COURSEWORK 1

OCCUPANCY-BASED CONTROL STRATEGIES IN A HOSPITAL WARD

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Sense, Sensing and Controls – BARC0168

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INTRODUCTION

We shape the environment around us to achieve a particular function, and the key function of hospital wards is to make people healthy. There has been a variety of studies into the effect of office design on productivity and efficiency, but there is far less research on other work environments like hospitals and their impact on the health of both patients and working staff. It is well known that factors including lighting, use of colour, acoustics, noise levels and smells can all significantly affect the wellbeing and mood of people in hospitals. Among these factors the degree of control people that have over their environment is what this coursework is tries to model and investigate. The basic information for this coursework is listed in Table 1.

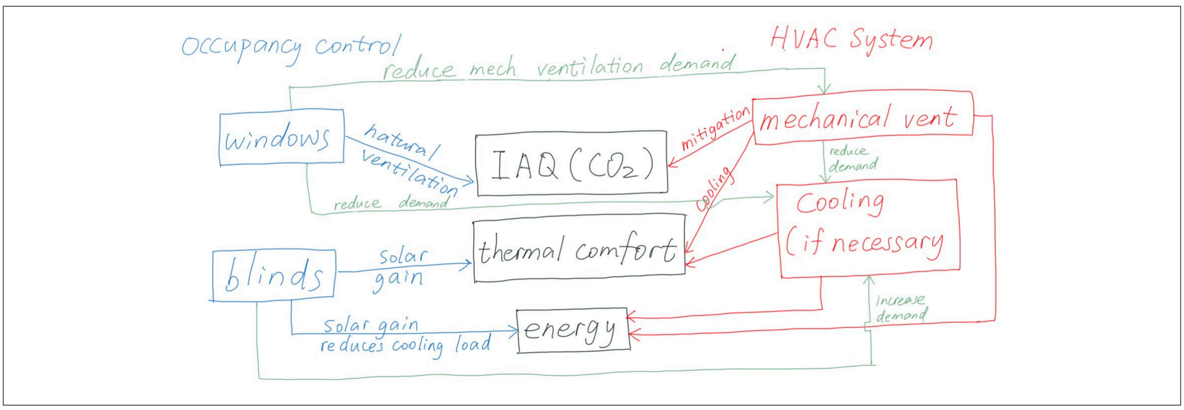
Basic Building Profile

Location	Room type	Glazing ratio	Floor area (m^2)	Height (m)	volume (m^3)	Glazing size(m^2)
Gatwick	Hospital ward	15%	80	3.5	280	12
Given by brief	Given by brief	Given by brief	Assumption of a typical UCL Hospital ward	Typical height of hospital wards	Calculated with data	Calculated with data

Table 1. Basic building profile.

