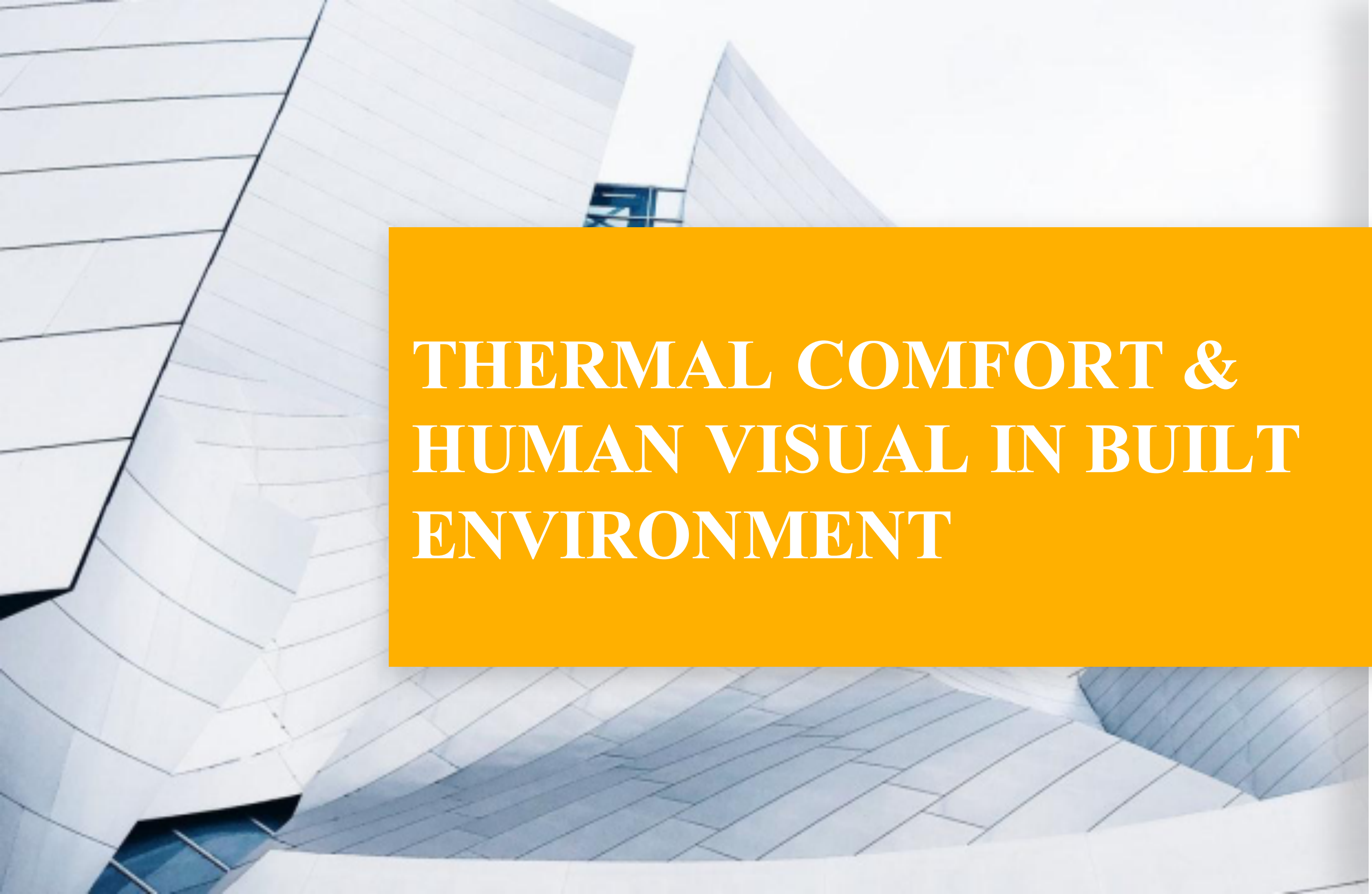

THERMAL COMFORT & HUMAN VISUAL IN BUILT ENVIRONMENT

ASSALAMMUALAIKUM & SALAM SEJAHTERA!

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Table of Content

WHAT IS INDOOR ENVIRONMENTAL QUALITY (IEQ)?

- Indoor Environmental Quality (IEQ) refers to all environmental factors that affect the ‘**health** and **comfort**’ of building occupants

  - JKR Guidelines on Indoor Environmental Quality (IEQ) for Government Office Building, 2013

- Indoor comfort constitutes **acoustic, thermal, visual** and **indoor air quality**

  - Pigliautile et al., 2019; Pistore et al., 2019

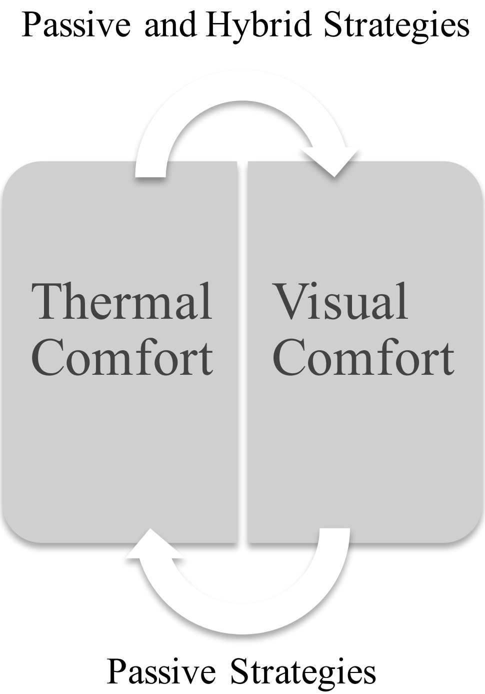
Indoor Air Quality	Acoustic Comfort
✔ Thermal Comfort	✔ Visual Comfort

Thermal Comfort & Visual Comfort

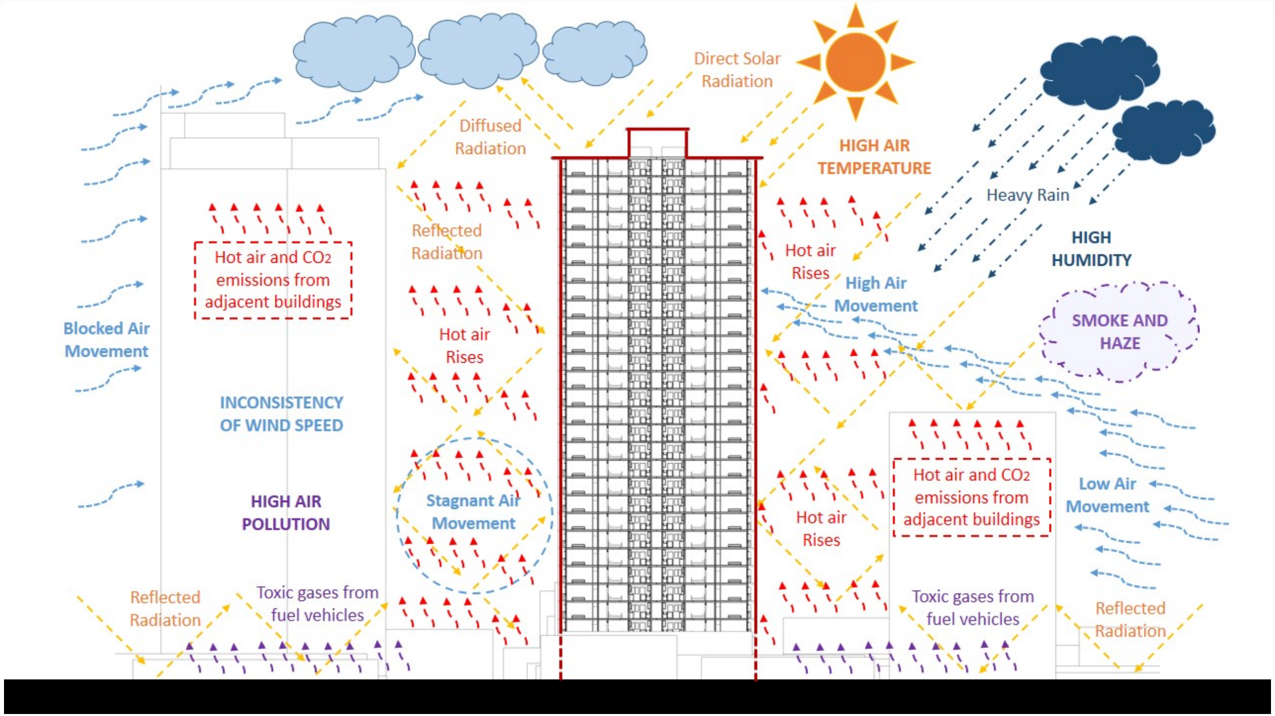
- For many years these components have been researched/designed in **isolation** by physiologists, engineers, architects, occupational health and industrial hygiene experts.

  (d'Ambrosio Alfano et al., 2019)

- This talk focuses on **thermal comfort** and **visual comfort** with the ultimate scope to maximise **passive and hybrid design** potentials.

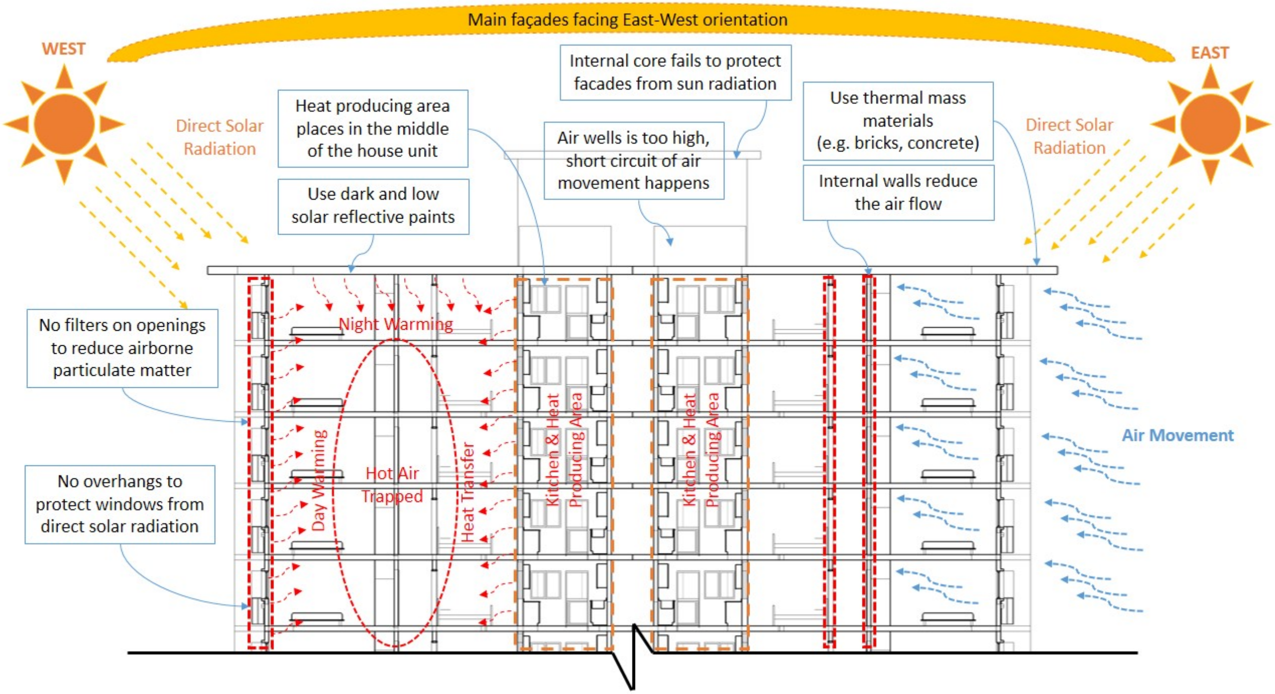


Factors of Indoor Discomfort (Surrounding)



Source: Author

Factors of Indoor Discomfort (Building Design)



Source: Author

Our Climate Condition

Temperature

- Uniform throughout the year
- Diurnal Temperature Range (DTR) for coastal areas is 5°C to 10°C
- And DTR for midland areas is 8°C to 12°C
- Peak day-time temperature average 29°C to 35°C
- Peak night-time temperature average 21°C to 24°C
- Average daily 26°C to 29°C

Daylight

- Average 6 to 8 hours daily
- Most days are covered by clouds

Humidity

- High humidity
- Average in wet season 70% to 90%
- Average in dry season 40% 50%
- Average high 90% to 100%

Wind

- Low air movement
- Northeast Monsoon (November – March)
- Transition Period Monsoon (March – May & October - November)
- Southwest Monsoon (May – September)
- Average wind in KL: 1.1 m/s

Source: Malaysian Meteorological Department (2020)

THERMAL COMFORT

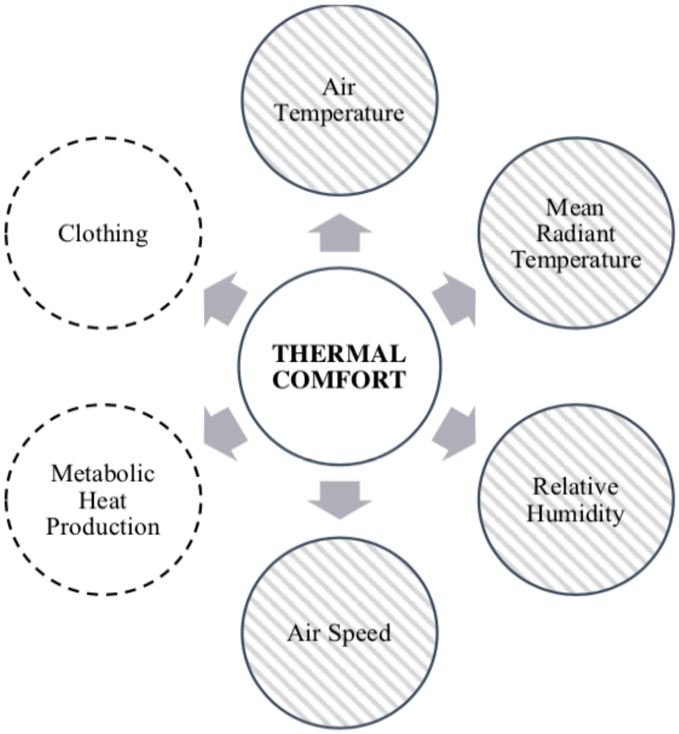
The Definition

“

That condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation.

