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CONSIDERATIONS ON WOMEN'S NEEDS FOR DAYLIGHT IN CONTEMPORARY RESIDENTIAL ARCHITECTURE

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Abstract

Humans share common needs and rights; however, there are special needs which vary according to gender. Women in Saudi Arabia spend long periods of time at home and are responsible for domestic duties. This creates particular needs for women which for men are easily fulfilled in the outside world, such as exposure to daylight. Furthermore, privacy has been studied as a major concern for Muslims and Arabs in their homes, and a number of studies have discussed window design and privacy culture in the vernacular architecture of different Muslim countries. Yet little attention is given to the point of how privacy effects daylight level in contemporary homes, where glass windows are the major source daylight and ventilation. This contributes to figuring out factors affecting daylight level according to each case variation. Therefore, this study aims to find out if women mandatory right of daylight is sufficiently considered inside homes by studying daylight level during daytime in Jeddah city. This research studies daylight lux level in twelve modern flats in Jeddah. Diva for Rhinoceros is the tool to figure out the accurate daylight in different daytime of different seasons. Finding reported that the amount of daylight that enter all examined living rooms are less than the required level. The paper concludes that there is major lack of daylight in most examined flats due to different factors such as glass type, exterior obstruction, and window size.

Keywords

Daylight, Contemporary Flats, Window Design, Glass Type, Gender Studies

1. Introduction

Daylight provides occupants with psychological comfort. It also enhances the interior space environment (Cheung & Chung, 2008). Likewise, the interior atmosphere could be uncomfortable for the occupants if it does not provide sufficient daylight (Mohelnikova, 2010). Many researchers agree with above claim, having studied people's reactions toward daylight in relation to psychological comfort in the workplace, and found that daylight is mostly preferred to artificial light (Cuttle, 1983; Veitch & Gifford, 1996). Lifestyle in the Middle East means women have to spend long periods in their homes since most of their life duty is about fulfilling family needs. This shows that homes must be designed in a way that provides habitants, especially women, with natural light as this is mandatory for wellbeing (Alawad, 2017; Alawad, Badr, Bahy-Eldin, Al-dharrab, & Malibari, 2016; Shatwan, 2017). However, there is a lack of attention to daylight levels in contemporary flats in Arab research. Given the considerable limitations of the provision of daylight in Saudi Arabia revealed by various studies, this study, therefore, aims to investigate daylight level in contemporary flats in Jeddah city. The study will focus on the living room since it is the most commonly used space at home during the daytime.

Daylight level is measured by different methods, such as daylight factor, foot candle and lux (Khalid Asker Alshaibani, 2009; Hayman, 2003; M. Hegazy, Attia, & Moro, 2013; Su, Han, Riffat, & Patel, 2010). For instance, 2% DF (daylight factor) is equal to 100 lux (Phillips, 2004, p. xxii). In this research, lux will be used as the measure for daylight in interviewees' flats. The amount of required lux differs according to space function (Tregenza, 1998). For instance, 100 lux is considered suitable for corridors and changing rooms. The daylight lux should be very high, reaching 5000 lux in spaces that require detailed work (Tregenza, 1998). Many researchers have studied lux levels in commercial spaces such as offices and claim that 100 to 500 lux is appropriate for offices because people need high daylight level when using a computer or doing other such tasks; however, this can vary according to climate and window orientation (Boyce & Raynham, 2009; Mardaljevic, 2016; Nabil & Mardaljevic, 2005; Schuler, 1995). For instance, Nabil and Mardaljevic (2005) used a computer simulation tool to study daylight in office buildings for different 14 locations, including Miami, Hong Kong and Cairo, as climate data can be freely accessed online. Interior reflection was set at 0.7, 0.8 and 0.2 for wall and floor, respectively. The examined space had a 6mm clear double glazing window facing south. As a result, the authors found that 500 lux is best for office space. Another study surveyed employee satisfaction of daylight level in a computer hardware and software distribution company. Each office in this company had a minimum of two computers and the study finding showed that employees felt comfortable with a low lux level of not more than 100 lux and that they found 500 too extensive, which is in contradiction to the standard regulation of 300-500 lux (Schuler, 1995).

A study by Simpson & Tarrant (1983) was conducted in Surrey with 101 occupants from different ages and social classes and found that daylight in interior residential space was weak whereby daylight reached only 70 lux or less in some rooms. The authors claimed that daylight was inadequately low in most surveyed homes and went on to assert that this low daylight level was the reason for home accidents by the occupants (Simpson & Tarrant, 1983). Although this is an old study, the author believes low daylight does not provide visual clarity. However, Liu, Luo, and Li (2015) investigated the effect of daylight level on the perception of living space atmosphere. They found that cosiness and liveliness are the feelings most required for living room atmosphere.