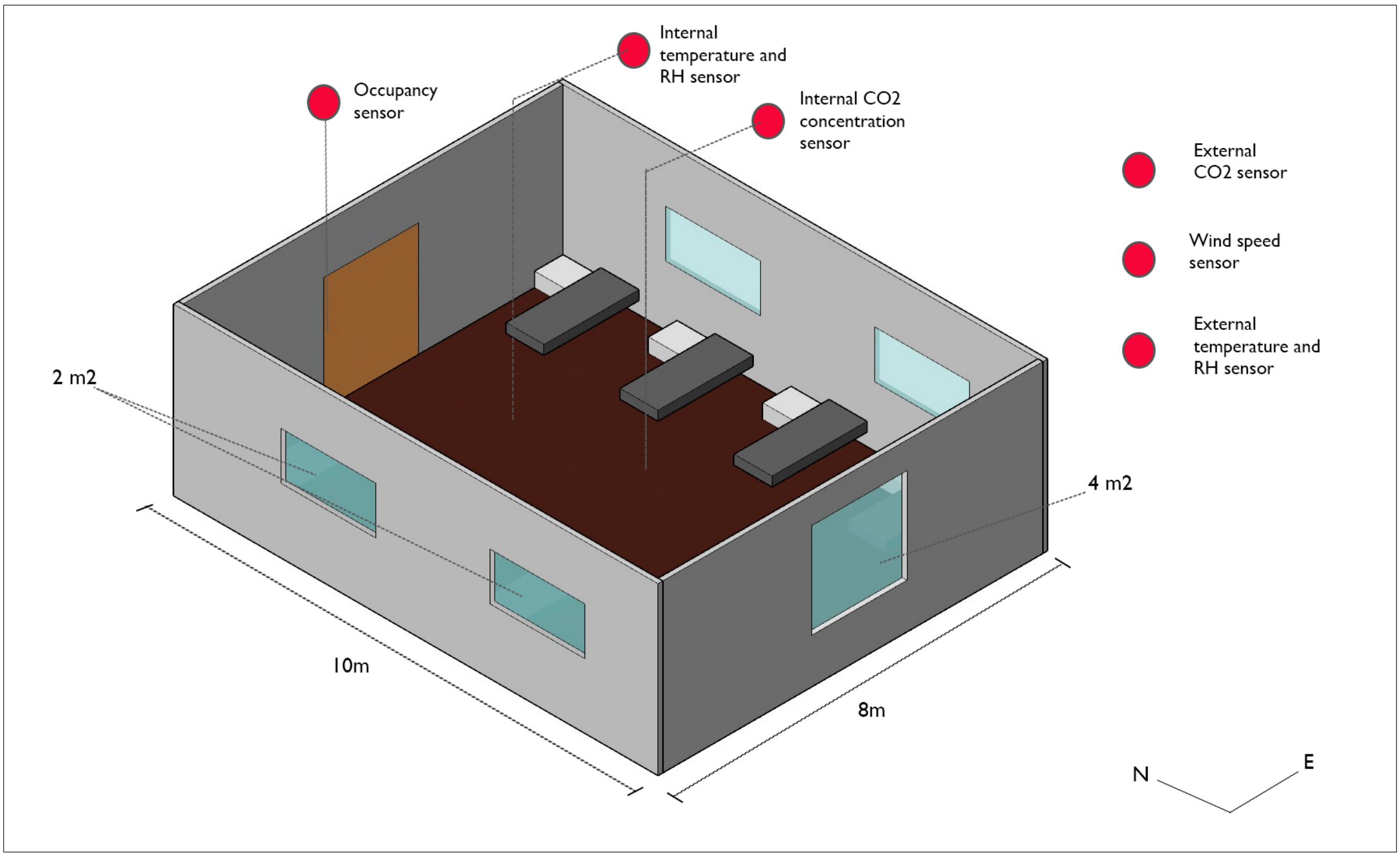
1. METHOD

This coursework aims at exploring occupancy-based control strategies of a hospital ward and examining their impact on indoor environmental quality and energy consumption. It investigates if the space can run passively during 1 July to 28 July. The formulae used in this report are detailed in listed in Appendix 0. A diagram of relationship between variables are illustrated below.



2. MODEL

The building profiles and sensors are illustrated in Graph 1.



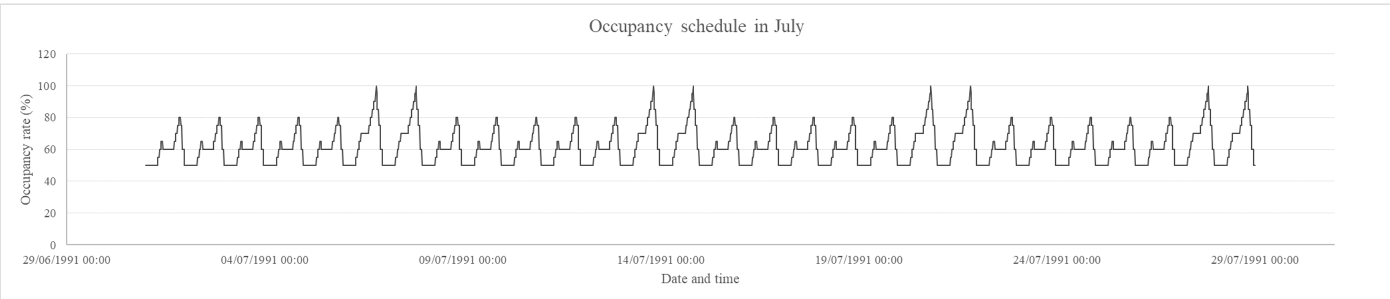
Graph 1. Hospital ward space and sensors

	details	Guidelines
1.Model	The modelled space is a small-scale general ward with 8 beds. The size of each bed is 80cm*200cm. Each bed has equipment of width 80cm, and all beds are equally spaced with an 80cm gap.	NHS guidelines
2.Occupancy	Occupancy rate of hospital beds should be 90%, so it is assumed 7 beds will always be occupied. 7 patients are always in the ward. Nurses and doctors visit regularly between 7am and 11pm. Visitors of patients visit occasionally between 7am and 11pm, and more frequently on weekends. The peak occupancy is 14 people. Shown in Graph 2.	NHS guidelines and assumptions
3.Windows & blinds	The South window cannot be opened, and East and West windows can be opened to form cross ventilation. Blinds are installed on all windows.	Assumptions
4.Temperature	Ideal temperatures are dependent on gender and age, occupancy activities, seasons, etc. In this report it takes 20-25oC as comfortable range for summer.	https://www.primexinc.com
5.CO2	This space is a general ward, not an intensive care ward or a surgical ward. Therefore, there is no special need for pollutant removal. The maximum CO2 concentration is taken as 800ppm.	NHS guidelines and CIBSE Guide A

Table 2. Basic assumptions of the space.