- ASHRAE 55: Thermal Environmental Conditions for Human Occupancy

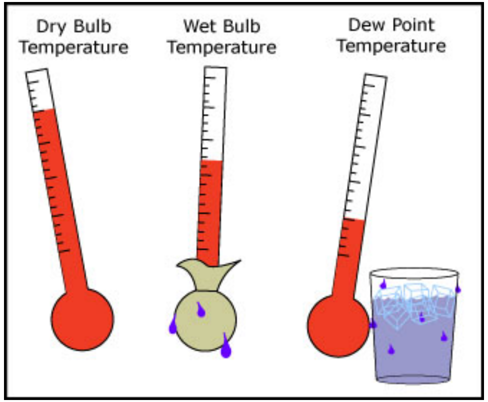
6 Primary Factors of Thermal Comfort



Source: CIBSE Guide A

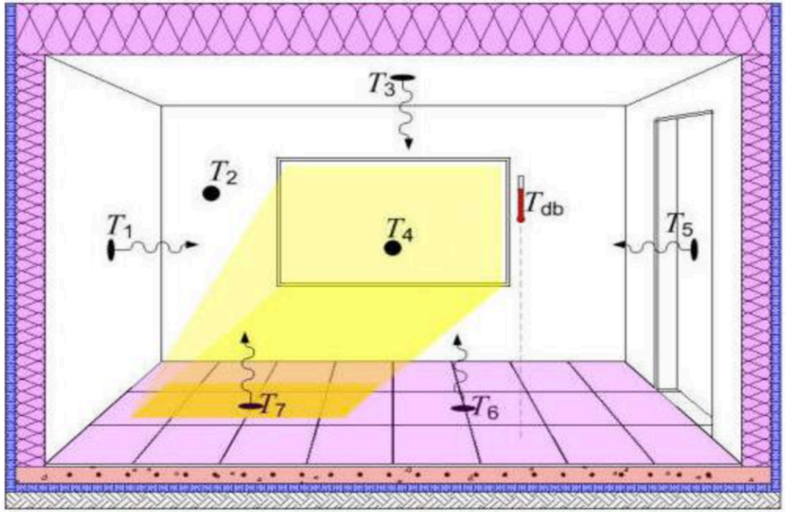
Air Temperature (AT)

- Air Temperature is also called ‘Dry-Bulb Temperature’
- ‘Dry Bulb’ means the air temperature (indicated by a thermometer) is exposed to air flow but shaded from the sun and radiation.
- What is ‘Wet-Bulb Temperature’?
- What is ‘Dew-Point Temperature’?



Source: https://evapopedia.com/

Mean Radiant Temperature (MRT)



Source: Bean, 2010

- The MRT is the average surface temperature of the surrounding walls, windows, roof and floor ($T_{1\text{-}7}$) .
- Hot or cold equipment like ovens, lights, and freezer also add to the MRT of a space.

Operative Temperature (OT)

Air Temperature (°C)	Mean Radiant Temperature (°C)	Operative Temperature (°C)
22	28	25
23	27	25
24	26	25
25	25	25
26	24	25
27	23	25
28	22	25

Table 1: Relationship of AT, MRT Towards OT

Source: Building Energy Efficiency Technical Guideline For Passive Design (2013)

- ‘Operative Temperature’ (OT) is the combination of AT and MRT to express their joint effect (CIBSE, 2015).
- Example: If the AT is 26°C, the maximum allowable MRT is 24°C in order to obtain an OT of 25°C (Table 1).

Defining Comfort Temperatures

Year	Author(s)	Type of Study	SEA Country	Ventilation Approach	Temperature range (°C)
1953	Ellis	Field study	Singapore	Natural	24.4 to 29.4
1992	Busch	Field study	Thailand	Mechanical	23.0 to 28.0
1997	Zain Ahmed et al.	Field study	Malaysia	Hybrid	24.5 to 28.0
2000	Karyono	Field study	Indonesia	Hybrid	23.3 to 29.5
2000	Khedari et al.	Field study	Thailand	Natural	27.0 to 31.0
2001	Sapian et al.	Field study	Malaysia	Natural	26.0 to 29.5
2001	Ismail & Barber	Field survey	Malaysia	Mechanical	20.8 to 28.6
2005	Sh Ahmad	Simulation	Malaysia	Natural	23.6 to 28.6
2012	Mohd Sahabuddin	Simulation	Malaysia	Natural	25.0 to 27.0
2014	SIRIM	Simulation	Malaysia	Mechanical	24.0 to 26.0

Source: Author

- The lowest of 20.8°C and the highest of 31.0°C.
- Average lowest is **24.2°C** and the average highest is **28.6°C**.

a) Humprey's Equation

Tn = 11.9 + 0.534 To

- Humprey's equation to predict comfort temperature (Tn) in a naturally ventilated building using outdoor monthly average temperature (To)

- In July 2017, Kuala Lumpur received an average outdoor air temperature (To) of **29°C** (MET, 2017).

- Accordance with the Humprey's equation, the comfort temperature (Tn) that should be aimed is **27.4°C**.

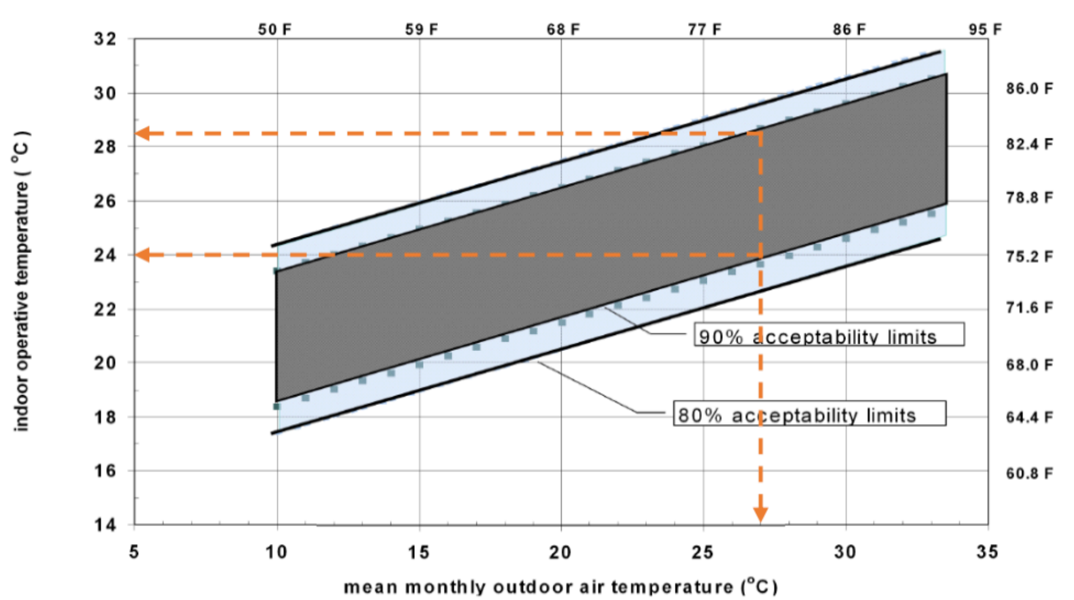
b) CIBSE Guide A Equations

a) Upper margin: $\boldsymbol{\theta_{com} = 0.33\ \theta_{rm} + 20.8}$

b) Lower margin: $\boldsymbol{\theta_{com} = 0.33\ \theta_{rm} + 16.8}$

- Where **θcom** is the comfort temperature (°C) and **θrm** is the mean of the daily mean outdoor temperature (°C)
- The daily mean outdoor temperature in Kuala Lumpur is **24°C** (Milne, 2016)
- The lower margin of the comfort temperature is **24.7°C** and the upper margin is **28.7°C**.

c) ASHRAE 55 Diagram



Source: ASHRAE 55 (2013)

- Kuala Lumpur's mean monthly outdoor air temperature is **27.0°C** (Milne, 2016).
- Thus, suggested temperature range is between **24.0°C** and **28.4°C** (ASHRAE 55, 2013).

Relative Humidity (RH)

- ‘Relative Humidity’ is a measure of the amount of water (moisture) in the air to the maximum amount of water the air can absorb (Tang & Chin, 2013).
- In tropical climate, when the OT rises above 28^{o}C, the skin damp with sweat may become apparent (CIBSE, 2015).
- Controlling the humidity of <70% is also important in the context of preventing microbiological growth.

Air Speed (AS)

- ‘Air Speed’ is the rate of air movement at a point, without regard to direction.
- In indoor spaces, AS is crucial to stimulate evaporative cooling effect – heat-loss rate by both convection and evaporation (Lechner, 2014).
- In a hot-humid climate, using fan is one of the common methods to achieve thermal comfort through evaporative cooling.

Thermal Comfort Conditions

Parameters	CIBSE Guide A (2015)	ASHRAE 55 (2013)	MS1525* (2014)
Recommended Thermal Comfort Criteria			
Operative Temperature	24.7 – 28.7ºC	24.0°C – 28.4ºC	24.0°C – 26.0ºC
Relative Humidity	40 – 70 %RH	<65 %RH	50 – 70 %RH
Air Speed	0.15 – 0.50 m/s	0.15–0.80 m/s	0.15 – 0.50 m/s

Source: Author

Note: *For Air Conditioned Space

3 Basic Thermal Comfort Approaches

3 approaches in order of priority:

A. Dealing with Solar Radiation (Heat Avoidance)

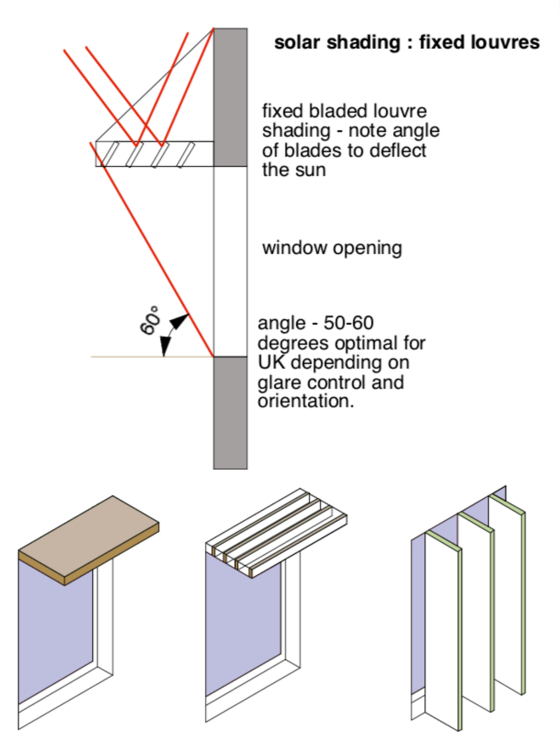
B. Air Movement through The Building (Modify Thermal Comfort Parameters)

C. Passive/Hybrid Cooling Strategies (Additional Cooling Effect Assistance)

A) Dealing With Solar Radiation

1) Shading Device

- Devices such as wide roof overhangs, shading fins, thick vegetation or external shutters protect windows and wall surfaces.
- Shade can also be aided using large overhangs on roofs and other elements of the building fabric to shield openings and glazed areas.