Similarly, According to Phillips (2004) in *Daylighting: Natural Light in Architecture*, home living space with 100 lux is considered a suitable amount of daylight for people to relax in (Phillips, 2004). According to averaging across the working plane, 100 lux is adequate at floor level in corridors and stairs, 150 lux at floor level in lounges and 150 lux at table height (typically 0.8m) in dining halls, study areas, kitchens and utility rooms (Boyce & Raynham, 2009). Similarly, Afroz, Rahman, Islam, and Ahmed (2014) consider 150 lux is required daylight for living space in south-facing residential buildings in Dhaka city in all seasons, where the latitude is 20º 34N to 26º 33N and 88º 01 E to 92º41 E. Also, Nedhal, Syed, and Adel (2016) consider 100-200 lux sufficient for living space in Malaysia with a temperature if 23-34C from April to July with latitude 1°–7° N, 100°– 120° E. They go on to assert that, in cases where lux is more than 200, it creates glare and heat gain. In Egypt, 300 lux is considered the target luminance in the Egyptian code of Energy Efficiency in Residential Buildings (EERB) (M. Hegazy et al., 2013).

2. Research Issue

There are some recent studied about similar cases in Arab countries. However, climate and culture vary from country to another and from city to another. Most previous findings cannot fit in Saudi buildings since window design is effected by culture factors such as privacy. Therefore, the objective of this research is to study daylight level in contemporary flats in Jeddah while considering the importance of privacy in Saudi culture. This study will fulfil gap in knowledge by measuring daylight levels in 12 living rooms in Jeddah city. It will investigate different factors that affect daylight level in domestic buildings.

3. Methodology

A reliable set of quantitative data to be analysed for the lux level during daytime has been considered crucial for this investigation. This helps in providing a clear understanding of the accurate amount of daylight that enters living spaces during different hours of daytime. Researchers have applied two different methods of measuring daylight in interior space. There are researchers who have measured the light on-site or on a scale model (Ahmed, 2000; Husin & Harith, 2012; Ruck et al., 2000). However, this method is not commonly used these days, with advanced computer programs being available. Current researchers use a light calculation computer program such as DIVA-for-Rhino (Garcia Hansen, Kennedy, Sanders, & Varendorff, 2012; M. Hegazy et al., 2013; M. A. Hegazy & Attia, 2014; Mahmoud & Elghazi, 2016; Mohsenin & Hu, 2015; Yun, Yoon, & Kim, 2014)..

The following analysis is conducted for 12 living rooms in contemporary flats with different window sizes, numbers, glass types and window orientation in Jeddah. The research focused on flats because it is a rental type of residence, so the inhabitants are not allowed to make changes in flat design. On the other hand, most people who live in a villa in Jeddah own the residence, so they have the freedom to design what they need. In addition, the building regulations for flats vary from those for houses. According to the Municipality of Jeddah, gaps between residential flat buildings should be two metres between the side and back of each building; however, the gap between villas should be four metres for each side of each villa (MOJ, 2015).

Window size in the 12 living rooms varies from small, medium and big. Daylight is measured in participants' living rooms by the DIVA-for-Rhino program. The calculations are carried out in four different periods of the daytime 10am, 12pm, 2pm and 4pm in relation to sun movement. Daylight lux level is calculated for these hours for day 15 of the middle month for each season of the year. For instance, the calculation is done in January, April, July and October. Analysis is done for flats from the first to fifth floor with daylight of less than 100 lux and with 50% of the living room.

4. Experiment Description

The following experiment in this paper is conducted for 12 living rooms. Four living rooms in the first, second and third floor. Living rooms with different window sizes, numbers, and glass types, window ratio to floor area and window orientation are analysed in Table **1**. Also, window to floor area is measured as the following:

Floor area (F) = L*W

Window area (W) = L*W

Window area ÷Floor area = ( )*100 = Window to floor area (WFR)

The following table shows the characteristics of the 12 flats for participants' from floor 1 to floor 3.

