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Design Intervention of retrofit Fixed Solar Shading Device for care homes in Sheffield, UK

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Abstract:
Climate Based Daylight Modelling simulation has been used in this study to simulate existing care homes in Sheffield, UK. The bedrooms were simulated in terms of the Useful Daylight Index and Daylight factor to understand the current daylight situation. Along with the illuminance values, glare indices have been measured. The CIE Glare index of the bedroom was above the critical level (CGI>19). Among the five different shading devices employed, one of the shading devices placed 500mm apart from the window with four horizontal panels proved to effectively control glare in the bedroom on the southern façade. After installing the shading device, the CIE Glare Index was reduced to 17.54 with a UDI(a) of 78.53%. This study made it possible (a) to examine the current Useful Daylight Index and Daylight factor of the care homes in Sheffield and (b) to implement and experiment with fixed solar shading devices in the care home of Sheffield, UK.

Keywords: Daylight, Glare, Care Home, CBDM, Solar shading device

1. Background

According to carehome.co.uk, 70% of the care homes in the UK are in residential settings (Berg, V., 2021). People aged 85 and above in the UK are 2.1% of the total population, and an estimated projection reveals that it will increase to 3.1% by 2030 (Office for National Statistics, 2023). The light needed by a 60-year-old person to perform a task is three times the amount required to perform the same task by a 20-year-old person (Sinoo et al.,2011). With ageing, the light transmission capacity of the eye can reduce (CIBSE, 2022). Along with daylight, glare can happen as well. Glare creates irritation and makes it difficult to see things. In this study Average Daylight Factor (ADF) will be used as a primary metric to evaluate daylighting conditions, as the daylight factor is used for a uniform sky condition. According to BREEAM, 80% of a living space should have an daylight factor of 2% on an average, and the range of 100 Lux to 3000 Lux of illumination can be considered adequate with a single illumination source. (CIBSE, 2014). When an elderly person is exposed to a glare source to a minimal degree, for best visual acuity, it could take 3 minutes longer than a young person to get a full recovery; further studies show it could take nine times the recovery time to get to the initial stage (Erdinest, N. et al., 2021).

Moreover, there is a gap in the data about window retrofit shading design. The direction of this research is validating a fundamental question: if shading devices control glare while maintaining an adequate Useful Daylight Index and average daylight factor in the UK care homes at Sheffield?

2. Methodology

To find out the correct shading device for care homes, the following steps involve Climate Based Daylight Modelling (CBDM) simulation for the three existing projects. The average Daylight Factor – ADF were simulated for the projects to understand the current illumination situation in the chosen care homes bedrooms. Useful Daylight Index (UDI) has been calculated as well. For the simulation IESVE computer application was used. For this study, only the top-floor bedrooms of the care homes were simulated. One bedroom from each orientation will be chosen for the simulation. Working plane height of 750mm would be chosen for the bedroom as in this height table or desk tops are placed. Working grid set to 250mm for the rooms. Ground reflectance of surroundings was considered 20%. The area of interest shrinkage parameter was considered zero. The maintenance factor was set to 80%.

The window frame size was set according to the project's information. A detailed sky resolution sky model with 2305 patches has been used. As the care homes are used for 365 days throughout the year, weekends were included in the simulation. Daylit time for the bedrooms was considered from 8:00 to 18:00. According to the results, one of the projects has been tested for glare in the bedroom. According to the test results, five different shading devices were employed to examine glare in the bedrooms of the care homes.

3. CBDM Simulation Results

These three projects selected for the simulation are fully functional and run annually, operated by sheffcare (sheffcare.co.uk, n.d.). The projects are: 01. Burnt tree croft residential care home, 02. Grange Crescent residential care home & 03. Midhurst Road residential care home. This study deals with daylighting and shading devices, so they were carefully chosen for their window and internal layout. None of the projects are overshadowed by surrounding buildings or objects. A common trait of these projects is that there are no existing shading devices. In all the projects, residential bedrooms are primarily placed on the first floor. For simulation, a 3D model of the whole floor plan was made. In the model, only four rooms orienting towards north, south, east and west have been detailed with a window. Useful Daylight Index simulation results come in a range. The percentage of the light amount which is dropping below 100 lux during the simulation period is termed UDI – Supplemental or UDI(s), and light amount between the range of 100 lux to 3000 lux is termed UDI – Autonomous or UDI(a), the light amount above the threshold of 3000 lux is termed as UDI Excessive or UDI(x). From these parameters, the daylighting scenario in the bedroom has been evaluated. Simulation results for the three projects are given below.