(Source: Edinburgh College of Arts, 2011)

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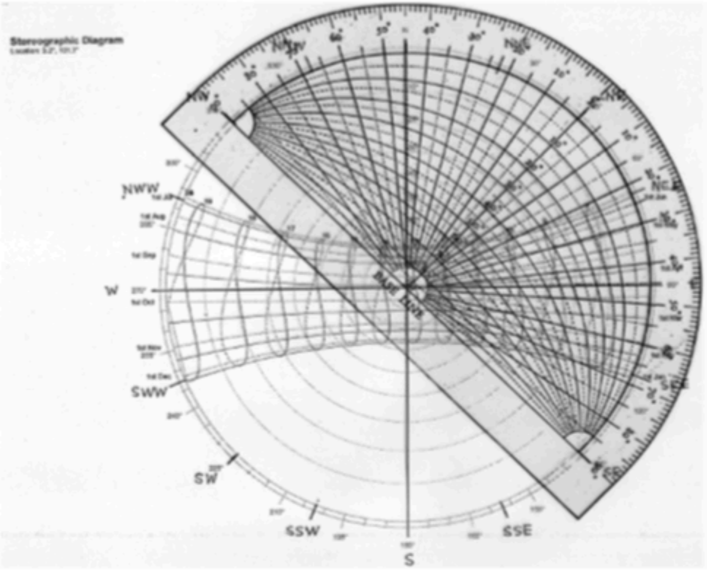
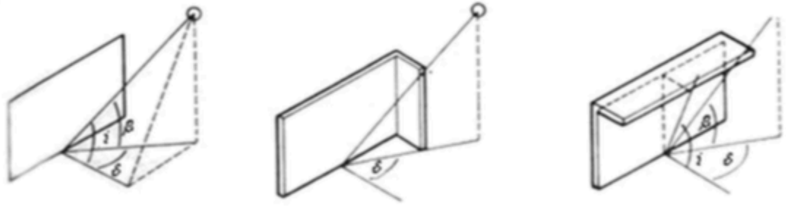


Figure 3. Superimposed shadow angle protractor on sun path diagram

(Source: MS1525:2014)



a) Solar azimuth and Solar altitude

b) Altitude and HSA

c) Solar altitude, HSA and VSA

Figure 4. Solar angles and shadow angles

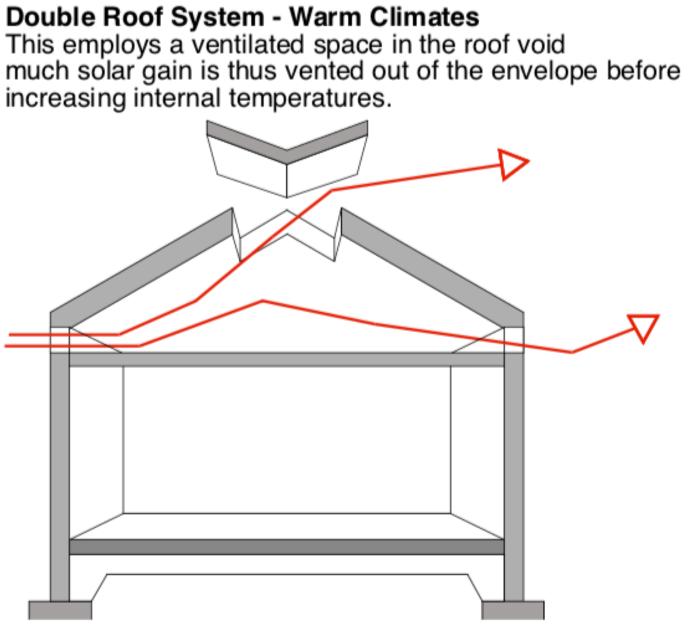
Table 2. Shadow angle guidelines for Kuala Lumpur

Orientation	VSA	HSA		Remarks
		(-)	(+)	
N	65°	60°	60°	Full shading
NE	35°	-	20°	Shading from 09:30 hr
E	35°	-	-	Shading from 09:00 hr
SE	30°	18°	-	Shading from 09:30 hr
S	60°	55°	55°	Full shading
SW	30°	-	15°	Shading until 17:00 hr
W	35°	-	-	Shading until 17:00 hr
NW	45°	15°	-	Full shading

Cont.

2) Double Roof

- A double roof system uses a ventilated air gap between an upper exposed roof and a lower protected roof.
- Much of the solar gain from the upper leaf is carried away by the air before it can pass to the lower leaf.



(Source: Edinburgh College of Arts, 2011)

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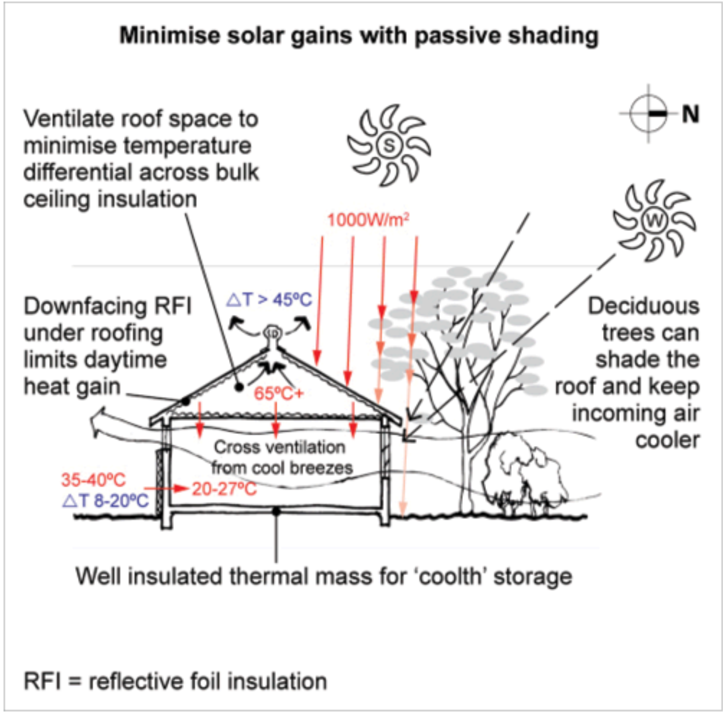
3) Insulation

- Any surface that is exposed to high levels of solar radiation should be well insulated to reduce the transfer of heat from outside to inside.
- The best location for this insulation is on the outside surface.



(Source: https://www.yourhome.gov.au/)

Cont.

4) Solar Control Glass

- External shading can reduce 80% solar radiation.
- If external shading is not practical, low solar gain glazing can be used (can reduce 60% solar radiation).
- Clear glazing and indoor shading (blinds/curtains) are the least effective option as they allow >80% of radiation to enter the space.

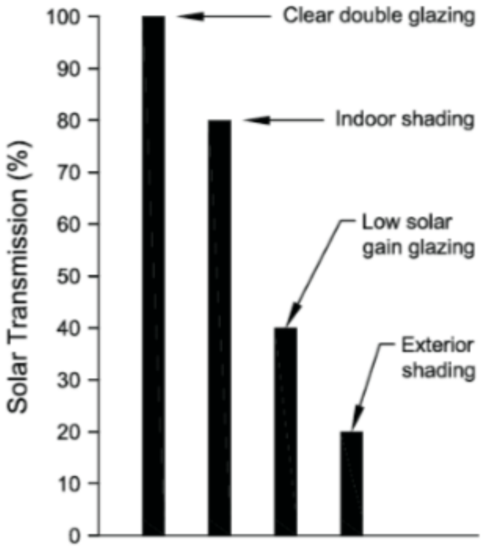
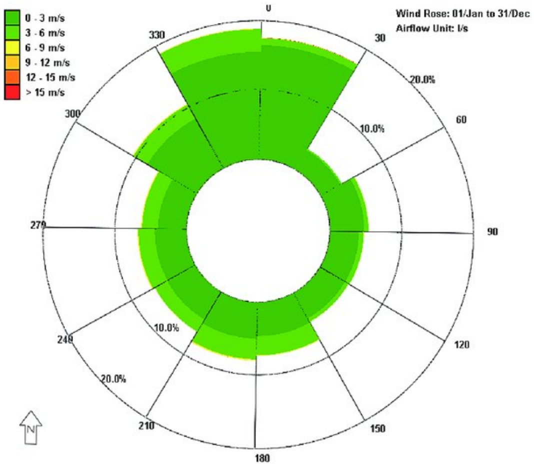


Figure 9.2g Exterior shading devices block about 80 percent of the solar gain through clear windows, while indoor shading blocks only about 20 percent. Low solar gain glazing blocks almost as much solar gain as exterior shading, but, unfortunately, also blocks much of the winter sun and light from the view.

B) AIR MOVEMENT THROUGH THE BUILDING

1) Wind Orientation and Wind Direction

- Wind enters at maximum pressure when perpendicular to an opening.
- Indoor ventilation is effective with angled paths because they create greater turbulence indoors.
- Fin walls can increase the ventilation through windows on the same side of a building by changing pressure distribution.

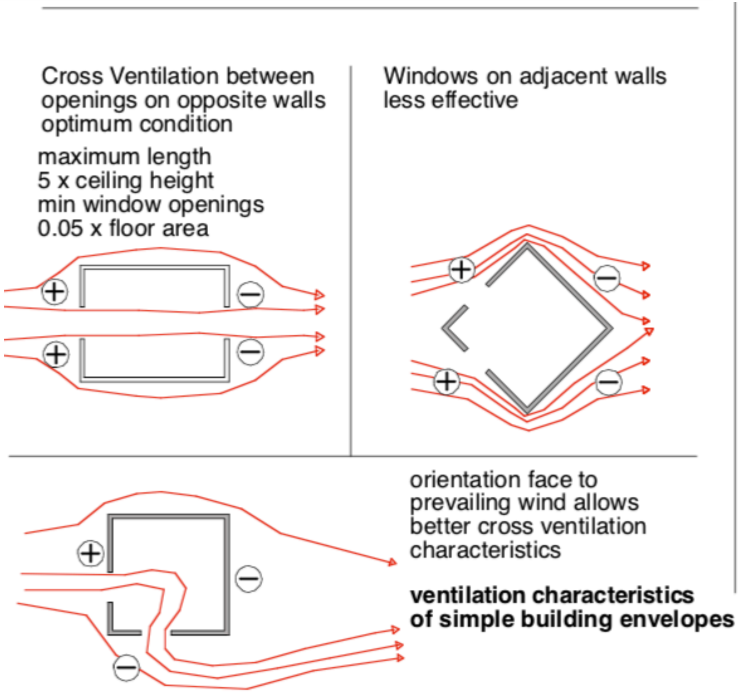


Wind rose, Kuala Lumpur Subang, Malaysia (Integrated Environmental Solution, 2012).

Cont.

2) Window Locations

- Cross ventilation is very effective on opposite ends of a building enclosure because of the movement of air from positive pressure to negative pressure.
- Asymmetric placing of windows in a building enclosure can improve air movement.

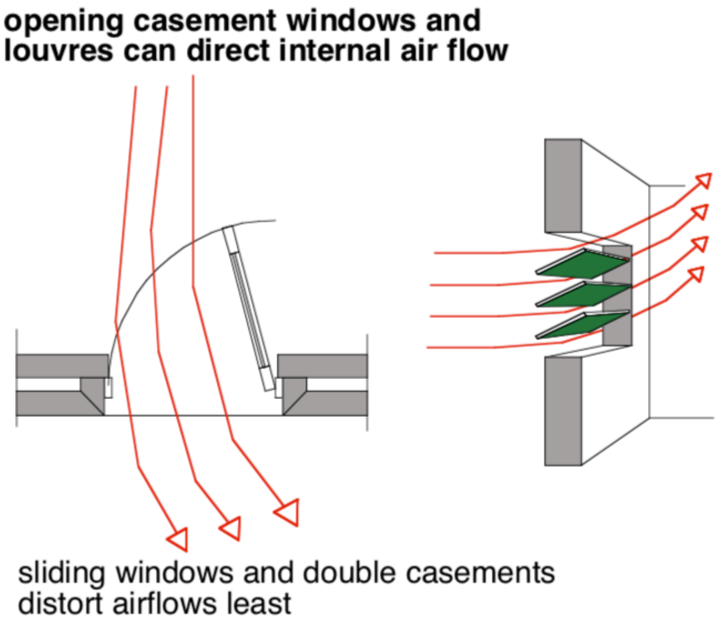


(Source: Edinburgh College of Arts, 2011)

Cont.

3) Window Types

- Double hung and casement windows do not change the direction of any airstream, they block a minimum of 50% of any airflow.
- Casement windows however whilst allowing greater air ingress can deflect airstreams in a similar way to fin walls.

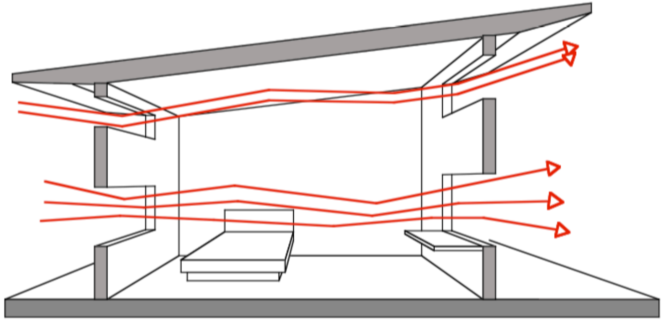


(Source: Edinburgh College of Arts, 2011)

Cont.

4) Vertical Disposition of Windows

- For comfortable ventilation, windows should be low at the level of persons in any room placing a window sill in the region of 600-1000mm above floor level.
- Additional high windows should be considered in some climatic circumstances to exhaust hot air reaching the ceiling.



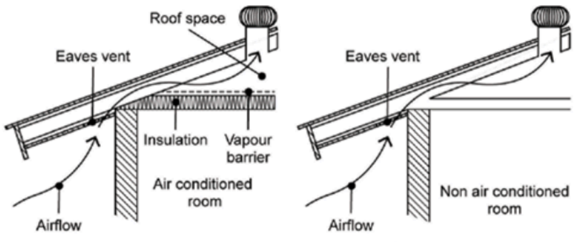
in warm climates:
align window openings to user height - eg desks, seats, tables.
high level openings allow night cooling of thermal mass

(Source: Edinburgh College of Arts, 2011)

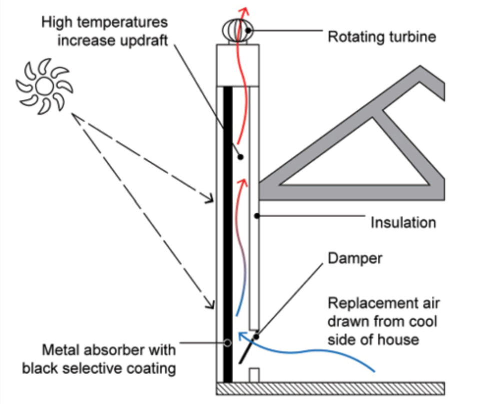
Cont.

5) Roof Vents

- Passive roof ventilators are typically used to reduce the accumulation of solar radiation.
- Roof ventilators can also do facilitate stack ventilation and have a radical effect on the amount of air extracted.
- The use of foil insulation and light coloured roofing limits radiant heat flow into the roof space.