Table 1: Window Characteristics of Participants' Living Rooms

Room number	Floor Level	Window glazing type and size	Living room floor area	Window Orientation	WFR
Room 1	1st floor	Transparent glass W=1*.80	F=3.50*4	West	F = 14 m^2 W = 0.8 m^2 WFR = 5.7%
Room 2	1st floor	2 forsted glass W=1.20*1 W=1.20*1	F=3 *4	North and West	F = 12 m^2 W = 2.4 m^2 WFR = 20%
Room 3	1st floor	Tinted Glass W=1.20*.88 W=1.20*.88	F=4*4	North and east	F = 16 m^2 W = 2.11 m^2 WFR = 13.18%

Room 4	1st floor	Transparent W=1.50*3	F=6.20*5	East	F = 31 m^2 W = 4.5 m^2 WFR = 14.51%
Room 5	2nd floor	Transparent glass W=.90*.70 Frosted glass W=1*.90	F=4*4	west and South west	F = 16 m^2 W = 1.53 m^2 WFR = 9.5%
Room 6	2nd floor	Frosted glass W=1*.80	F=4*4	West	F = 16 m^2 W = 0.8 m^2 WFR = 5%
Room 7	2nd floor	Frosted glass W=1*.80	F=4*4	South	F = 16 m^2 W = 0.8 m^2 WFR = 5%
Room 8	2st floor	Frsoted glass W=1.60*2.50	F=4.20*4	West	F = 16.8 m^2 W = 2.08 m^2 WFR = 12.38%
Room 9	3rd floor	Transparent glass W=1*.80	F=3.50*4	North	F = 14 m^2 W = 0.8 m^2 WFR = 5.7%
Room 10	3rd floor	Transparent glass W=1*.80	F=4*4	East	F = 16 m^2 W = 0.8 m^2 WFR = 5%
Room 11	3rd floor	Transparent W=1.50*.70	F=3.55*4	East	F = 14.2 m^2 W = 1.05 m^2 WFR = 7.39%

Room 12	3rd floor	Transparent Glass W=.50*.60	F=3.80*4	West	F = 15.4 m^2 W = 0.3 m^2 WFR = 1.94%

Source: Author

Building regulations in different countries require certain requirements for building glazing areas. For instance, in the 2014 Dubai Green Building Regulation it requires a minimum of 50% glazed area to be on the north ordination; however, if a window is located towards the south or west orientation, then consideration of environmental treatment is required. Additionally, if the glazing exceeds 60% of the building, certain shading elements are required (DEWA, 2017). On the other hand, after analysing window characteristics in living rooms in Jeddah, as shown in Table **1**, it is found that the only common characteristic is that all windows are sliding windows, which are placed in the interior surface of the wall. Table1 shows the significant variation in window size, window orientation and glass type. Glass types are either transparent, tinted or frosted. Also, window orientation shows that no attention is given to this point, as windows face in different orientations. The ratio for window to floor area is very low in living rooms. This shows that there is no study of window design in Jeddah's flats. There was a clear lack of daylight in all tested living rooms due to different reasons, except for those who live on the roof floor. This substantiates the original claim by providing a quantitative set of data using DIVA-for-Rhino to calculate the accurate lux level in all tested living rooms.

5. Simulation Study

In order to test the daylight lux level in each living room with exterior wall window, a series of simulation studies were carried out. Although it would be more appropriate to conduct these simulations in real space, participants were not welcoming of this idea as the lux meter measuring device has to remain in their homes for a day. Therefore, computer simulation with DIVA-for-Rhino was used to investigate daylight in 12 rooms. A number of assumptions were made for room and climate conditions, since this is an exploratory study:

- Jeddah latitude 21.300N and longitude 39.100E was inserted in the DIVA plug-in to set the climate.

- In the absence of references in Saudi studies and Saudi building regulations regarding the target lux or daylight factors, 100 lux was chosen as the target luminance. This level is taken from the standard for British regulations as discussed before in this chapter (Phillips 2004, p. 65, p.65). However, due to climate variation between the UK and Saudi Arabia, daylight might need to be 200 to 300 lux in interior spaces in Saudi Arabia.
- DIVA-for-Rhino program was used for daylight simulation.
- Clear-sky was used as Saudi Arabia has clear-sky.
- Jeddah weather reaches 20C in winter and 39C in summer, as shown in Table 2.

Table 2: *Average Weather in Jeddah.*

Month	Mean Daily Minimum Temperature (°C)	Mean Daily Maximum Temperature (°C)	Mean Total Rainfall (mm)	Mean Number of Rain Days
Jan	18.2	28.9	11.1	2.2
Feb	17.9	29.4	3.2	0.7
Mar	19.3	31.6	2.5	1.0
Apr	22.0	34.8	2.4	0.8
May	24.0	37.1	0.2	0.3
Jun	24.8	38.2	0.0	0.1
Jul	26.4	39.4	0.2	0.0
Aug	27.3	38.7	0.5	0.6
Sep	26.3	37.6	0.1	0.1
Oct	24.0	36.6	1.0	0.5
Nov	22.1	33.3	23.0	2.3
Dec	19.9	30.6	11.4	1.8

