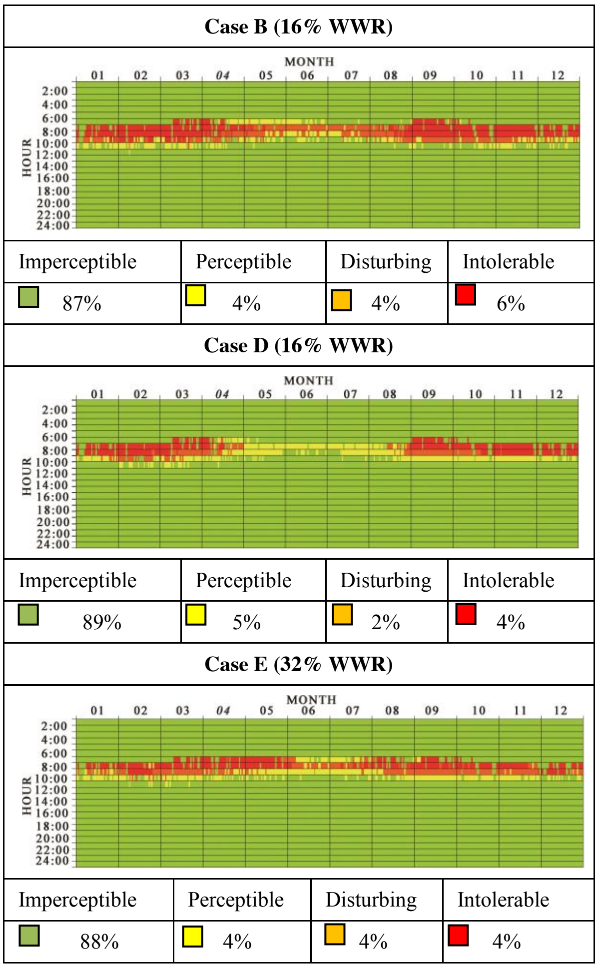


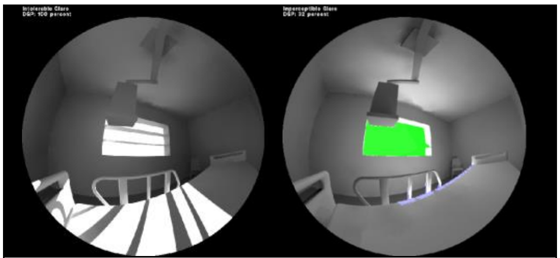
Figure 6: Annual Daylight Glare Probability percentages for Phase three tested cases

Case B (at a 16% WWR) did not succeed in satisfying the assumed criteria. The disturbing and intolerable glares were found to be present at 10% of the occupied simulation time. The imperceptible glare was present at 87% of the time, while the perceptible glare was found at only 4%.

As for Case D (at a 16% WWR), it achieved a better result. The disturbing and intolerable glares were found to be present at only 6% of the occupied simulation time. The imperceptible glare reached 89%, while the perceptible glare was found to be present at only 5% of the time.

As for Case E (at a 32% WWR), it achieved a slightly lower result. The disturbing and intolerable glares were found to be present at only 8% of the occupied simulation time. The imperceptible glare reached 89%, while the perceptible glare was found to be present at only 4% of the time.

However, the disturbing glare was observed at 8 AM almost all year-round, and at 9 and 10 AM in all seasons, except in the summer. In addition, the intolerable glare was observed almost all year round at the same times. Their effect is illustrated in Figure 7. Temporary sun protection systems, such as blinds and curtains, should be used at these specific time periods to totally eliminate glare occurrence.



Case B (16% WWR)	
21 Dec. 8:00 AM	21 Jun. 8:00 AM
DGP: 100%	DGP: 32%
Intolerable	Imperceptible

Figure 7: Comparison between intolerable and imperceptible DGP for Case B (at 16% WWR)

North Orientation

North Orientation Phase one results

In the North orientation, all cases achieved the required threshold at the two measuring reference planes (Table 5). All tested window configurations were successful in this orientation which receives very little direct sun rays in limited times of the year. All solutions were successful in offering the designer with a wide range of WWRs to choose from. The only exception was the 8% WWR, where no case was successful.

Use of horizontal sun breakers in Case B proved useful in this orientation also. It provided the widest range WWR of solutions (from 16% to 48%), where the “daylit” area reached 100% in the majority of acceptable cases at the tested bed surface area.

The combined configuration of case E was second best. It provided a wide range of acceptable WWRs (from 24% to 48%), where the “daylit” area reached 100% in all acceptable cases at the tested bed surface area.

An excellent performance was also observed on the floor surface plane in the acceptable WWRs for these two cases.

Cases C, D and E also provided very good performance, where the range of acceptable WWRs was between 16% and 40% in the first two cases and between 24 and 48% in Case E. The “daylit” area reached 100% in the majority of acceptable cases at the tested bed surface area.

Use of an unprotected window (Case A) was the least successful among all alternatives. Although this façade does not receive a large amount of direct sun light only two WWRs were found acceptable. These were the 16% and 24% WWRs. This was due to the failure of most of the other WWRs in achieving the minimum threshold values on the floor surface level.

It is worth noting that some cases achieved a 100% daylit area on both reference planes in the North orientation. These were: Case B at 32% and 40% WWRs, Case D at 24% WWR, Case E at 48% WWR and Case F at 40% and 48% WWR.