Using ventilation to cool the roof space

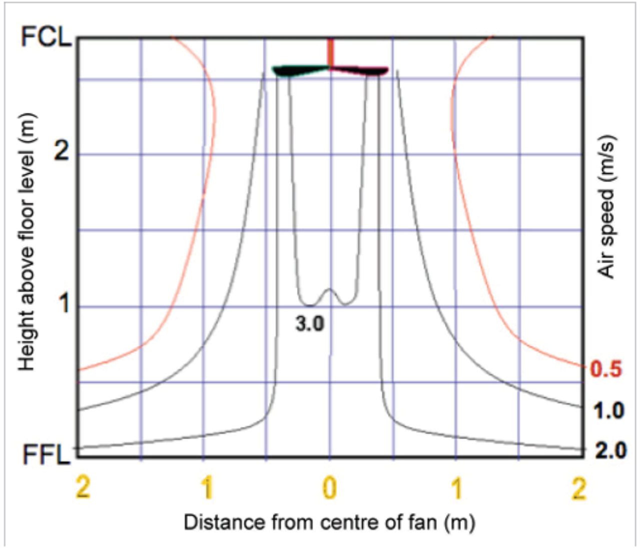


(Source: https://www.yourhome.gov.au/)

Cont.

6) Fans

- In tropical climates, wind is insufficient and inconsistent.
- Fans provide consistent air movement and supplementing breezes during still periods.
- It can assist evaporative cooling and circulate indoor air.
- Fans should be located centrally in each space because air speed decreases with distance from the fan.

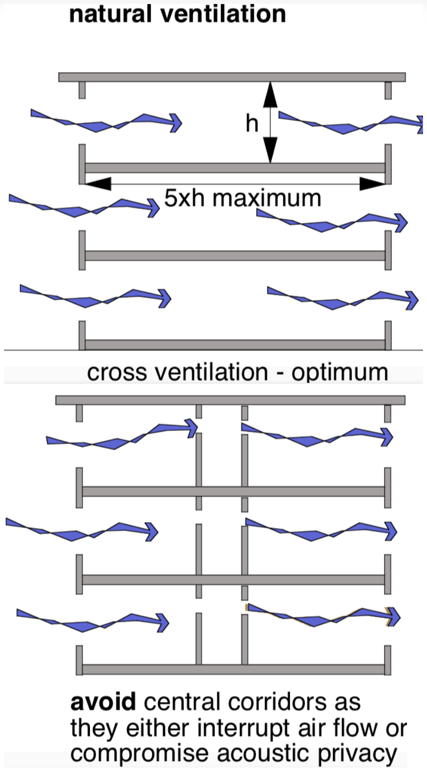


(Source: https://www.yourhome.gov.au/)

Cont.

7) Internal Planning Guidelines

- Open plan forms are preferable for better air movement.
- Where partitions are unavoidable, high internal vents is possible for cross ventilation.
- Passive ventilation is effective with single corridor layout.
- For cross ventilation to be effective a maximum cross section of 5x ceiling height is recommended.



(Source: Edinburgh College of Arts, 2011)

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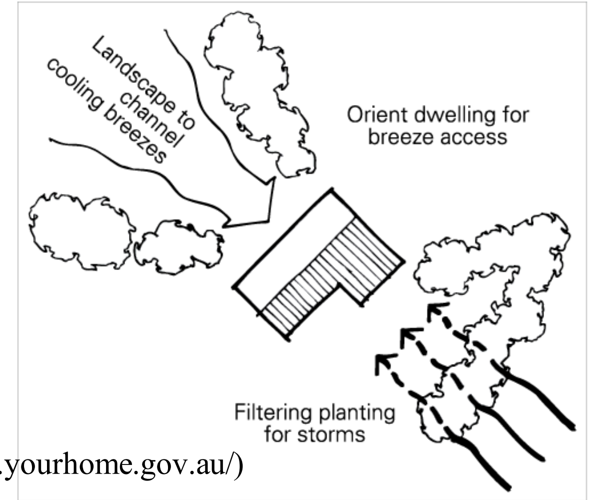
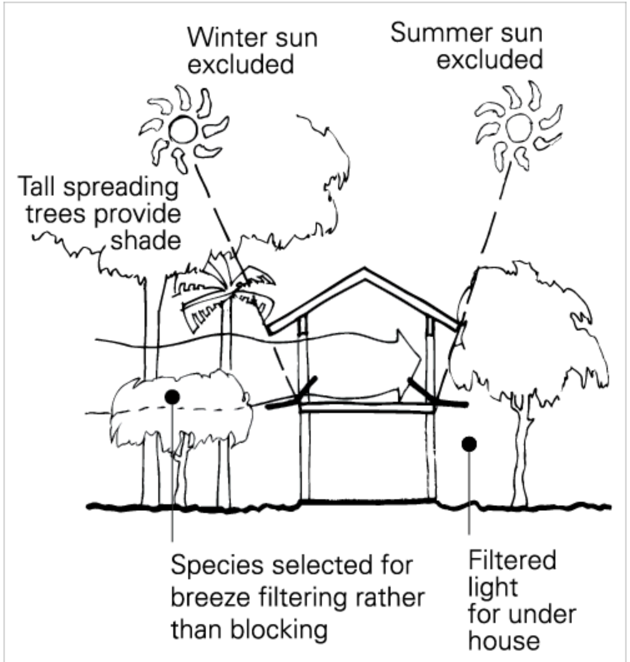
8) Greeneries for Shade and Cool Breezes

- Tall trees to give shade
- Small trees to filter dust and cool the breezes





(Source: https://www.yourhome.gov.au/)

C) PASSIVE/HYBRID COOLING STRATEGIES

Remove heat by using a heat sink method of passive cooling such as:

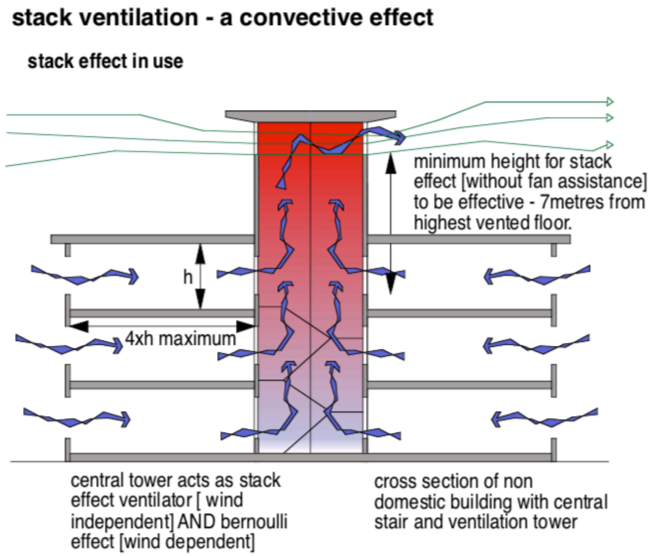
- Stack Effect
- Night Flush Cooling (More suitable for hot & dry)
- Earth Cooling (More suitable for hot & dry)

Note: In tropical climate, passive cooling may not be sufficient to achieve thermal comfort. Thus, mechanical assistance is required to maintain comfort conditions.

Cont.

1) Stack Effect

- Stack effect can naturally exhaust air if the indoor temperature is greater than the outdoor temperature between openings.
- A height of 7 metres between inlet and outlet is desirable.
- However, it is a relatively weak force that cannot move air quickly. Combination of Bernoulli-shaped and fans may increase its efficiency.

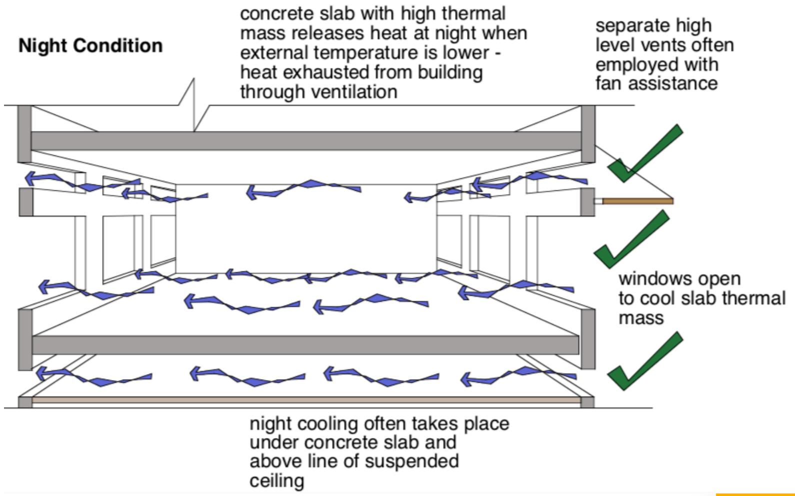


(Source: Edinburgh College of Arts, 2011)

Cont.

2) Night Flush Cooling

- Suitable for hot and dry climate but still effective in humid regions with the daily range above 11^0C.
- Windows or fans should be used to flush out the hot air at night.
- The mass has to be on the indoor side of the insulation.
- Windows should be open at night and closed during the day.

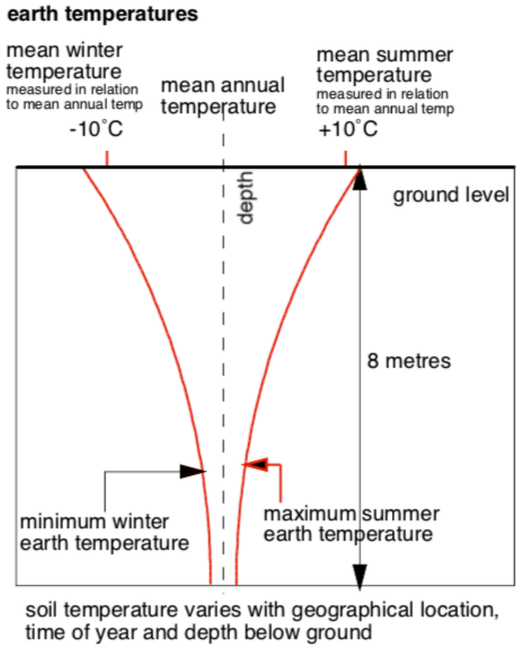


(Source: Edinburgh College of Arts, 2011)

Cont.

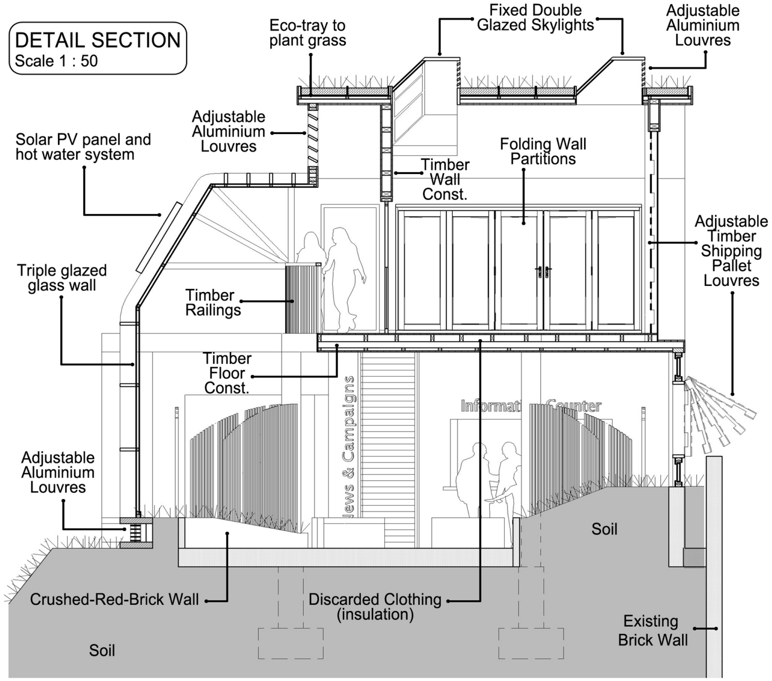
3) Earth Cooling

- Earth or wet earth is both a good conductor and absorber of heat.
- At 2 meters depth, the soil temperature is 6^0C lower than ground surface temperature.
- In humid climates, the condensation on walls or in earth tubes might cause biological activity and health risk.
- Fans are required to extract cool air into the building core.



(Source: Edinburgh College of Arts, 2011)

Application in Building Design



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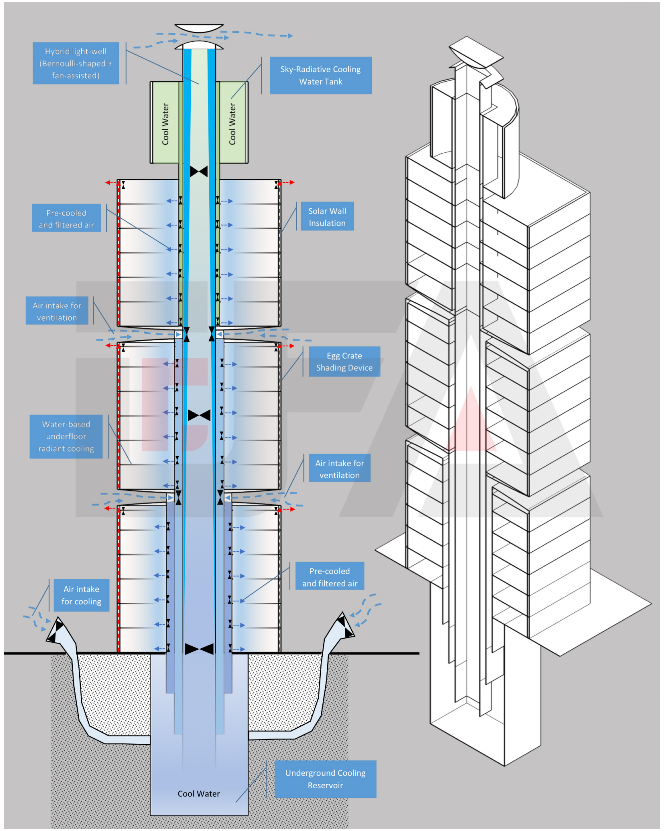


Summary

- Remove solar gain as much as possible that causes temperature rise in the building.
- Air movement through a building can increase evaporative cooling on the skin.
- Night flushing allows cool air to flush out the heat of the building.
- Passive cooling systems are unable to provide the cooling required without the assistance of fans.
- The building design should integrate passive cooling techniques at the beginning of a design.