Source (WWIS, 2016)

- Ceiling reflection is 50% and floor and wall reflection is 20% for all rooms since dark colour furniture was covering both floor and wall, there was dark paint on some walls and dark coloured curtains or big paintings on walls, as shown in Figure 1. According to Meek and Van Den Wymelenberg (2014), interior furniture in terms of size and colour affect the amount of daylight in interior space. The brighter the colour, the lighter is diffused. However, most furniture is in dark colours, like red or brown. Even the walls are painted with dark colours or covered with dark coloured curtain or paintings. Therefore, furniture reflection is selected to be 20%. No artificial light reflection is calculated.

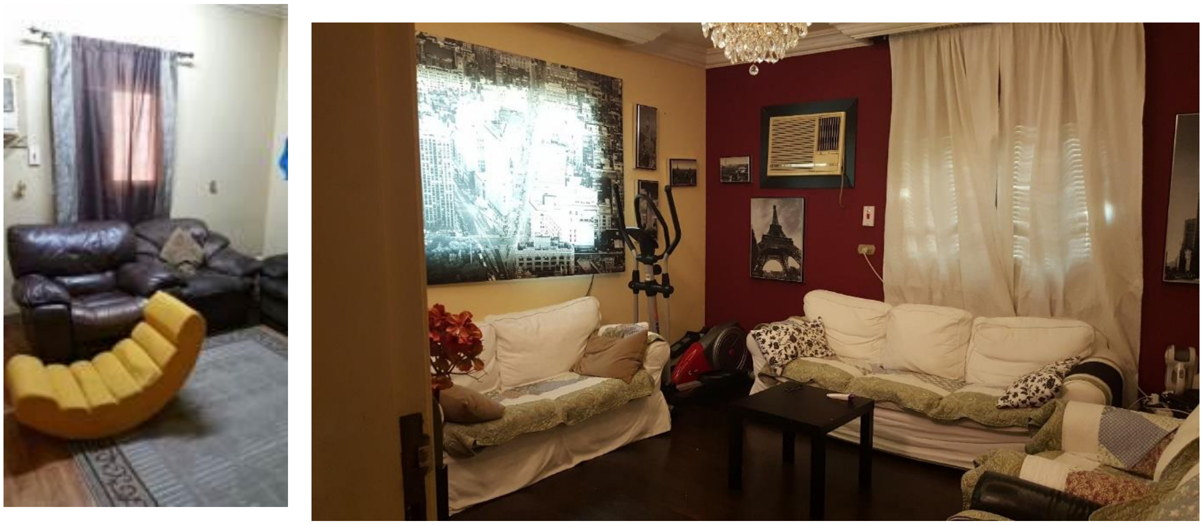

Figure 1: *Dark Colors in Living Rooms*
Source: Author

- Glass transmittance was set on tinted glass for living rooms with tinted glass windows and frosted for frosted windows and transparent for the transparent ones.
- Windows were located in the orientation as they are in reality.
- Daylight calculation was set on lux for each metre in the room above 1 metre from floor.

On the Rhino program, which is a 3D computer graphics and computer-aided design, each participant's building was drawn with specific identification to its living room. Additionally, before running the simulation on DIVA, neighbouring buildings were also drawn in the right width and height and a two-metre gap between buildings was also set, as shown in Figure 2.