Burnt tree croft residential care home

Table 1: Bedrooms UDI & DF simulation results, Burnt Tree Croft care home

Lighting Metrics	Threshold	South Bedroom	North Bedroom	West Bedroom	East Bedroom	Average value
UDI (s)	<100 LUX	10.34(%)	10.01(%)	9.72(%)	8.81(%)	9.72
UDI (a)	100LUX-3000LUX	77.36(%)	87.64(%)	85.78(%)	77.92(%)	82.18
UDI (x)	>3000 LUX	12.30(%)	2.35(%)	4.50(%)	13.28(%)	8.11
ADF	0 - 100	3.15	3.65	3.55	3.98	3.58
DF	>2	43.33(%)	50.83(%)	50.96(%)	52.89(%)	49.50

Grange Crescent residential care home

Table 2: Bedrooms UDI & DF simulation results, Grange Crescent Residential care

Lighting Metrics	Threshold	South West Bedroom	South East Bedroom	North East Bedroom	North West Bedroom	Average Value
UDI (s)	<100 LUX	11.48 (%)	8.95 (%)	11.66 (%)	11.72 (%)	10.95
UDI (a)	100 LUX-3000 LUX	78.83 (%)	73.42 (%)	84.42 (%)	85.65 (%)	80.58
UDI (x)	>3000 LUX	9.69 (%)	17.63 (%)	3.92 (%)	2.64 (%)	8.47
ADF	0 - 100	3.49	3.62	3.95	3.95	3.75
DF	>2	53.91 (%)	56.31 (%)	58.26 (%)	58.26 (%)	56.69

Midhurst Road residential care home

Table 3: Bedrooms UDI & DF simulation results, Midhurst Residential care

Lighting Metrics	Threshold	South Bedroom	East Bedroom	West Bedroom	Average Value
UDI (s)	<100 LUX	8.96 (%)	13.64 (%)	13.16 (%)	11.92
UDI (a)	100 LUX-3000 LUX	78. 18 (%)	78.57 (%)	81.34 (%)	79.36
UDI (x)	>3000 LUX	12.87(%)	7.79 (%)	5.49 (%)	8.72
ADF	0 - 100	3.91	3.46	3.89	3.75
DF	>2	52.55 (%)	55.91 (%)	57.02 (%)	55.16

3.1.1 Comparison of UDI, DF and ADF of the three projects:

Table 4: UDI, DF & ADF comparison among 3 projects

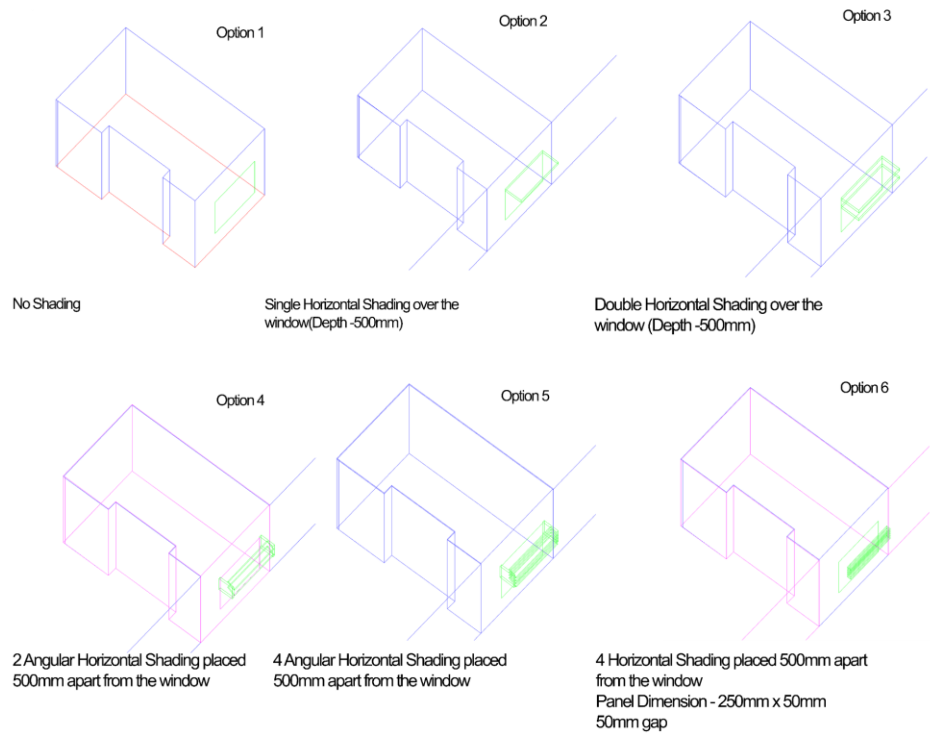
Average Value		Projects		
Lighting Metrics	Threshold	Burnt Tree Croft	Grange Crescent	Midhurst
UDI (s)	<100 LUX	9.72	10.95	11.92
UDI (a)	100 LUX-3000 LUX	82.18	80.58	79.36
UDI (x)	>3000 LUX	8.11	8.47	8.72
ADF	0 - 100	3.58	3.75	3.75
DF	>2	49.50	56.69	55.16

The comparison of the average results in Table 4 illustrates that UDI (s), UDI (a), UDI (x), ADF, and DF>2 of the projects provide similar patterns in results. For instance, the Average Daylight Factor ranges from 3.58 to 3.75 for all three projects. In every project, more than 50% of the bedroom space has an average daylight factor of that range.