VISUAL COMFORT

The Definition

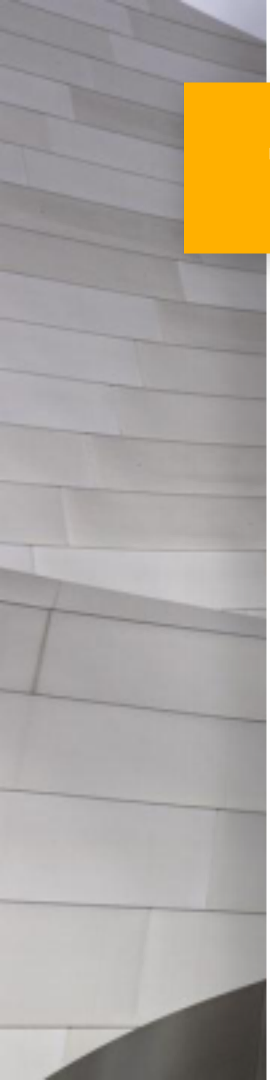
“

Good lighting will create a visual environment that enables people to see, to move and to perform visual tasks efficiently and safely without causing undue visual fatigue and discomfort.

- ISO 8995 : Lighting of Indoor Work Places

Sources of Light

- Any source or object which emits its own light:
  - Natural (Sun – Direct, Diffuse, Reflected)
    - (Fire – Candles etc.)
  - Artificial (Light Fixtures – Lamps etc.)
- **Lighting** includes the use of both **natural illumination** by capturing **daylight** as well as artificial **light sources** like lamps and **light** fixtures (ISO 8995, 2002).
- **Daylighting** (using windows, skylights, or **light** shelves) is sometimes used as the main **source of light** during daytime in **buildings**.



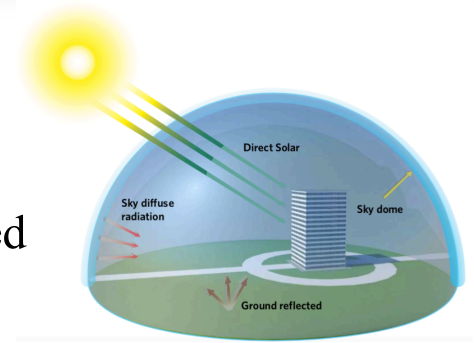
The Relevance of Harvesting Solar Energy

- Important to environmental design which can be harnessed to provide:
  - An enhanced daylight strategy for buildings
  - Passive solar gain can be used to heat water for daily usage
- Daylight and sunlight are subjectively important components in good architectural design.
- Can save energy consumption for lighting and water heating.

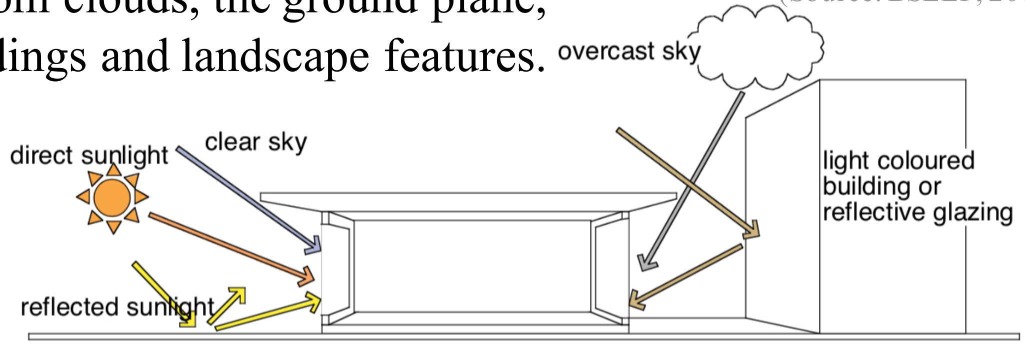
Sources of Daylighting

Daylight on entering a building can originate from a variety of sources:

- **Direct** sunlight
- **Diffuse** light from the sky after it has been reflected by the gases and water droplets in the atmosphere.
- **Reflected** light from clouds, the ground plane, surrounding buildings and landscape features.



(Source: BSEEP, 2013)



The Various Forms of Daylight

(Source: Edinburgh College of Arts, 2011)

Daylighting Goals

- **Allow light to penetrate deeper** into a building to raise interior illumination levels and to reduce the illumination gradient across the room.
- Reduce or **prevent severe direct glare** of unprotected windows and skylights.
- **Prevent excessive brightness ratios**, for example direct sunlight on a work surface causing difficulties in viewing documents.
- **Encourage diffuse light** by means of multiple reflections from ceiling and walls to minimise visual discomfort

Daylight Factor (DF)

- DF is the ratio expressed as a percentage of the illumination outdoors to indoors on an overcast day.

- Typical preferable daylight factors are:

Type of Space	**Daylight Factor [%]**
Art studios & Galleries	3-5
Factories & Laboratories	2.0
Offices	1.0
Living Rooms, Corridors, Bedrooms	0.5

(Source: Edinburgh College of Arts, 2011)

Ligthing Illuminance Levels

Recommended Average Illuminance (Incidence) levels (Source: MS1525:2014)

Task and Applications	Illuminance (Lux)	Minimum CRI
a) Lighting for infrequently used area:		
- Minimum service illuminance	20	30
- Interior walkway and car-park	100	40
- Hotel bedroom	100	60
- Lift interior	100	40
- Corridor, passageways, stairs	100	40
- Escalator, travellator	150	40
- Entrance and exit	100	60
- Staff changing room, locker and cleaner room, cloak room, lavatories, stores.	100	60
- Entrance hall, lobbies, waiting room	100	60
- Inquiry desk	300	80
- Gate house	200	80
b) Lighting for working interiors		
- Infrequent reading and writing	200	80
- General offices, shops and stores, reading and writing	300 - 400	80
- Drawing office	300 - 400	85
- Restroom	150	80
- Restaurant, canteen, cafeteria	200	80
- Kitchen	150 - 300	80
- Lounge	150	60
- Bathroom	150	80
- Toilet	100	60
- Bedroom	100	80
- Class room, library	300 - 500	80
- Shop/supermarket/department store	200 - 750	80
- Museum and gallery	300	80
c) Localised lighting for exacting task		
- Proof reading	500	80
- Exacting drawing	1000	80
- Detailed and precise work	2000	80

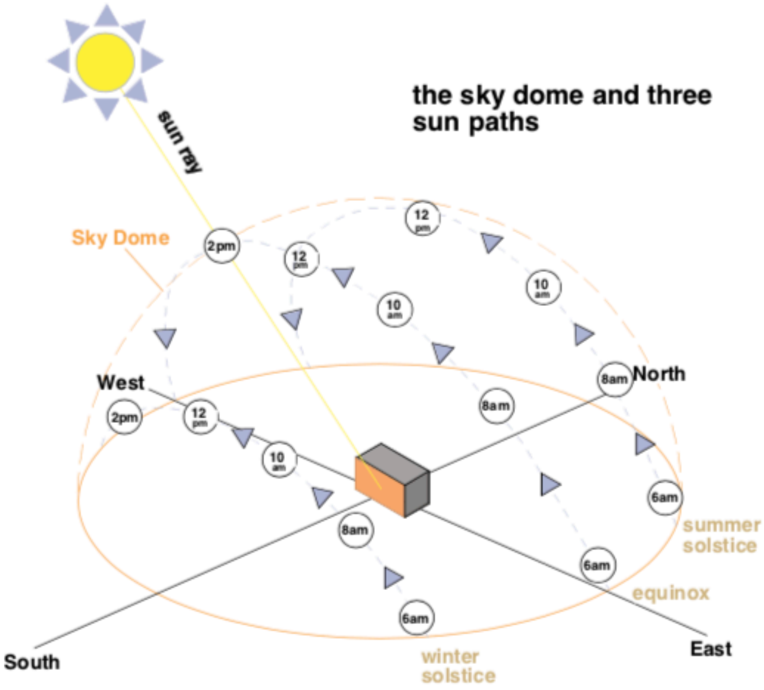
- Working environments lit uniformly to less than 200 lux tend to be rated as unsatisfactory for continuous occupation (ISO8995, 2002).

Basic Daylight Strategies

1. Orientation
2. Opening Design
3. Building Form
4. Internal Layout
5. Roof lighting
6. Fenestration
7. External & Internal Light Shelves
8. Colour

1) Orientation

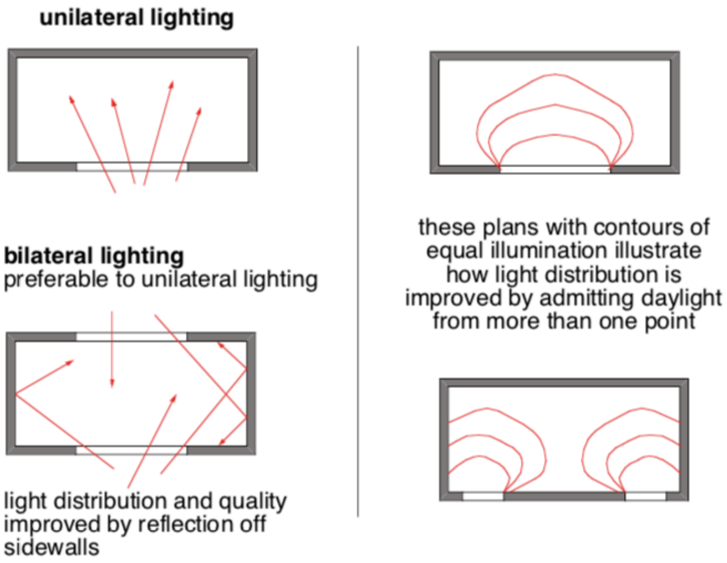
- The best building orientation is North-South. Quantity of light is low but the quality of sunlight passing through a space is high.
- This orientation has little problem with glare associated with direct sunlight and openings do not require solar control devices.
- The worst orientations are East-West. Facing to the strong sun direction and directional light incident on a surface.



(Source: Edinburgh College of Arts, 2011)

2) Opening Design

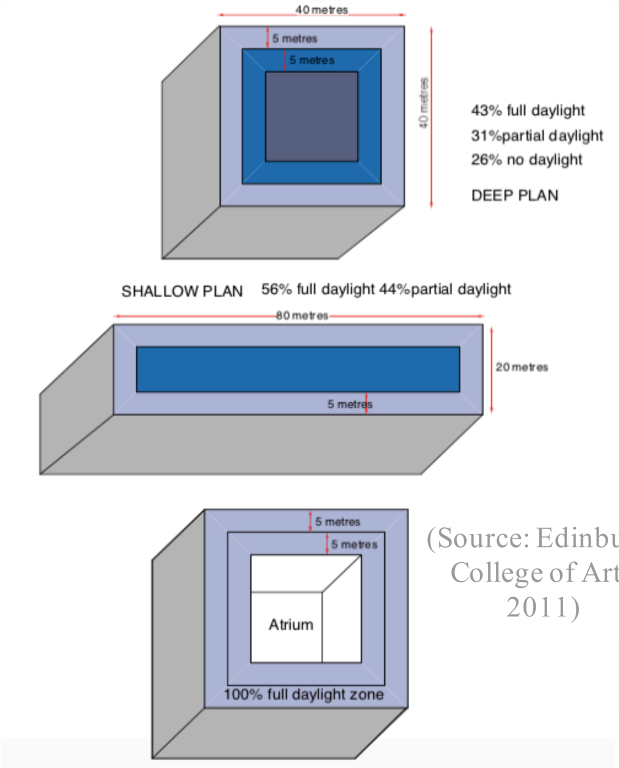
- Place windows on more that one wall for better light distribution and less glare.
- Place windows adjacent to interior walls to act as low intensity reflectors to reduce strong directionality of daylighting.
- Sunlight can be filtered and softened by having trees, plants and greenery.
- Shade windows from excess sunlight using overhangs & louvers.



(Source: Edinburgh College of Arts, 2011)

3) Building Form

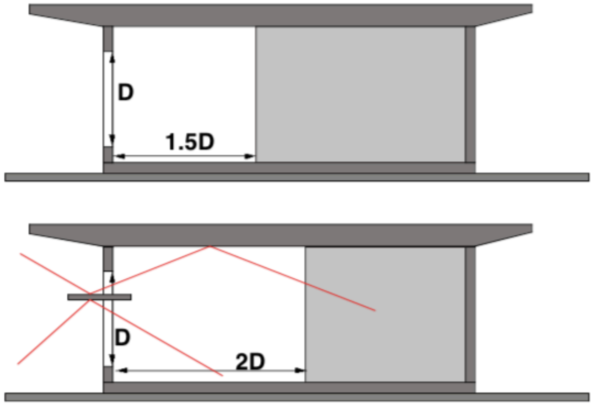
- A good rule of thumb is that spaces can only be adequately day lit to a depth of 5m from the edge of the building envelope.
- A building can by changing shape have radically different daylighting levels.
- By designing buildings with central atria, daylighting can be introduced deep into the building.
- The amount of light available at the base is a function of the translucency of the atrium roof, the reflectance of the surrounding walls and the geometry of the space – width vs. depth.