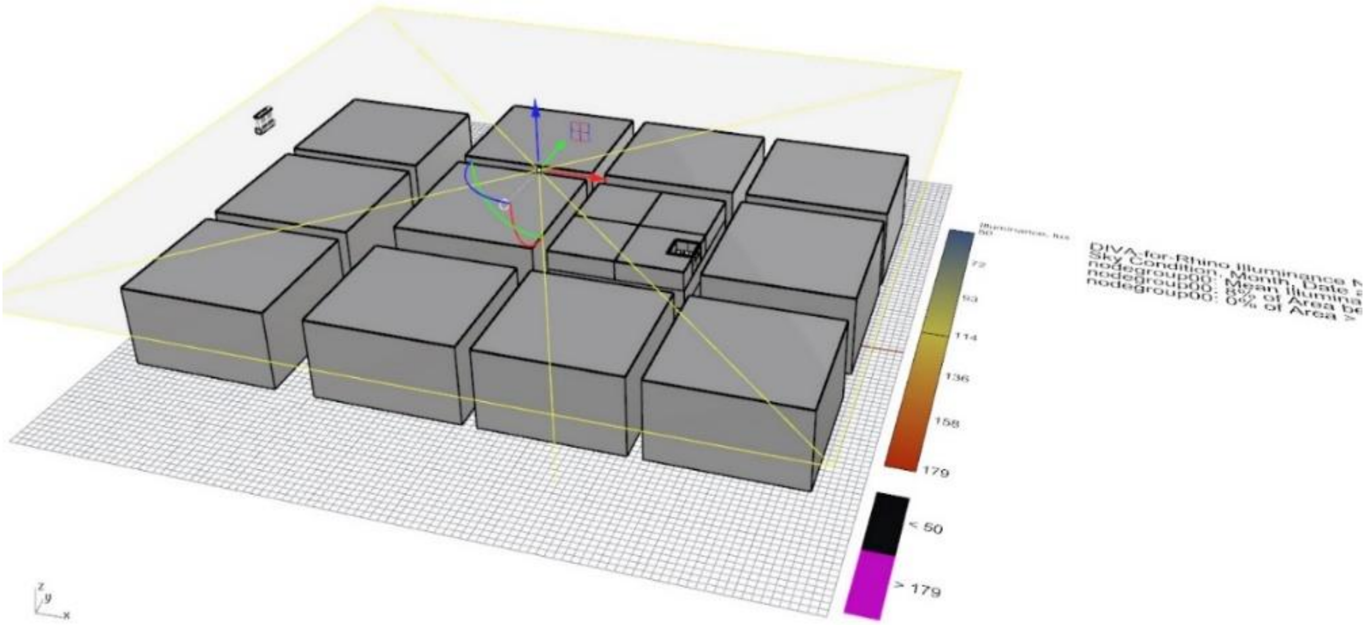

Figure 2: *Neighbourhood in Simulation Study*
Source: Author

The simulation study findings for four of the 12 rooms are discussed in the following six points:

- Daylight level and glass type
- Window orientation
- Daylight and exterior obstruction
- Daylight level in room zones
- Window to floor ration
- Daylight in roof flats

5.1 Daylight Level and Glass Type

Findings revealed that daylight is less than 100 lux in most of the tested living rooms in all seasons and during four different daytimes, as shown in Table 3, Table 4 and Table 5. On the first floor, Table 3 shows that the majority of living rooms have weak daylight, except for two living rooms, which are rooms 2 and 4, where daylight is between 108 and 196 lux in April and July at 10am and 12pm. Room 2 continues to have daylight levels of more than 100 lux at 14pm from January to July and at 16pm in April and July. These two flats are on the first floor. Also, it was found that having two medium-size frosted glass windows for room 2 can provide as much daylight as one big transparent window for room 4, shown in Table 3; however, shutters are closed all day in room 4 due to privacy, as shown in Figure 3.

Table 3: *Number of Living Rooms on the First Floor That Have Daylight of Less Than 100 Lux*

	10am	**12pm**	**14pm**	**16pm**
15 January	4	4	3	4
15 April	2	2	3	3
15 July	2	2	3	3
15 October	4	4	4	4

(Source: Author)

Figure 3: *Living Room Number 4 (Source: Author)*

Additionally, on the second floor, shows that the same issue of weak daylight continues, except in two living rooms with frosted glass, which are rooms 5 and 6. Daylight lux in room 5 is between 116 and 147 at 12pm in April and July, respectively. Daylight lux in room 6 varies between 114 and 131 lux in all seasons at 14pm. In the same room, daylight ranges between 101 and 119 in April and July, respectively, at 16pm. In this scenario, it could be argued that frosted glass is better, as it matches the culture's need for privacy.

Table 4 shows that the same issue of weak daylight continues, except in two living rooms with frosted glass, which are rooms 5 and 6. Daylight lux in room 5 is between 116 and 147 at 12pm in April and July, respectively. Daylight lux in room 6 varies between 114 and 131 lux in all seasons at 14pm. In the same room, daylight ranges between 101 and 119 in April and July, respectively, at 16pm. In this scenario, it could be argued that frosted glass is better, as it matches the culture's need for privacy.

Table 4: *Number of Living Rooms on the Second Floor That Have Daylight of Less Than 100 Lux*

	10am	**12pm**	**14pm**	**16pm**
15 January	4	4	3	4
15April	4	3	3	3
15July	4	3	3	3
15 October	4	4	2	4

(Source: Author)

Weak daylight continues to third floor, as shown in Table 5, except for two living rooms, which are rooms 11 and 12. Although both rooms have transparent glass windows, in room 11, the window is placed in a high part of the wall to insure privacy. In room 12, the window is small and is facing the main road, so there is no need for privacy from neighbours. In this room, daylight lux ranges from 100-200 lux at 12 and 14pm in January, 14pm and 16pm in April and July and 12pm, 14pm and 16pm in October. However, in room 11, daylight is more than 100 lux at 10am in all seasons, except January. According to Gordon (2003), one of the daylight design rules is that high located windows provide daylight in the deep part of the space. Similarly, Meek and Van Den Wymelenberg (2014) claim that upper wall glazing provides enough daylight at twice the amount of middle wall windows and, in this scenario, daylight reaches the deep part of the space (Meek & Van Den Wymelenberg, 2014). In the current study, daylight is weak during daytime in room 8 with an upper window, except at 10am.