Table 5
Percentage of “Daylit” relative to the total area on both measuring reference planes in the North orientation.(Lighter shades: Acceptable cases)

Window to Wall Ratio	Daylit Area Percentages at Floor / Bed Reference planes											
	Case A		Case B		Case C		Case D		Case E		Case F	
	Floor	Bed	Floor	Bed	Floor	Bed	Floor	Bed	Floor	Bed	Floor	Bed
8%	68%	11%	0%	0%	20%	0%	9%	0%	0%	0%	0%	0%
16%	97%	100%	77%	83%	79%	89%	92%	61%	20%	0%	11%	28%
24%	74%	100%	97%	100%	92%	100%	100%	100%	72%	33%	80%	100%
32%	41%	100%	100%	100%	81%	100%	87%	100%	93%	100%	96%	100%
40%	15%	100%	100%	100%	60%	100%	56%	100%	98%	100%	100%	100%
48%	0%	100%	98%	100%	39%	100%	26%	100%	100%	100%	100%	100%

North Orientation Phase two results

The analysis of glare probability was not considered in the North orientation. None of the accepted cases had witnessed the existence of "over lit" areas at the patient bed reference plane.

SUMMARY AND CONCLUSION

Daylighting performance was simulated for a typical hospital Intensive Care Unit space (ICU) located in Cairo, Egypt that enjoys a desert clear-sky. Several window configuration cases were modeled and simulated in the four main orientations. These included a simple unprotected window, a window protected by external horizontal and vertical sun breakers or solar screens. They also included a window provided with a light shelf and a window having a solar screen and a light shelf. The daylighting performance of these cases was examined in a range of Window to Wall ratios.

A two phase methodology was adopted, where year-round daylight availability was examined first for determining acceptable solutions. Then the possibility of glare occurrence was tested for the critical accepted ones. This allowed for identification of acceptable window configurations for each orientation. A satisfaction balance between acceptable “daylit” areas (50%) at the floor and bed planes and the patient visual comfort (disturbing and intolerable glare ≥ 10% of the simulation occupied time) was the main goal of these two phases.

In the harsh desert environment of Cairo, Egypt, unprotected windows failed to provide acceptable performance, except in the North orientation where a realistic Window to Wall Ratio of 16% proved successful. Use of horizontal sun breakers and solar screens to protect windows proved to be most successful. They provided successful configurations in a wide range of Window to Wall Ratios. These showed acceptable performance in all orientations, with a minimum occurrence of glare.

By contrast, use of vertical shading devices seemed questionable. They failed to provide good daylighting performance in all orientations, except in the North where direct sun ray penetrates the space for a very limited time.

It was also observed that windows facing East and West have a very limited number of successful configurations. Moreover, although most of these satisfied the minimum threshold of glare occurrence, they require additional local shading measures at times of glare incidence.

By contrast, windows facing the North direction enjoy a wide range of successful configuration possibilities at different Window to Wall Ratios. Also, windows facing the South enjoy a number of configuration options at different Window to Wall Ratios.

Table 6 illustrates the recommended window configurations for each orientation and their relation to the different window to wall ratio values.

Table 6

Recommended window configurations

	Window to Wall Ratio	**Acceptable Window Configuration**	**Case**
South Orientation	8%	Simple Window	Case A
	16%	Horizontal sun breakers Light shelf	Case B Case D
	24%	Horizontal sun breakers Solar screen Solar screen and light shelf	Case B Case E Case F
	32%	Solar screen	Case E
	40%		
	48%		
East / West Orientation	8%	None.	
	16%	Light shelf	Case D
	24%	Solar screen and light shelf	Case F
	32%	Solar screen	Case E
	40%		
	48%	None.	
North Orientation	8%	None.	
	16%	Simple Window Horizontal sun breakers Vertical sun breakers Light shelf	Case A Case B Case C Case D
	24%	Simple Window Horizontal sun breakers Vertical sun breakers Light shelf Solar screen and light shelf	Case A Case B Case C Case D Case F
	32%	Horizontal sun breakers Vertical sun breakers Light shelf Solar screen Solar screen and light shelf	Case B Case C Case D Case E Case F
	40%		
	48%	Horizontal sun breakers Solar screen Solar screen and light shelf	Case B Case E Case F

Therefore, it is recommended to use external solar screens and horizontal sun breakers to protect the windows of Intensive Care Unit spaces from the harsh clear desert skies. These proved to be most successful and should be implemented at the range recommended Window to Wall Ratios in the different directions.

Furthermore, it is recommended to avoid placing the windows of Intensive Care Unit spaces in the East/West directions, as many of these will produce disturbing and intolerable glare in more than 10% of the occupied time. Placing the windows to face the North and South directions will provide the designer with a wide range of window configurations that suit the different Window to Wall Ratios, while avoiding the possibility of glare occurrence.

In conclusion, it became apparent that utilizing solar control and daylighting systems as part of widow configurations could drastically improve the daylight distribution in the Intensive Care Unit spaces of the hospitals located in desert climates. However, it is important to balance this improvement with glare analysis to assure visual comfort at the same time. Local shading devices (e.g. blinds or curtains) could play an instrumental role in providing a balance between natural light brightness and patients comfort preferences.

In this paper, glare aspects were evaluated from the patient's point of view at the patient's bed. Staff visual comfort, which is equally important, requires further investigation. Moreover, a study of the energy consumption associated with each of the suggested solutions could reinforce the results of this research.

Finally, there is an untapped potential that could be explored when examining the impact of different window configurations and systems on access to external view and the relation between the patient position and the outside environment in hospital intensive care units. Furthermore, the methodology adopted in this paper could be implemented in other types of buildings such as offices. This could be explored in future research.

ACKNOWLEDGEMENTS

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