		values	unit	source of data
Building Profile				
infiltration rate		0.15	ACH	See Appendix 4
U-values	walls	0.28	W/m2K	See Appendix 5
	roof	0.18		
	floor	0.22		
	windows	1.6		Building Regulations Part L2A , Table 3
	doors	3.5		
Heat Transfer Coefficient of fabric (H_fab)		99.22	W/K	Calculated from U values of building components
Thermal Mass Parameter (TMP)		450000	J/Km2	SAP 2012, mediumweight buildings
Heat Capacity (C)		36000000	J/K	C: thermal capacity. C=TMP*floor area
Internal heat gain		960	W	Calculated from lighting and equipment loads
Occupancy profile				
Guideline occupancy rate		14	m2/ppl	CIBSE Guide A, Table 6.2, Hospital Wards
Guideline occupancy		5.714285714	ppl	Occupancy in the space according to CIBSE Guide A
Real typical occupancy		7	ppl	Assumption 2.
Real typical occupancy rate		11.42857143	m2/ppl	Occupancy rate according to assumption 2.
max occupancy		14	ppl	Assumption 2.
Typical occupancy density		0.0875	ppl/m2	Occupancy density according to assumption 2.
CO2 emission rate		5.55	cm3/s/ppl	CIBSE AM10
Ventilation profile				
Windows	S	4	m2	Assumption
	N	0		
	E	4		
	W	4		
	Glazed area	12		Assumption
	Frame Factor	0.77		
	Access Factor	0.8		
	g value	0.69		
	Ventilation rate	6	ACH	CIBASE Guide A, Table 4.4, Hospitals and Health care, recommended ventilation rate (see Appendix 1&6)
	air provision in l/s/p	33.33333333	l/s/person	Conversion of ventilation rate above
	Minimum air provision	10	l/s/person	Building Regulations Part F
Heating profile				
Heat gain: people		57	W/m2	CIBSE Guide A, Table 6.1, Seated
Heat gain: lighting		9	W/m2	Assumption
Heat gain: equipment		3	W/m2	Assumption
Heat gain: Metabolic (emission rate)		90	W/ppl	CIBSE Guide A, Table 6.2, Hospital wards

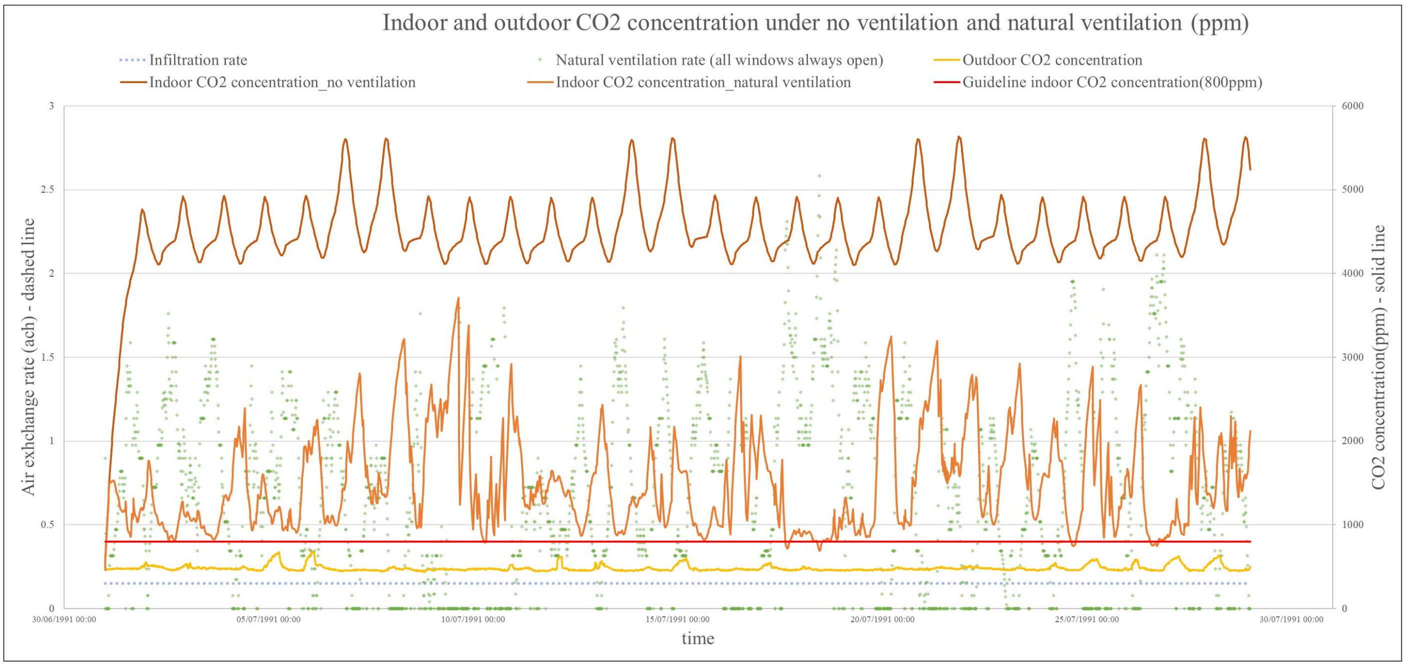
Table 3. Building profile, occupancy profile, ventilation profile and heating profile.