Table 5: *Number of living rooms on the third floor that have daylight of less than 100 lux*

	10am	12pm	14pm	16pm
15 January	4	3	3	4
15April	3	4	3	3
15July	3	4	3	3
15 October	3	3	3	3

(Source: Author)

Study of daylight and glass type shows that glass type has a significant effect on daylight level in living rooms. It is found that tinted glass provides the lowest level of daylight, even if windows are big or if the room has more than one window. This finding contradicts with Hashim and Rahim (2010) who argue that tinted glass is preferable in Muslim cultures, such as Malaya. They go on to assert that cultural requirements such as privacy must be considered in home design. Therefore, is it observed that tinted glass can provide habitants with privacy. On the other hand, it is also understood that, although tinted glass provides privacy, it also blocks daylight from entering the interior space. Since one of the main reasons for windows is providing daylight, tinted glass is, therefore, not a suitable solution as it creates another issue by blocking out daylight.

M. Hegazy et al. (2013) did a similar study on Cairo and found out that daylight was weak in different glass windows combined with shaded or tinted glass with different ratios on the ground and first floors. Daylight did not reach 300 lux in any of the examined cases. They went on to assert that this issue continues even in the upper floors, such as the third floor, with the same glass type. However, this study was limited to south orientation. The current study examines tinted glass or glass in east and the north orientation and transparent glass in south and west and finds the same issue. This strengthens the author claim that transparent glass should not be used in Saudi culture as it renders windows as having no function since window design and its glass material are responsible for the amount of daylight in the indoor area (Baker & Steemers, 2002; Evans, 1981; McMullan, 2012; Szokolay, 2008). Glass type should match cultural needs in terms of privacy. Although a transparent glass window may provide enough daylight in certain parts of the world, it might block daylight in Saudi homes due to privacy concerns.

Afroz et al. (2014) found that lower floor residences with south facing single plane glazing under overcast sky receive less daylight than upper floors in Dhaka climate in all seasons. However, the current study shows that floor level does not create an issue if window size is studied and the glass type provides both privacy and daylight. Therefore, floor level does not create an issue in blocking daylight as much as glass type.

5.2 Window Orientation

According to Littlefair (1991) and Parise and Martirano (2013), window orientation is important to provide sufficient daylight. Littlefair (1991) asserts that windows should be located towards a south location to get more light (Littlefair, 1991). M. A. Hegazy and Attia (2014) studied daylight in hot Cairo weather in four locations and found that eastern and northern façades provide the highest level of daylight in comparison to west and south. Similarly, Khalid A Alshaibani (2015) studied daylight in an administrative building in the eastern province in Saudi Arabia and found that locating windows in the north and south prevented heat and direct solar radiation from entering the interior space. Hence, shading devices are also recommended in these two orientations.

In the current study, after analysing daylight and glazing type, it is found that that daylight reached 100 lux in only six rooms out of 12 in most daytime hours, especially the afternoon. Additionally, four rooms out of six are located towards a west orientation, which are rooms 5, 6, 2 and 12. However, rooms 11 and 4 are located towards the north and east, respectively. As previously discussed, room 11 gets daylight at 10am only and room 4 at 10am in all seasons except October, and 12pm in April and July. However, it cannot be claimed that other orientation do not provide daylight, as there are other factors to consider, which could be the reason for weak daylight level, such as exterior obstruction, which will be discussed in the next finding.

5.3 Daylight and Exterior Obstruction

Distance between buildings has major negative impact on daylight among different studies, such as Littlefair (1991) and Afroz et al. (2014) In the study by Afroz et al. (2014) discussed in the previous point, the authors studied the effect of road width on obstructing daylight from entering the space. They found that obstructing windows with another building at close distance has a significant impact on daylight penetrating into the interior space. They asserted that the wider the distance, the more daylight can penetrate inside a room. Li et al. (2006) studied a similar case, but in a Hong Kong high rise building in a high density area. The authors found that closeness between buildings creates a major obstruction for daylight entering the interior space (Li, Wong, Tsang, & Cheung, 2006).