3.1.2 Glare Situation in the care homes, Sheffield

For this study, the Burnt tree croft residential care home project has been chosen for glare analysis. Glare simulation has been performed incorporating shading devices to analyse the room's glare impact and lighting condition (Figure 1).

Figure 1: Shading Devices options for Burnt Tree Croft South Bedroom



In one study, Navvab and Mojtaba (1997) used the CIE Glare Index as the basis of glare calculations to analyse glare from daylighting in a museum. They proposed a shading device to minimise glare for the visitors. This study uses the CIE glare index to analyse the glare too.

Table 5: Shading device option comparison

Shading Option	**Luminance Threshold for Glare**	**CIE Glare Index Range**	**Daylight Factor**	**Daylight Glare Probability**
Option 1. No Shading	134.39 cd/m2	16.18 – 22.39	3.15	3.96
Option 2. Single Horizontal Shading over the window (Depth - 500mm)	95.58 cd/m2	14.54 - 20.82	2.35	2.92
Option 3. Double Horizontal Shading over the window (Depth - 500mm)	77.29 cd/m2	15.50 – 21.71	1.67	1.74
Option 4. 2 Angular Horizontal Shading placed 500mm apart from the window	76.49 cd/m2	11.05 – 17.28	1.86	1.18
Option 5. 4 Angular Horizontal Shading placed 500mm apart from the window	43.92 cd/m2	7.76 – 13.93	1.58	0.77
Option 6. 4 Horizontal Shading placed 500mm apart from the window (250mm x 50mm), 50 mm gap between panels	56.16 cd/m2	**11.61 - 17.54**	**2.04**	**1.49**

A further simulation for UDI(s), UDI(a) and UDI(x) has been done to get the daylight situation in the room. The simulation result illustrates that the UDI(s) is 14.24%. The autonomous index UDI(a) is 78.53%. Furthermore, the UDI(x) is 7.23 (Table 6). Compared to the other shading devices, this is doing well in terms of autonomous and excessive Useful Daylight Index.

Table 6:UDI Simulation with option 6

Lighting Metrics	Threshold	South Bedroom
UDI (s)	<100 LUX	14.24(%)
UDI (a)	100LUX-3000LUX	78.53(%)
UDI (x)	>3000 LUX	7.23(%)

4. Overall Analysis

4.1.1 Analysis of Useful Daylight Index(UDI) and Daylight Factor (DF) for bedrooms of three care homes

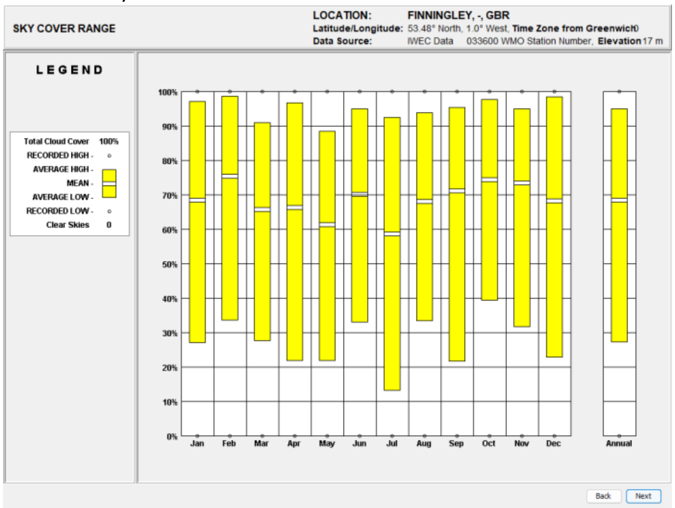
The results shown in Table 1, Table 2 & Table 3 show significant similarities between all three projects. All three projects' average UDI(s) is from 9.72% -11.92% (Table 4Table 1). On the other hand, the critical factor is UDI(a), the lux range between 100 to 3000. The UDI(a) range is between 79.36% - 82.18%. On average, it is 80%, which indicates that the autonomous lighting condition in the bedrooms is good. Above that range, any exceeds considered excessive light, UDI(x). Table 4 further illustrates that the UDI(x) percentage ranges from 8.11% to 8.72%. The average daylight factor in the bedrooms is in the range of 3.58- 3.75. More than 50 % of bedroom space is lit with that daylight factor. It is evident that care homes are getting adequate daylight according to CIBSE (2014) guidelines through the windows in the living spaces, specifically in the bedrooms.