Graph 2. Occupancy schedule used for this report. Assumptions are listed in Table 2.

3. BASELINE SIMULATIONS

To optimize the building performance, baseline simulations are carried out to examine what mechanical ventilation strategies can satisfy the requirements of mitigating CO2 while maintaining comfortable temperature.



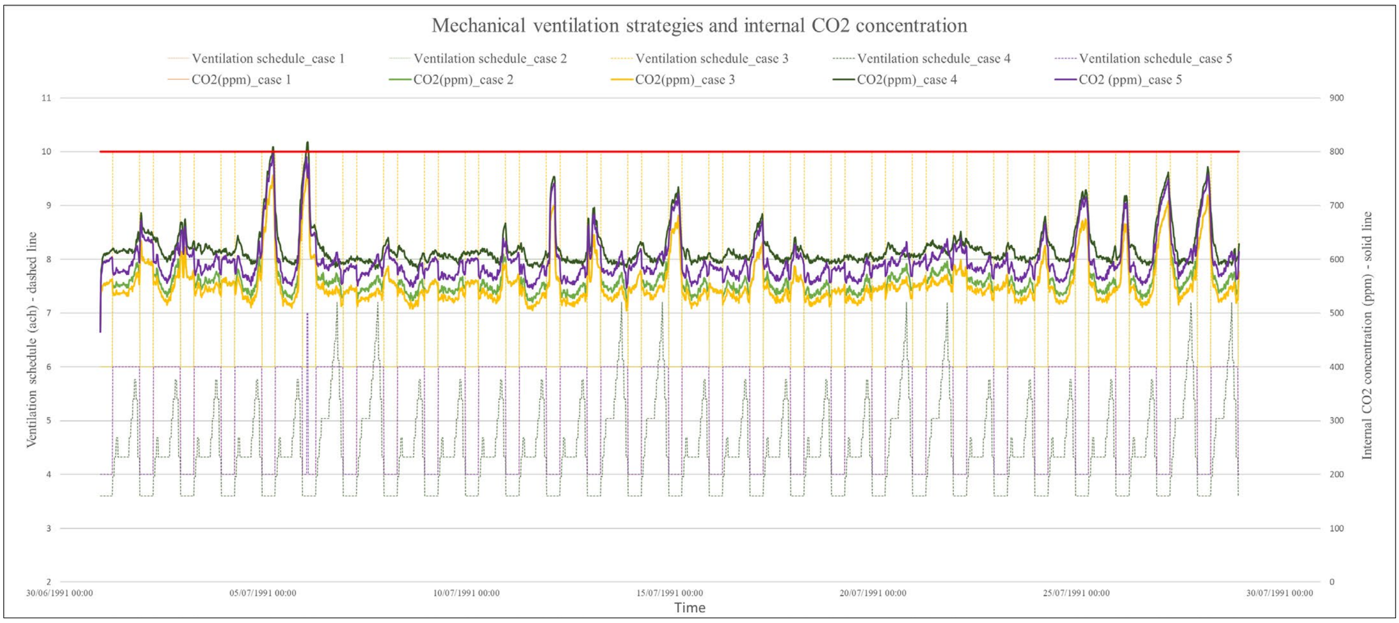
Graph 3. Indoor and outdoor CO2 levels in the space with no ventilation and natural ventilation

It can be observed from Graph 3 that the CO2 concentration is significantly higher than 800ppm when there's no ventilation or when only natural ventilation is introduced. Five mechanical ventilation strategies are explored to see if they can maintain the indoor CO2 level under 800ppm.

case	Mechanical ventilation strategies	Reference
1	If occupancy in the room is more than 7 (which is the number of patients always in the room), ventilation rate is 6 ach. When occupancy is 7, ventilation rate is 4 ach.	Appendix 1, 6 & 7. An air exchange rate of 6-10 ach for the room, or 40L/s/person, should be provided to hospital wards
2	If occupancy in the room is more than 7, ventilation rate is 8 ach. When occupancy is 7, ventilation rate is 6 ach.	
3	If occupancy in the room is more than 7 , ventilation rate is 10 ach. When occupancy is 7, ventilation rate is 6 ach.	
4	A hypothetical scenario where ventilation rate responds to number of occupants in the space. Fresh air of 40L/s/ppl is provided to the room at all times.	
5	Ventilation rate responds to CO2 concentration in the room, based on case 1. If occupancy >7 and CO2 concentration > 800ppm, ventilation rate will increase by 3ach.	