(Source: Edinburgh College of Arts, 2011)

4) Internal Layout

- Open plan concept (usable space) should be zoned nearer to the building façade.
- Non-usable space/storage area should be located far from building facade in order to get maximum daylight and external views.
- Internal partition wall with more 1.2 meters height is encouraged to use transparent or glazed materials in order to get optimum daylight and visual comfort towards external views.
- Apply effective floor to ceiling height.

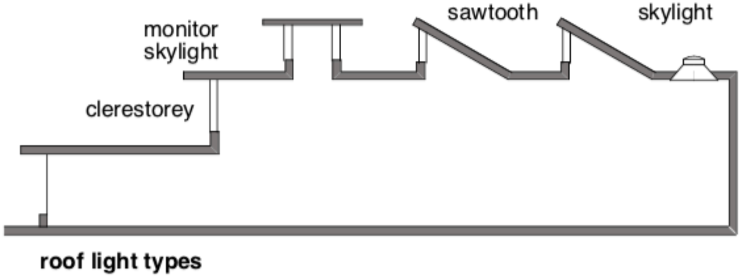


A 'rule of thumb' for daylight penetration is 1.5 x the height of a window. This can increase to 2x with the addition of a light shelf

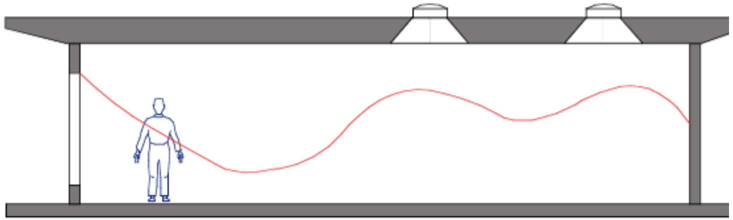
(Source: Edinburgh College of Arts, 2011)

5) Roof Lighting

- Rooflighting can allow large areas of uniform illumination deep into a building plan.
- Horizontal openings receive much more light than vertical openings.
- However it is difficult to shade adequately with louvres, thus, it is appropriate to utilise vertical glazing in the form of clerestorey, monitor or sawtooth profiles.



(Source: Edinburgh College of Arts, 2011)



(Source: Edinburgh College of Arts, 2011)

Cont.

Roof Monitor

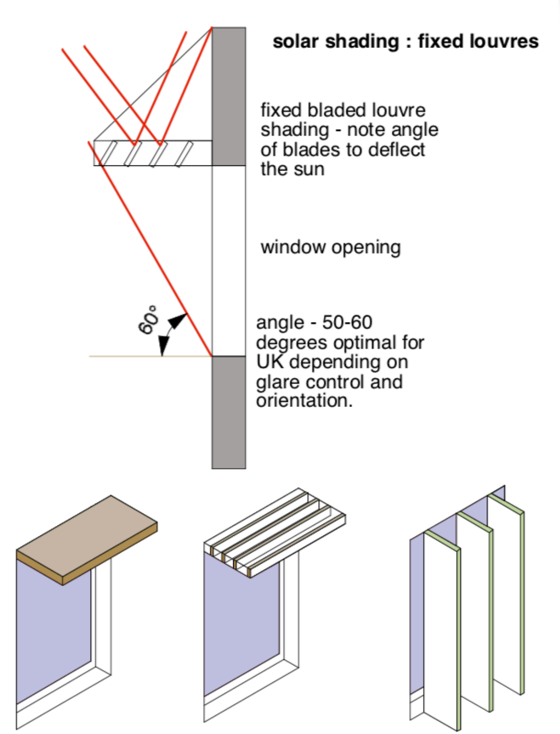
Sawtooth

Skylight

(Source: BSEEP, 2013)

6) Fenestration

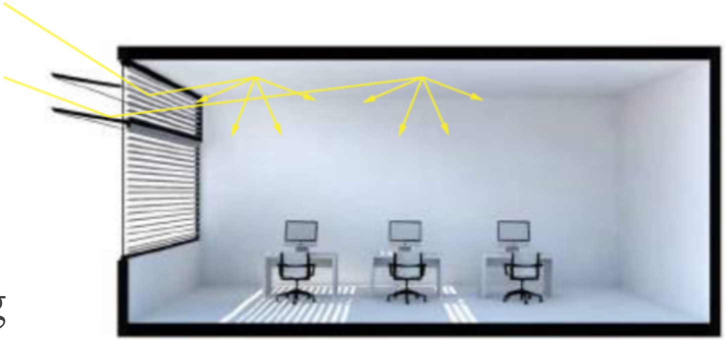
- Fenestration for daylighting should be designed to prevent direct solar radiation while allowing diffused light.
- A 'rule of thumb' for daylight penetration is 1.5x the height of a window. This can increase to 2x with the addition of a light shelf.
- Use shading device to avoid direct sunlight / glare by using blinds or facade screening.



(Source: Edinburgh College of Arts, 2011)

7) External & Internal Light Shelves

- External light shelves – capturing daylight from outside and deflecting it deeper into the space.
- Internal light shelves – reducing the light level near the façade to reduce the brightness contrast in the room.
- The blinds on glazing windows provide glare protection and enhance visual comfort.

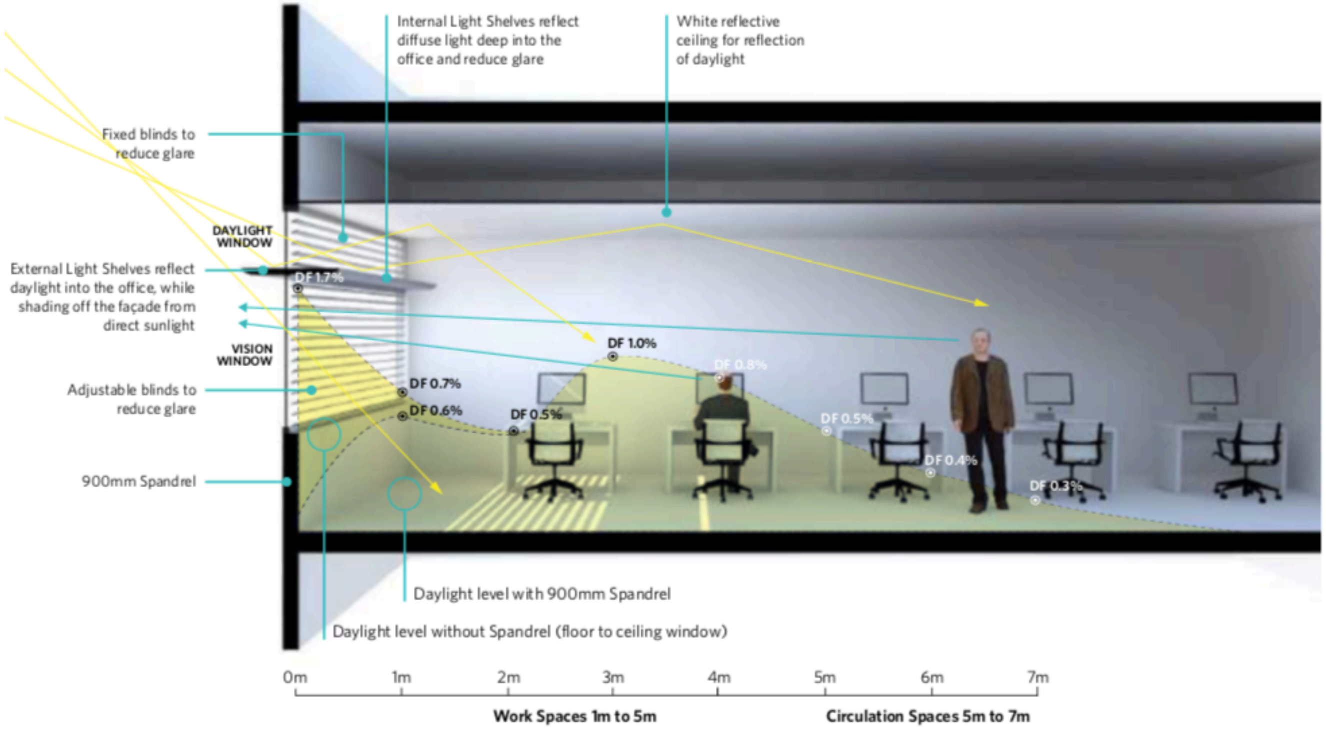


External Light Shelf

Internal Light Shelf

(Source: BSEEP, 2013)

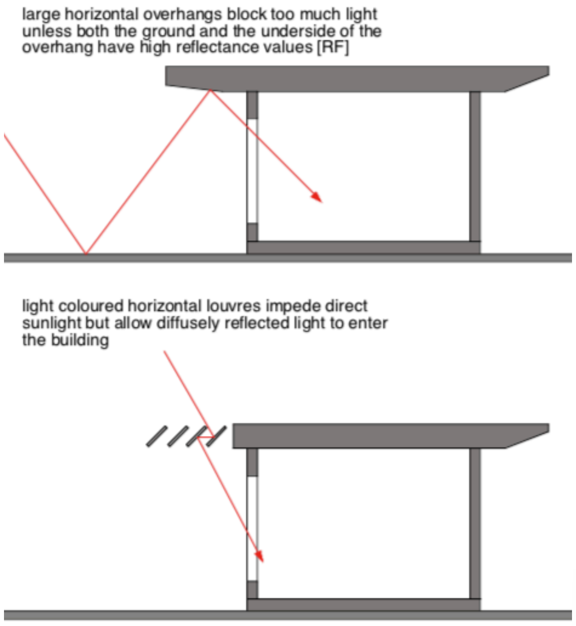
Cont.



Internal Light Shelves reflect diffuse light deep into the office and reduce glare
White reflective ceiling for reflection of daylight
Fixed blinds to reduce glare
DAYLIGHT WINDOW
External Light Shelves reflect daylight into the office, while shading off the façade from direct sunlight
VISION WINDOW
Adjustable blinds to reduce glare
900mm Spandrel
DF 1.7%
DF 1.0%
DF 0.8%
DF 0.7%
DF 0.6%
DF 0.5%
DF 0.5%
DF 0.4%
DF 0.3%
Daylight level with 900mm Spandrel
Daylight level without Spandrel (floor to ceiling window)
0m
1m
2m
3m
4m
5m
6m
7m
Work Spaces 1m to 5m
Circulation Spaces 5m to 7m

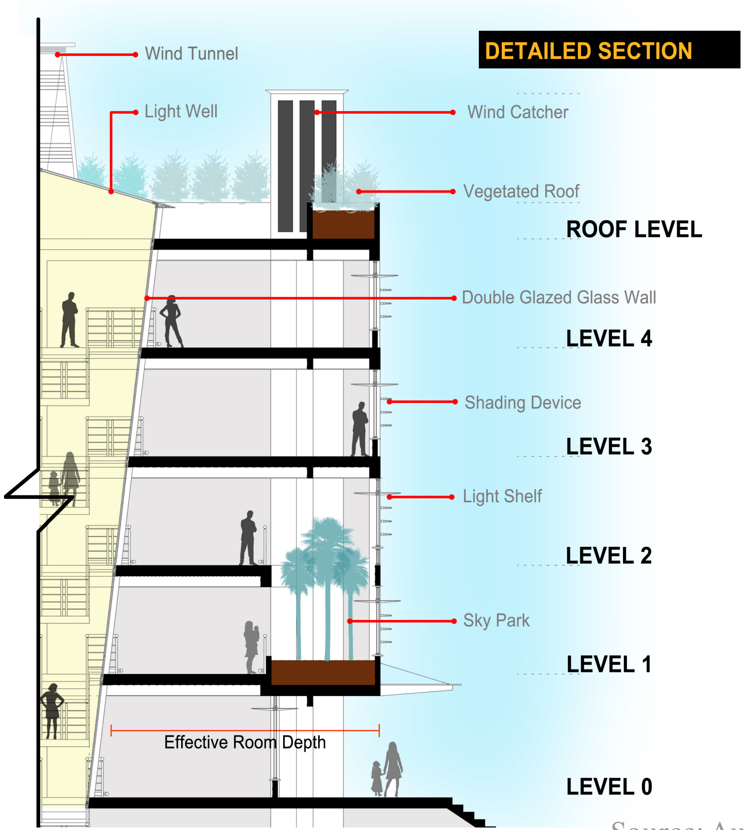
8) Colour

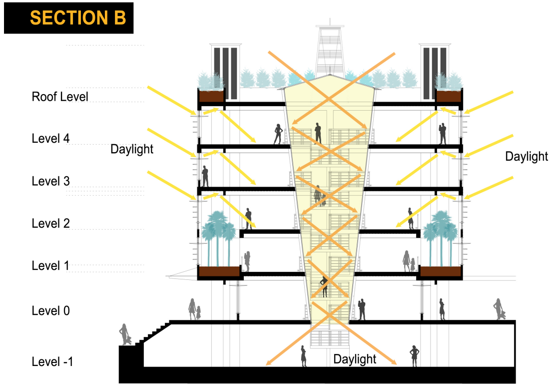
- Use light colours both indoors and outdoors to reflect more light into the building.
- Windows adjacent to or opposite to light coloured walls receive more daylight.
- Light coloured facades are important to reflect light to other buildings especially at low level.
- Light coloured interiors diffuse light to reduce shadow effects glare and excessive brightness ratios.
- Ceilings should have the highest possible reflectance factor followed by back walls, side walls, floors and furniture.