The current study finding shows that exterior obstructions are as important as type of glass and orientation. As mentioned in the previous section, east and north orientation provide a high level of daylight; however, it is observed that exterior obstruction can reduce or block this daylight, as is found in rooms 10, 1 and 9 with transparent glazing and room 8 with big size frosted glass. In all these four rooms daylight did not reach 100 lux at any part of the daytime in any season. These rooms are facing east, west and north, but no daylight in penetrating inside the rooms as distance between these rooms and the neighbouring building is just four metres. To confirm this finding, room 1 was examined again, but with distance of 10 metres between buildings. Daylight increased in this scenario rapidly from 40 lux to 110 lux in July. This shows that having exterior obstruction blocks daylight from reaching interior space.

This finding was compared with that for room 12 with a very small window, as shown in Figure 4. The window is facing the main road around an eight-metre distance between buildings and facing west. Daylight is more ranged between 100-200 lux at 12pm, 2pm and 4pm at most seasons. The reason for this living room to have this amount of daylight is not just that the window is transparent and facing west, but also because, in this scenario, the gap between buildings is wide at eight metres. This shows that, in addition to type of glass and window orientation, exterior obstruction is important in providing enough daylight. Although, west ordination is not recommended as the sun is so intense in the afternoon, this issue was, however, solved with a small window that provides enough daylight without extensive heat. Therefore, the gap between buildings has an important role in daylight level, as in rooms 5 and 2 one of the windows has no building to block the daylight. This could be one of the additional reasons for the daylight level in addition to frosted glass. Therefore, the factors that are found to help in increasing daylight in living space are glass type and exterior obstruction.

Figure 4: *Living room number 12 (Source: Author).*

5.4 Daylight Level in Room Zones

Although some living rooms have enough daylight, as discussed in previous findings. According to Afroz et al. (2014); Ibrahim and Hayman (2005), Kim and Kim (2010), Sherif, Sabry, and Rakha (2010) and daylight level should be studied in each zone of the room to make sure that all parts of the room have daylight, as shown in

Figure 5. Afroz et al. (2014) claim that daylight decreases in the deep parts of the room and they go on to assert that the depth of the room must be studied when designing window size. They also assert that vertical windows allow daylight to reach the deep part of a room more than horizontal ones. This point is supported by Meek and Van Den Wymelenberg (2014) who found that vertical windows provide more distributed daylight in interior space than horizontal windows (Meek & Van Den Wymelenberg, 2014).

In the current study, zones were divided into four parts with each zone being one metre. However, since daylight in most flats did not reach 100 lux, zone analysis was done as following with the first two zones considering 50% of room area starting from the window wall to the middle of the room at floor level, as shown in

Figure 5, since this is the seating area. The rest of the space is usually for T.V. and shelves so nobody will sit in the rest of the space. The finding revealed that, even if some daylight reaches 100 lux in some rooms, this does not, however, mean that 100 lux is available in the whole room. It is found that daylight in 11 out of 12 rooms from the first to the third floor did not reach 50% of the living rooms at any part of the daytime, as seen in Table 6. Daylight with 100 lux is only available in the zone near the window. However, it is found that only one room is excluded from this issue in April and July, which is room 2. Daylight is more than 100 lux in 50% of the room at 12pm in April and at 10am, 12pm and 2pm in July. This shows that window to floor ration is not considered as will be discussed in the next point.

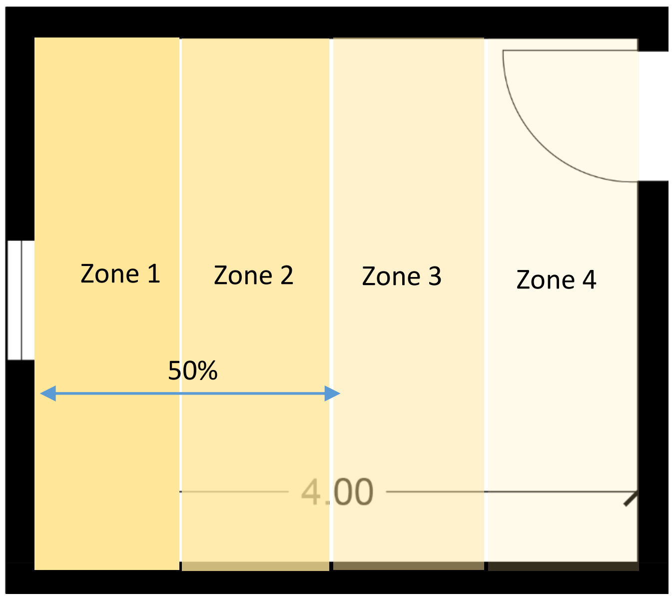

Figure 5: *Daylight level in different zones (Source: Author)*

Table 6*: Number of living rooms that do not have daylight in 50% of the living room*