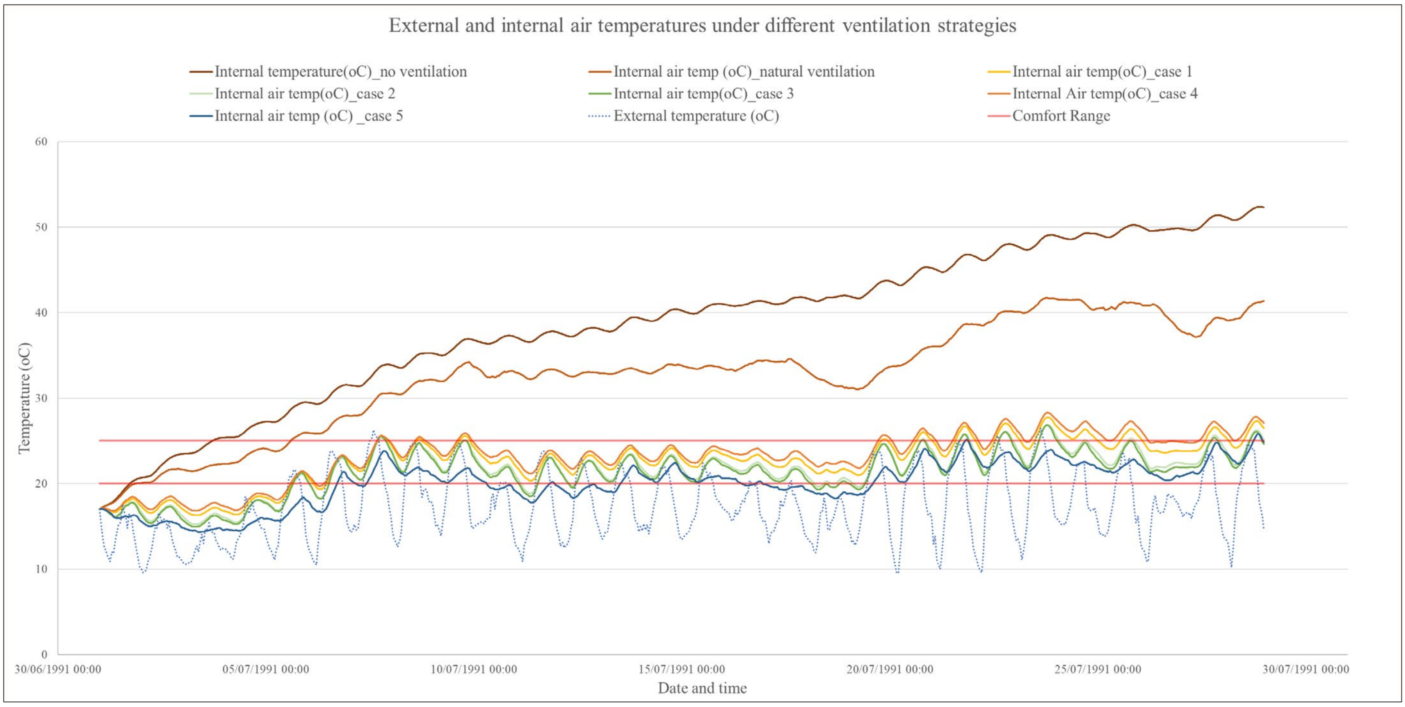
Table 4. Mechanical ventilation strategies used in Graph 4. Case 1-3 are fixed schedules. Case 4 is occupancy-based ventilation strategy. Case 5 is CO2-based ventilation strategy.

It can be observed in Graph 4 that all mechanical ventilations can significantly reduce internal CO2 concentration. CO2- based ventilation is not necessary so long as guideline ventilation rates for hospital wards are satisfied.



Graph 4. Indoor and outdoor CO2 levels in the space with no ventilation and natural ventilation.

The impacts of these mechanical ventilation strategies on indoor temperature are then investigated to see if the room can run without cooling during the summer month.



Graph 5. Indoor temperature using no ventilation, natural ventilation and mechanical ventilation strategies specified in Table 4.

It can be observed in Graph 5 that temperature will rise significantly in the room when there's no ventilation or only natural ventilation. It is therefore necessary to introduce mechanical ventilation to keep the room cool. It can also be found that case 2 and 3 can both significantly bring down the indoor temperature and maintain it within a relatively comfortable level (except for several days in late July). Given that case 2 uses less energy, it is selected as the baseline mechanical ventilation for further examination. It specifies that mechanical ventilation rate is 8 ach during daytime and 6 ach during nighttime.