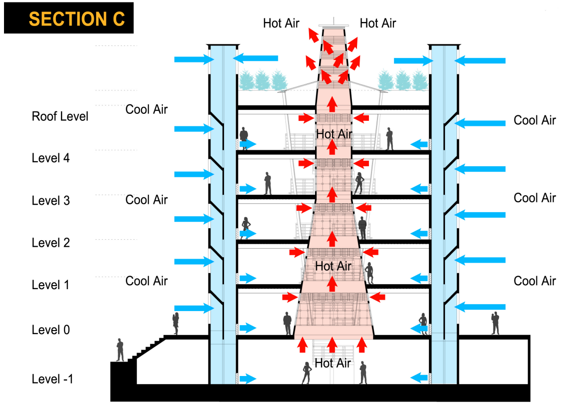


(Source: Edinburgh College of Arts, 2011)

Application in Building Design







Source: Author

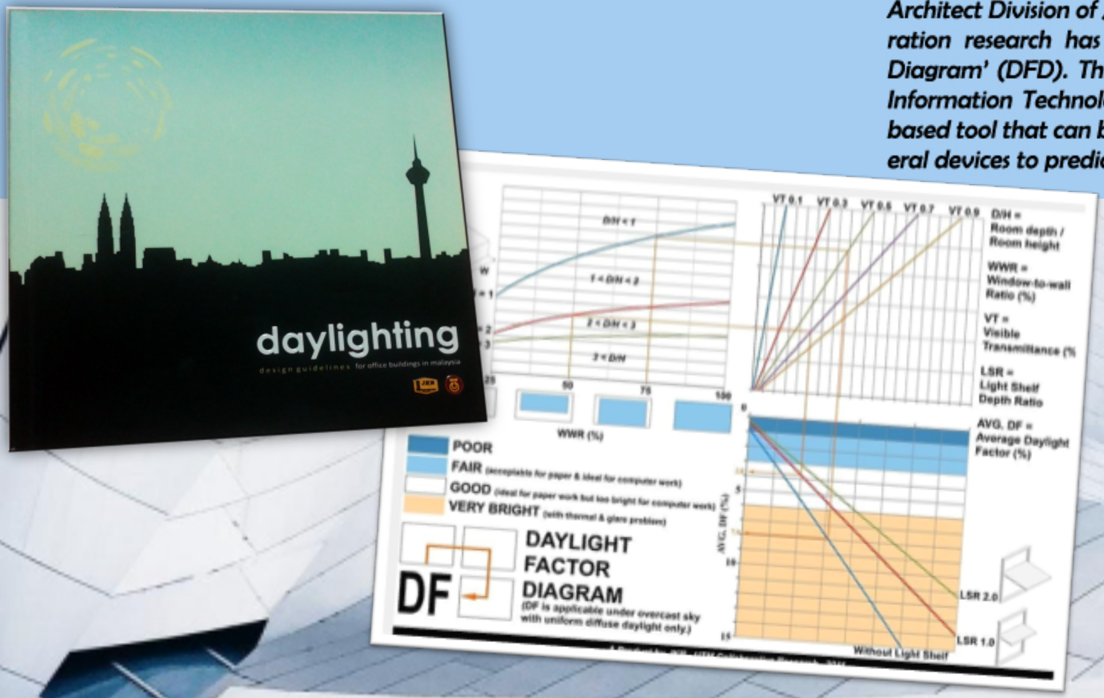
Summary

- Understanding sun-path and sun-angle is critical to predict direct sun angles and shadow.
- Daylighting is crucial because people need and enjoy the qualities of daylight within buildings.
- Using daylight can reduce energy demand and saves energy for a sustainable future.
- Daylighting design should evenly distribute light throughout a space through the day.
- Place windows and openings to the North-South, but avoid on East-West direction.

Df-TOOL

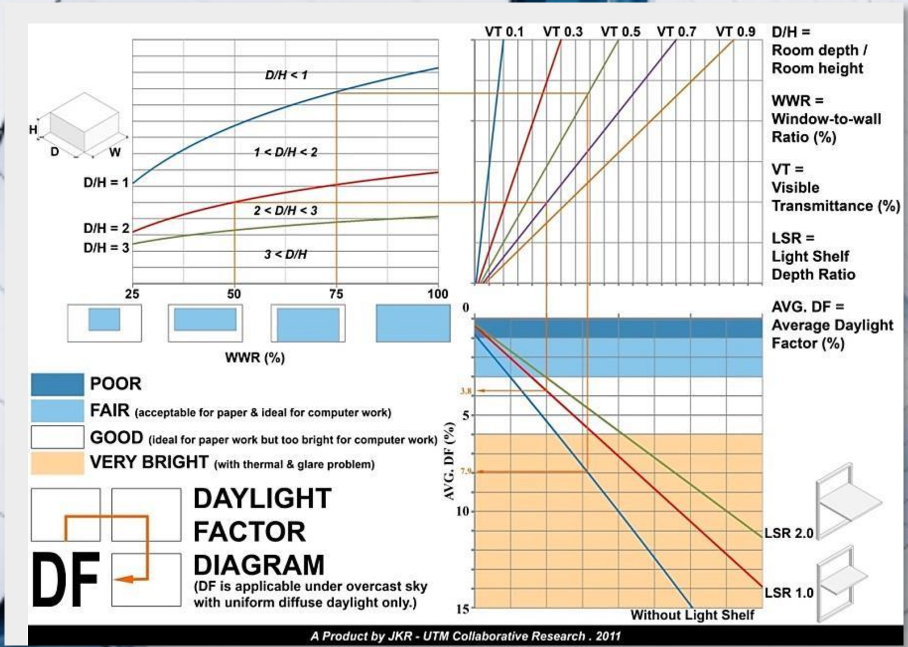
Daylight Factor Prediction Tool

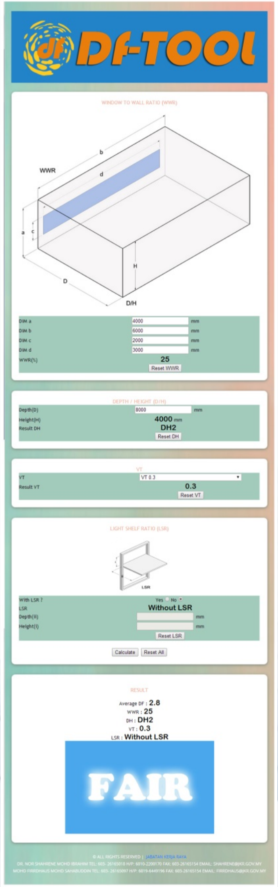
Df-TOOL is the result of improved innovation from the collaboration research between Architect Division of JKR and Universiti Teknologi Malaysia (UTM) in 2012. The collaboration research has produced a paper-based diagram called 'Daylighting Factor Diagram' (DFD). Thus, in response to the state-of-the-art, the Architect Branch and Information Technology Division of JKR jointly have developed an interactive web-based tool that can be used online by architects and building designers on their peripheral devices to predict daylight factor especially during early design stage.



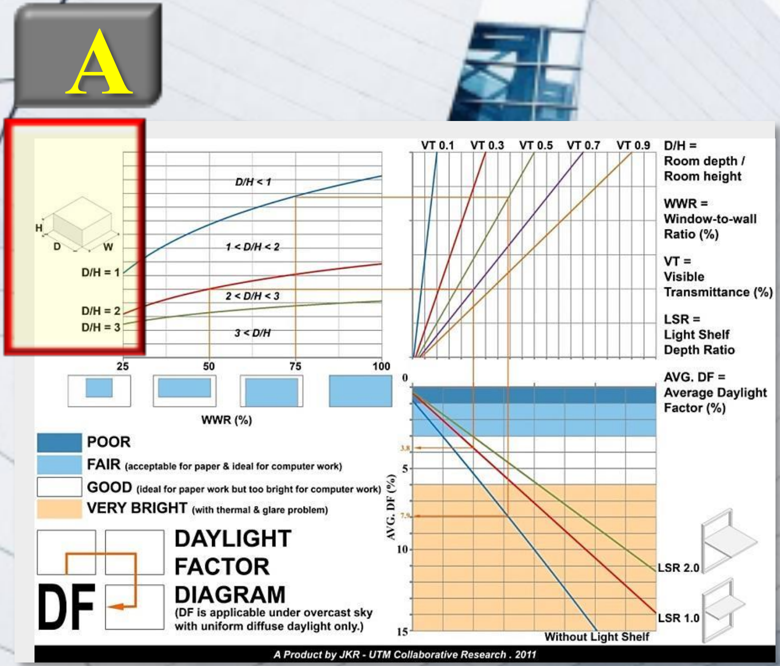
Why ‘Df-TOOL’

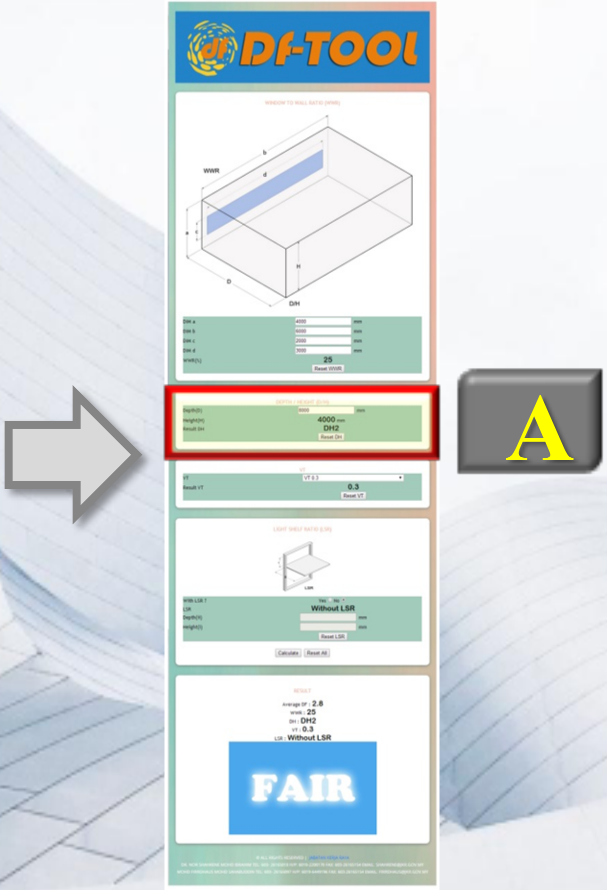
- Creative & user friendly
- Originality from primary data
- Suits to tropical climate
- Save time and cost
- Accurate results



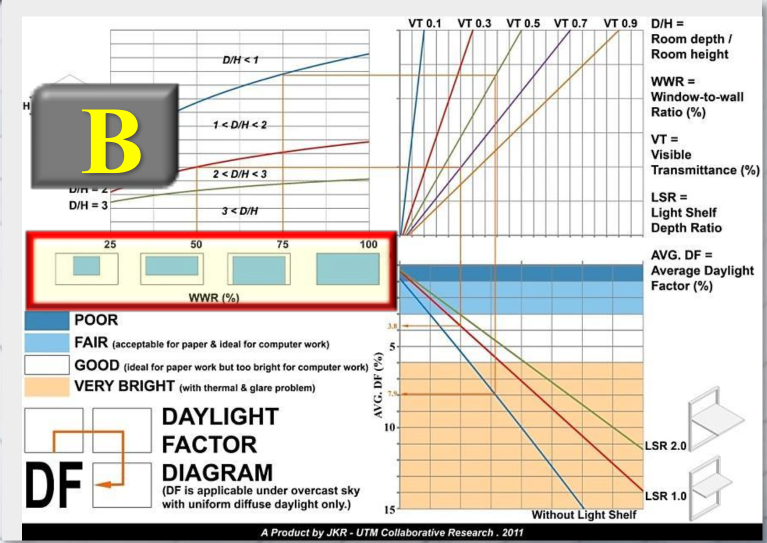


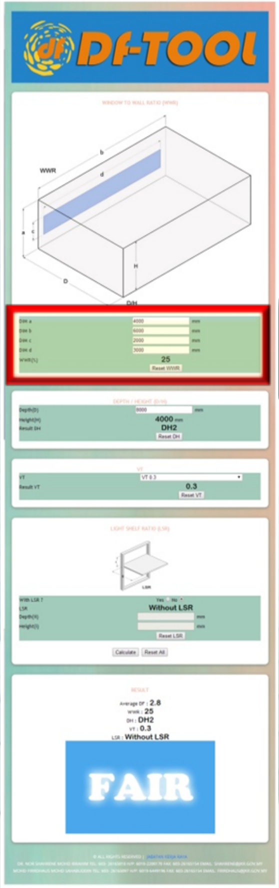
Depth / Height (D/H)





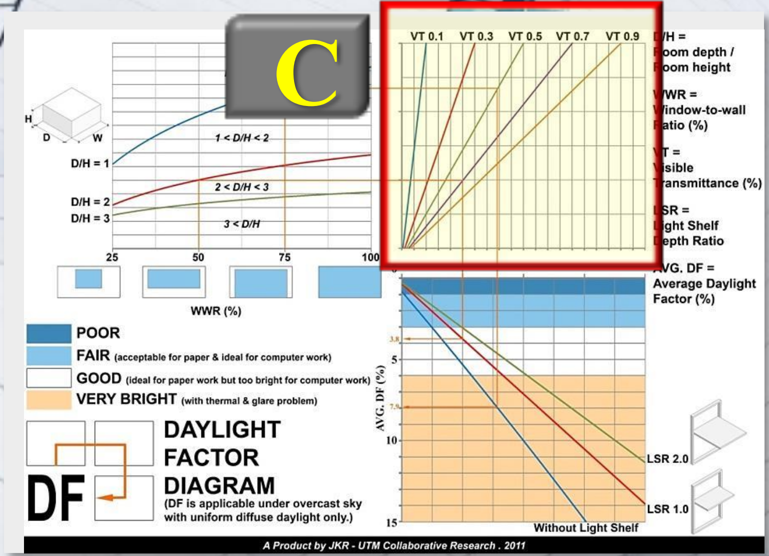
Window-Wall-Ratio (WWR)