4.1.2 Analysis on glare situation of the southern bedroom, Burnt Tree Croft residential care home

Figure 2 shows that the Sheffield, Finningley region's annual sky coverage is near 70%. Despite the high percentage of overcast sky, daylight is adequate in the
Sheffield care homes. There are no perfect metrics that can evaluate glare. One research work done in 2019 evaluated 22 glare metrics and their corresponding

performance (Wienold, J. et al., 2019). There are metrics that account for saturation and contrast while evaluating glare. Some of them account for both. CIE Glare Index accounts for Contrast and Daylight Glare Probability - DGP accounts for both saturation and contrast, hybrid-based (Quek, G. et al., 2021). Distinguishing surfaces, objects, signage, tops, and other belongings in the room is essential for elderly people.

Figure 2: Sky Coverage Range(Source: Climate Consultant)



4.1.3 Solar Shading Devices simulation analysis

The first simulation without shading devices (Table 5) illustrates that the glare threshold is 134.39 cd/m2. According to the glare simulation, CIE Glare Index Range reaches 22.39. The Navvab, Mojtaba., (1997) chart indicates that the bedroom has a CIE Glare Index above the critical level of 19. Five simple shading devices have been incorporated and tested to see if the shading devices are working correctly to eliminate glare inside the room. Option 2 shows a CIE Glare Index range is 20.82, above the critical level. option 3, was in the same place but with an extra horizontal panel at eye level. This panel reduces the glare threshold to 77.29 cd/m2 (Table 5). The CIE Glare threshold is above the critical level. Option 4, placing shading device 500mm apart from the window with 2 angular horizontal panels. This shading device creates almost the same Luminance threshold for glare around like option 3 (Table 5). However, it decreases the CIE Glare index to 17.28. This shading device reduces daylight factor below 2, which is a matter of concern. Option 5, was tested with an increased number of the same angular panel placed closely, four diagonal panels. The luminance glare threshold decreased to 43.92 cd/m2 (Table 5). The CIE Glare index reduces to 13.93. However, on the other hand, the Average daylight factor reduces to 1.58 (Table 5). The final shading device, option 6, is designed with 4 thin horizontal panels with a dimension of 50mmX250mm. The simulation result shows an increased threshold for glare with 56.16 cd/m2. The CIE Glare Index is is 17.54, which is below the critical level of 19. With this level of index, the daylight factor is above 2. This provides a good prospect for this shading device to better control the glare inside the bedroom and maintain a standard daylight factor above 2. Of all the shading devices, this one is balanced with a Daylight Factor above 2 and below the critical level of CGI. The simulation shows improvement in autonomous and excessive daylight index. UDI(a) ranging from 100 to 3000 increased to 78.53. This indicates a clear improvement in overall lighting inside the bedroom after instillation of shading device.

5. Limitations

This study is dependent on previous literature work and computer simulations. The glazing thickness was not taken into consideration. In order to get the exact amount of light, the amount of window space covered by the curtain was ignored for the simulation.

6. Conclusion

This study closely observed and employed computer-based simulations for analysing the Useful Daylight Index, Daylight Factor and Glare. Three functioning care homes were chosen for this research work. They showed significant similarities in terms of daylight amount. The similarities go for all orientation windows. Useful daylight index for supplemental, autonomous and excessive daylight all showed a similar pattern; the Daylight Factor was in a similar range for all the projects on average. Then, one project, the Burnt Tree Croft residential care home's southern bedroom, was analysed for glare. The simulation resulted in a glare above the critical range in the CIE Glare index metric. Five different shading devices were employed to examine the glare. Shading devices placed apart from the window showed promising results. Among the three, only one shading device, option 6, was up to the mark to have a CIE Glare Index below the critical level, and the index is 17.54 (Table 5). On the other hand, the Daylight factor was above 2 for the bedroom.

To summarise, as adequate light ensures distinguishing contrast in the visual field, glare reduces contrast to limit the ability to distinguish objects in the visual field. Low contrast can become a severe problem in care homes. Excessive light and reflection can cause glare, which can be controlled in care homes. This research opens the door to understanding the current daylight and glare situation in the care homes in the UK climate. And the study outcome shows the correct type of fixed solar shading devices for the southern façade of existing UK care homes in Sheffield.

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