4. APPLICATION AND EXAMINATION OF REAL OCCUPANT BEHAVIOUR PROFILES

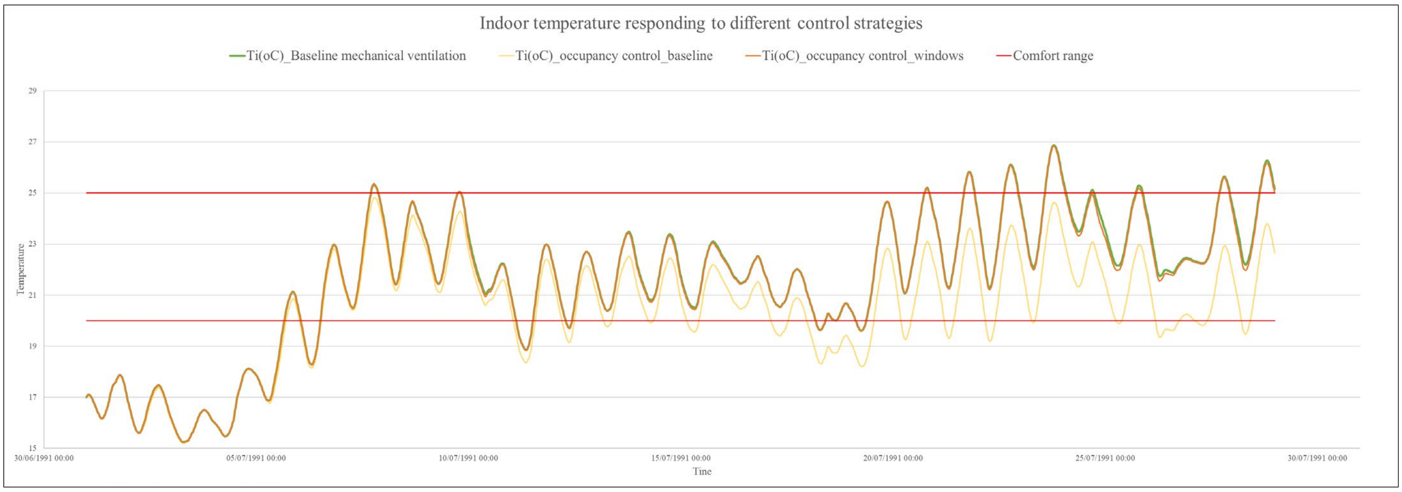
From previous examination it has been concluded that mechanical ventilation strategy 2 can successfully maintain ideal CO2 and temperature levels. This section aims at exploring how much control occupants can have so that they can feel like controlling their environment, whilst maintaining a comfortable indoor environment. The hospital ward examined in this report has three windows of 4m2 facing South, East and West respectively. It is assumed that the South window can not be opened, and cross ventilation can only happen between windows in the East and West.

The typical controls occupants get are:

	Control	Impact
windows	Open/close	ventilation
blinds	Open/close	Solar gain

No suitable occupancy behavior data is provided, so this report makes following assumptions of occupancy controls:

	Night (11pm-7am)	Day (7am-11pm)
Baseline mechanical system	6 ach	8 ach
Windows	When indoor temperature is above 23oC, East and West windows are all open simultaneous at the same time. Otherwise, all windows remain closed, and no natural ventilation is introduced.	
Blinds	On all East, West and South windows, if solar irradiance is above 300W/m2, blinds will be used.	



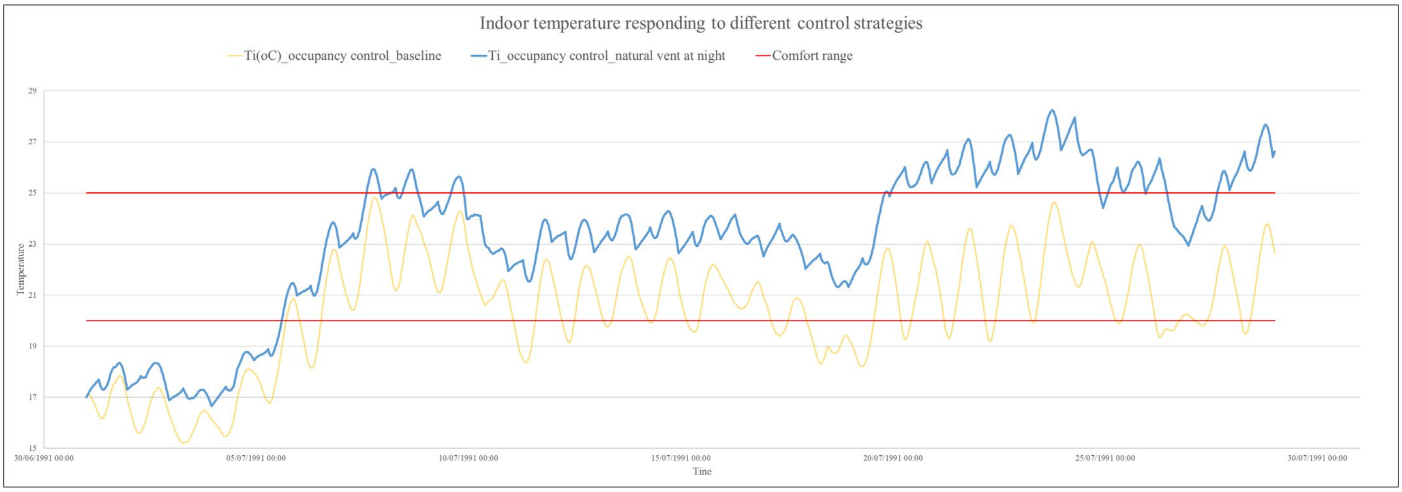
Graph 6. Comparison of indoor temperature responding to different control strategies, including the opening and closing of blinds and windows.