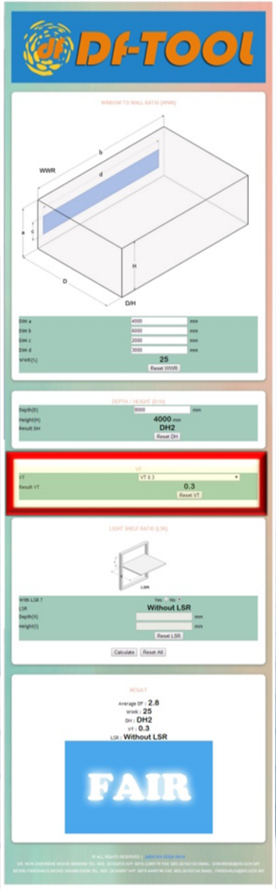


B

Visual Transmittence (VT)

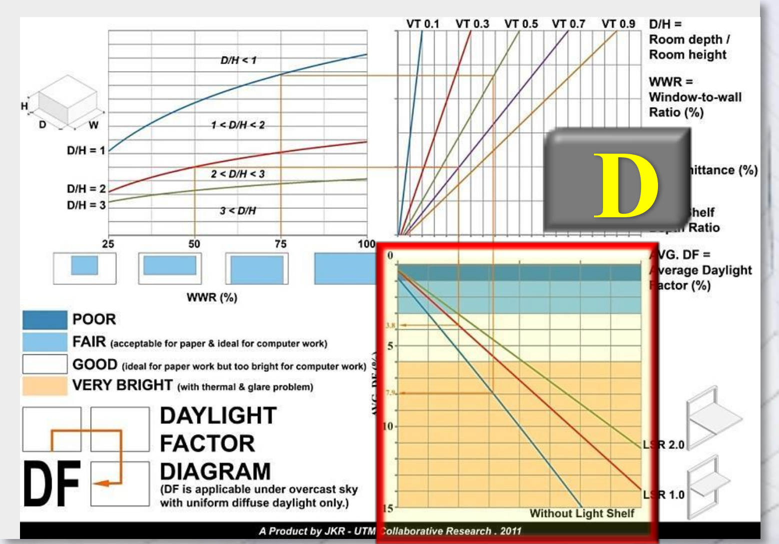


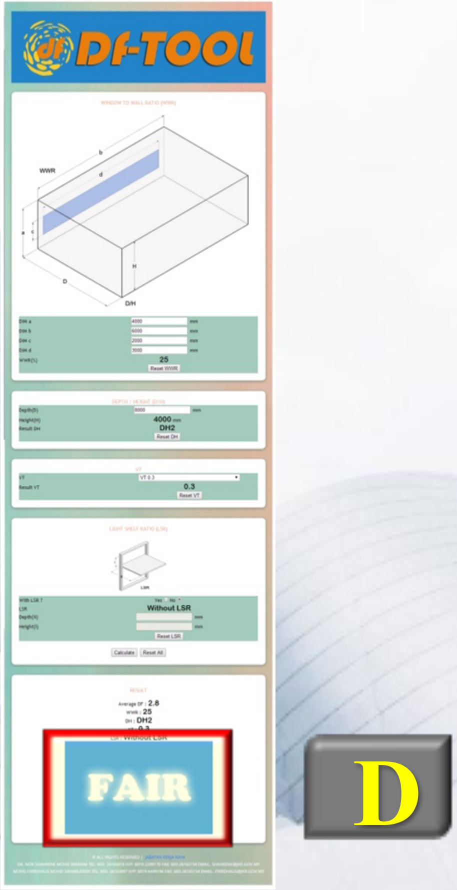
C



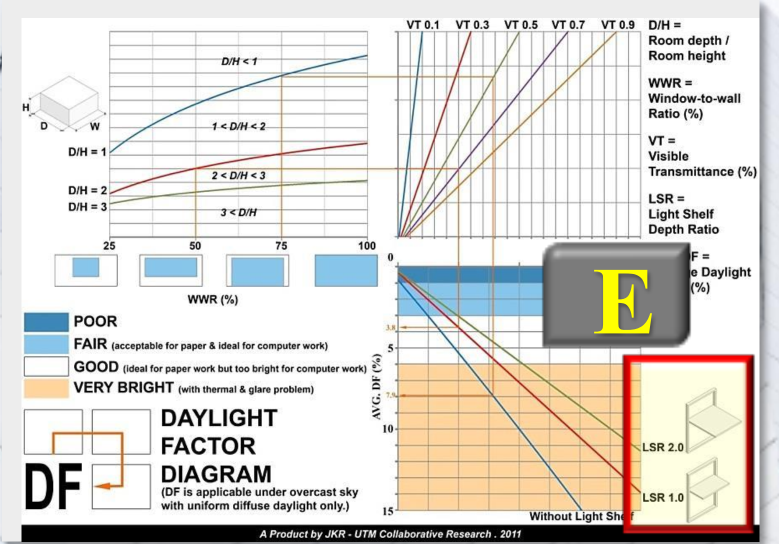
C

DF Average

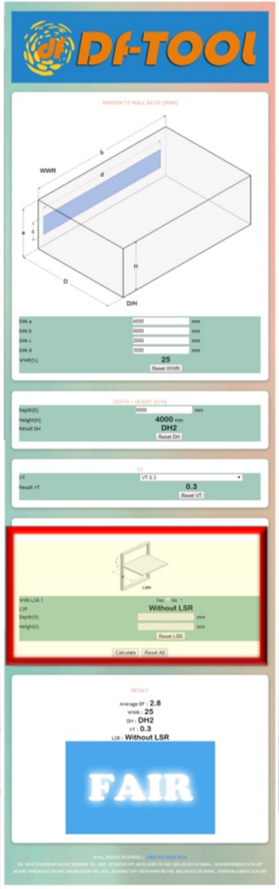

D/H < 1
1 < D/H < 2
2 < D/H < 3
3 < D/H
D/H = 1
D/H = 2
D/H = 3
VT 0.1
VT 0.3
VT 0.5
VT 0.7
VT 0.9
D/H =
Room depth /
Room height
WWR =
Window-to-wall
Ratio (%)
WWR (%)
POOR
FAIR (acceptable for paper & ideal for computer work)
GOOD (ideal for paper work but too bright for computer work)
VERY BRIGHT (with thermal & glare problem)
DAYLIGHT
FACTOR
DIAGRAM
DF
(DF is applicable under overcast sky
with uniform diffuse daylight only.)
LSR 2.0
LSR 1.0
Without Light Shelf
A Product by JKR - UTM Collaborative Research . 2011
D


DF-TOOL
FAIR
D

Light Shelf Ratio (LSR)

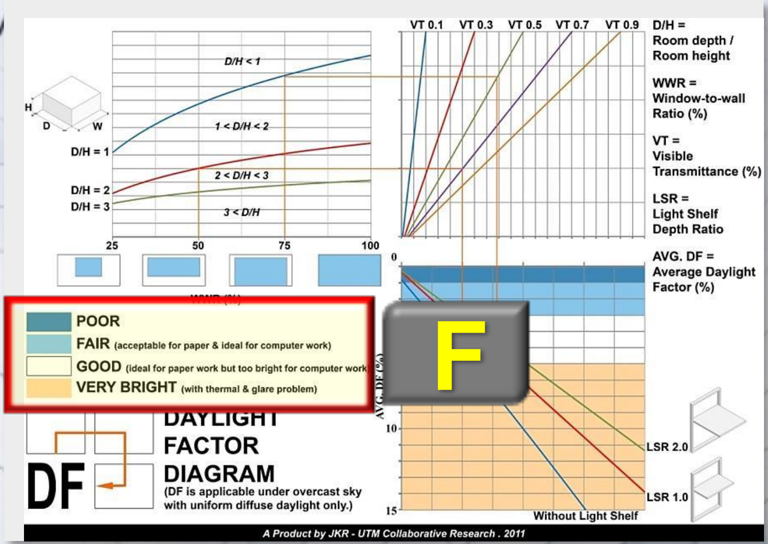


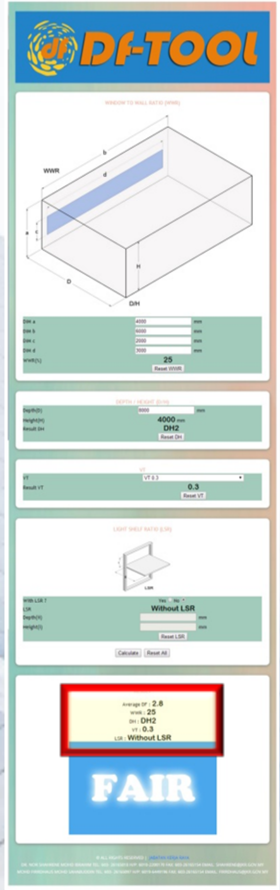
E



E

Performance Result





F

The link:

https://www.jkr.gov.my/cawarkitek/wp-includes/dftool/

How to use 'Df-TOOL'

1 Enter the length and height of the window

2 Enter the depth of the room

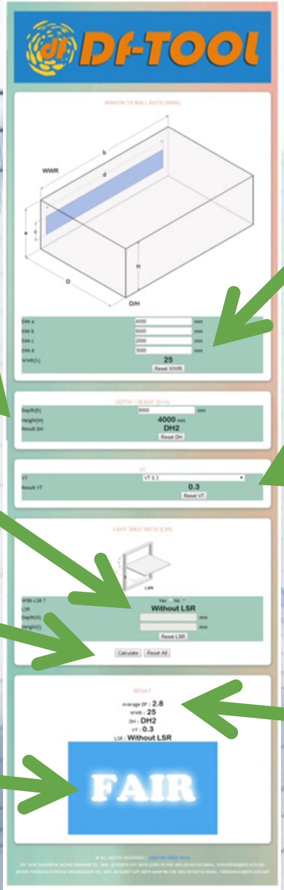
3 Enter the visual transmittance of the glass material

4 Enter the height and width of the light shelf

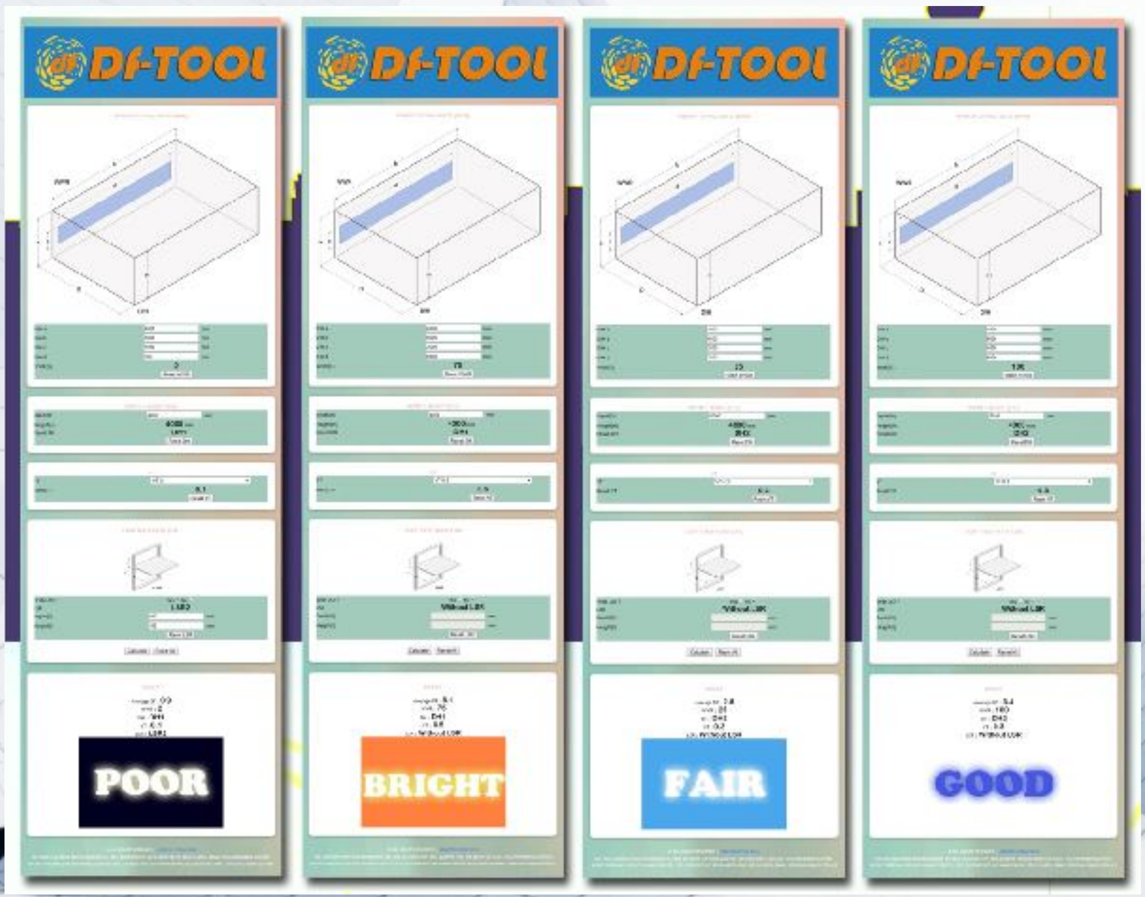
5 Press 'calculate' button for result

6 Average DF will be suggested here

7 DF performance result



Other Results



Can also be used on tablets and smartphones

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Intellectual Property Corporation of Malaysia

THANKS!

Any questions?

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- firrdhaus@um.edu.my
- firrdhaus@dfa-sustainability.com

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