	1 Floor	**2 Floor**	**3 Floor**	**Total 12**
15 January	4	4	4	12
15April	3	4	4	11
15July	3	4	4	11
15 October	4	4	4	12

(Source: Author)

5.5 Window to Floor Ratio

The amount of daylight required in interior space varies according to different reasons, such as climate. For instance, British building codes show that window to floor area should not be less than 25% (BCWHBC, 2013). In Japan, 1/7 is recommended for the window ratio to room floor area in homes, while it can vary from 1/7 to 1/10 in other buildings according to their function (Koga & Nakamura, 1998). In hot climates, 1/17 is recommended to provide sufficient daylight in interior space (Tregenza, 1998). In office buildings of cloudy, regions, 1/25 is considered suitable as it can provide a sense of daylight in interior space (PBWGSC, 1990). According to Nedhal et al. (2016), window to floor ratio is recommended to be 25%. This percentage provides daylight without creating an over lit space. The authors studied residential building in Malaysia in hot weather and found that 100-200 lux is sufficient in living space.

Therefore, window to floor ratio is analysed in my study to identify the common ratio in Jeddah flats, as shown previously in Table **1**. The analysis shows that the common ratio for most living rooms ranges from 5% to 13%, which is a low ratio. Five flats out of 12 have 5% WFR. This shows that ratio is not considered when designing windows in rental flats. Conversely, the surprising result is in room 12, as WFR is just 1.9%; however, daylight lux in this room reaches 100 lux and above as discussed previously. According to Nedhal et al. (2016), 5% WFR can be considered sufficient when daylight lux reaches the needed percentage in the space.

6. Conclusion

In Saudi Arabia, it is difficult for women to get daylight in the street or any place other than at home due to the hot weather and privacy concerns. This has made the home the only place where women can be exposed to daylight from a window. Therefore, the aim of this study is to identify whether window design in contemporary flats in Jeddah is designed in a way that provides women with adequate daylight, as this is one of their human rights. According to the finding in daylight analysis, it is shown that daylight is less than 100 lux in most living rooms from the first to third floor. It is also clear that more than 50% of living room space in all flats on the first, second and third floors have daylight of less than 100 lux. Previous literature found that daylight inside rooms is affected by many factors, such as window size, window to floor ratio, orientation (Li & Lam, 2003a, 2003b; Ochoa, Aries, van Loenen, & Hensen, 2012). This study adds that the first reason that has a great effect on daylight level is glass type and gap between buildings. It is found that transparent and frosted glass provide daylight, while tinted glass blocks daylight. Hence, due to cultural reasons, frosted glass is preferable since it provides privacy.

Secondly, windows that are facing the street provide enough daylight, even if they are small, but they have to be transparent or frosted. Additionally, the finding revealed that all flats on the first, second and third floors show weak daylight during the day except flats that are facing the street and not obstructed by a small gap between neighbouring buildings. Windows that are obstructed by neighbouring buildings which are four meters apart from each other block daylight even if the glass is frosted or in an east or north orientation.

Previous research claims that corner windows are a great source of daylight because it is provided from two directions (Afroz et al., 2014). However, this privilege can only be agreed if the glass is frosted due to cultural requirements. As found in the study, participants with corner windows enjoy enough daylight because both windows are of medium size and frosted. All of these flats have either frosted glass, while all flats with tinted windows show very weak daylight level, even if there are two corner windows in a small room. This shows that the study of culture is mandatory when designing windows in Saudi Arabia. Distance between buildings has a great effect on daylight level inside a building. Any obstructions in front of a window opening blocks or reduces daylight level. Therefore, the greater the distance between buildings, the better the daylight level inside them. This finding is supported by Afroz et al. (2014) who did a study on Dhaka city residential buildings. This study focused only on south facing windows. However, this result is found in all directions in the current study, which stresses the importance of increasing the gap between buildings. As observed, some participants have frosted or tinted glass for privacy due to the narrow gap. Additionally, a window as a device has other functions, such as providing occupants with a view in addition to daylight (Cheung & Chung, 2008; Galasiu & Veitch, 2006; Roche, Dewey, & Littlefair, 2000). This advantage of a window is missing in frosted and tinted glass in this study due to cultural requirements. Study is limited to 12 flats, further studies need to study more flats in the city and in other cities in Saudi Arabia.

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