It can be found in Graph 6 that occupants' control of window openings (natural ventilation) does not have a significant impact on internal temperature, possibly because of lower wind pressure during summer and less heat loss induced by natural ventilation. However, the use of blinds has a significant impact on the reduction of temperature during hot weather. However, it bears the risk of not providing enough heat gain during the day and the temperature is too low at night, as is shown in several days around 20 July in the graph (yellow line).

5. ADJUSTED CONTROL STRATEGIES

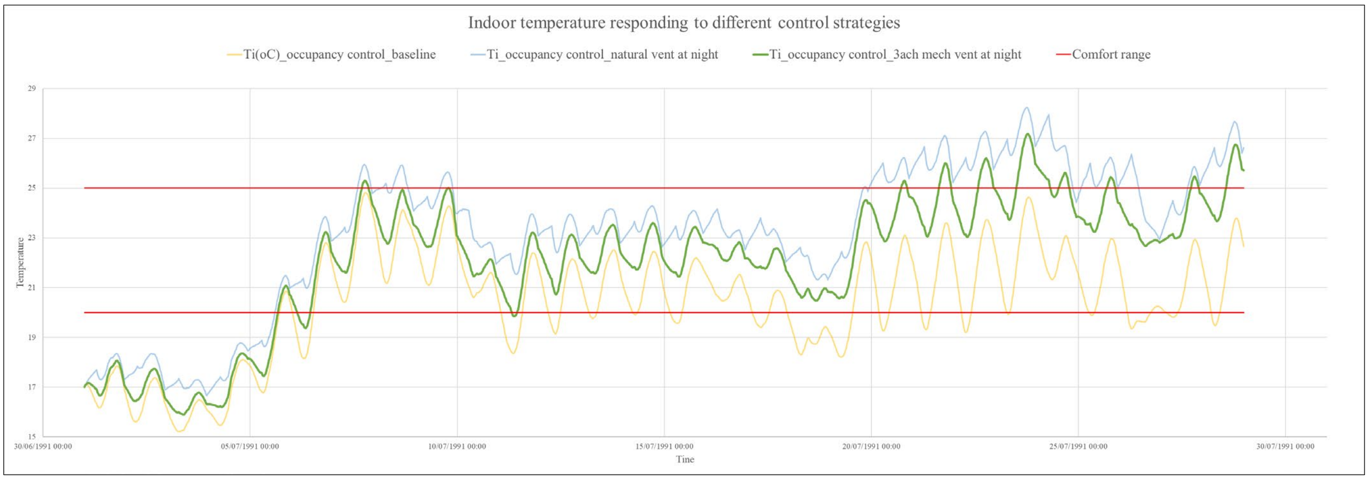
It is found in the previous section that the use of blinds can have a great impact on internal temperature, whilst the opening of windows does not. To improve control strategies, it is explored whether we can use only natural ventilation during the nights, so that noises of mechanical ventilation can be minimized, and energy consumptions can be reduced. The details have been listed in the table below.

	Night (11pm-7am)	Day (7am-11pm)
Baseline mechanical system	6 ach of mechanical ventilation. No natural ventilation.	8 ach of mechanical ventilation. When indoor temperature is above 23oC, East and West windows are all open simultaneous at the same time. Otherwise, all windows remain closed. On all East, West and South windows, if solar irradiance is above 300W/m2, blinds will be used.
Mechanical system – natural ventilation at night	0 ach of mechanical ventilation (so that noises and energy consumption and both be reduced) Windows fully open for full natural ventilation.	



Graph 7. Indoor temperature responding to baseline ventilation and occupancy-based control with natural ventilation at night.

It is found in Graph 7 that during nights when no mechanical ventilation is used, temperatures tend to rise above the comfortable range (blue line). Therefore, natural ventilation alone at night is not enough for the ward to keep cool. It is then examined if the introduction of 3 ach of mechanical ventilation at nights will achieve ideal indoor conditions, as is shown in Graph 8.



Graph 8. Indoor temperature responding to baseline ventilation, occupancy-based control with natural ventilation at night, and occupancy-based control with baseline & natural ventilation at night.

It can be observed that during night-time, mechanical ventilation of 3 ach and natural ventilation together can maintain ideal temperatures (green line), except for several days in late July. During daytime, the use of blinds and the control of window openings can help reduce solar gains and extract excessive heat. Compared with the baseline control strategy (yellow line), this strategy (green line) induces less risk of losing too much heat at night.

6. CONCLUSION

The processes and conclusions of examination in previous sections are listed in this table.

	Result	**Implication**
Baseline mechanical ventilation	A mechanical ventilation schedule of 6 ach during nighttime and 8 ach during daytime is enough to maintain comfortable indoor conditions (CO2 levels and temperatures) for the hospital ward.	Mechanical ventilation of 8 ach (day) and 6 ach (night) can be used as the baseline mechanical ventilation schedule for this report. No cooling is needed.
Baseline mechanical ventilation + occupancy behaviors	The use of blinds can affect indoor temperature effectively, whilst the opening/closing of windows cannot.	It is a reasonable assumption that occupants will use blinds when solar irradiance > 300 W/m2, and this control will help maintain ideal indoor temperatures. Natural ventilation can be introduced frequently, since it has positive psychological effects and does not influence indoor temperature too much.
Adjusted mechanical ventilation	Natural ventilation alone at night is not enough for the space to stay cool during summer. An adjusted schedule detailed as follows can maintain ideal indoor conditions: mechanical ventilation is of 8 ach (day) and 3 ach (night); windows are open all nights for natural ventilation and are open during days when temperatures are above 23oC; blinds are shut when solar irradiance > 300 W/m2.	Compared to baseline mechanical ventilation, the adjusted one reduces the ventilation rate to 3 ach at night, which will reduce both noises and energy demands. The opening and closing of windows and blinds give occupants more control of their environments whilst keeping the space comfortable. The use of blinds can also effectively reduce indoor temperatures.

There are several limitations of the research process of this report.

- It is assumed that all windows are open and closed at the same time and they are either fully open or fully closed. However in reality they can be controlled independently and can be partially open.
- The strategies in this report have not been validated by real occupancy behaviours (only assumed behaviours). For example, it is idealised that when solar irradiance >300W/m2 all blinds will be shut, whilst real schedules will be very different.
- The control behaviours in this report are limited to opening/closing windows and blinds, whilst in reality other factors can all make a difference, including doors, people turning on/off HVAC systems, etc.
- Energy consumption is not discussed in this report.

REFERENCES

Martin, A.J & Banyard, C.P, 1998. *Application Guide AG 7/98 LIBRARY OF SYSTEM CONTROL STRATEGIES.*.

Appendix 0.

Data of external temperature, relative humidity, solar irradiance, CO2 levels, wind speed and directions etc. are all provided in the epw file. The data are collected every 15min. The indoor temperature is calculated by:

$$Ti(n) = \frac{1}{1 + \frac{t_s}{C} H} Ti(n) + \frac{t_s}{C} HTe(n) + \frac{t_s}{C} Q_{heat}(n)$$

where $Ti(n)$ denotes internal temperature (oC), t_s denotes time step (15min), H denotes heat transfer coefficient (W/K), C denotes heat capacity of the room (J/K), $Te(n)$ denotes external temperature, and $Q_{heat}(n)$ denotes heat input of the space (W).

The heat transfer coefficient, H, is the sum of fabric heat loss, infiltration heat loss and ventilation heat loss:

$$H = H_{fabric} + H_{inf} + H_{vent}$$

where fabric heat loss is determined by the U values of construction materials, which will be listed in Table 3. Heat loss caused by infiltration and ventilation is calculated by the air change rate n and room volume V:

$$H = \frac{1}{3} \times n \times V$$

Infiltration rate is listed in Table 3, and ventilation rate is determined by mechanical ventilation schedules and natural ventilation, which is what this report tried to examine.

The natural ventilation rate is calculated by formula:

$$q = A \times C_d U \sqrt{\frac{\Delta C_p}{2}}$$

where A is the equal window area on each wall, C_d is commonly taken as 0.6, U is external wind speed, ΔC_p is the difference between coefficients determined by wind directions. When windows are open, natural ventilation will be drawn responding to the sizes of opening.

The total heat input, Q_{heat}, is the sum of internal heat gain, metabolic gain, heating/cooling gain and solar gain：

$$Q_{heat} = Q_{int} + Q_{met} + Q_{heating} + Q_{sol}$$

The data of Q_{int} is listed in Table 3. Q_{met} depends on occupancy rate. $Q_{heating}$ responds to the difference between indoor and setpoint temperatures. Q_{sol} can be calculated with:

$$Q_{sol} = 0.9 \times A_w \times S \times g \times FF \times Z$$

where the values of A_w, S, FF, Z are all listed in Table 2. The use of blinds will change the value of S and thus Q_{sol}.

Internal CO2 levels are also examined. The formula gives:

$$Ci(n) = C_e + \frac{G}{q} + (Ci(n-1) - C_e - \frac{G}{q})e^{-\frac{q}{V} \times t}$$

where $Ci(n)$ and $C_e$denotes internal and external CO2 concentration, C_e denotes generation rate of CO2 (cm3/s, caused by occupants), q denotes volumetric ventilation rate (m3/s, natural and mechanical), and V denotes room volume.

Appendix 1: CIBSE ventilation

Table 4.4 Recommended minimum ventilation rates from CIBSE Guide B2 (2015)

Building type	Ventilation strategies	Recommended ventilation rate	Building protection measures	Operation period/occupancy
Broadcasting studios	Mechanical ventilation Cooling comfort	6–10 ACH	None	Variable operation times and periods, 24 hours a day in operation
Clean room	Mechanical ventilation	10–120 ACH for non-laminar-flow clean room depending on type of work 500–600 ACH for laminar-flow clean room	HEPA filters, positive room pressure	24 hours a day
Computer room/data centre	Mechanical ventilation Air conditioning	Typical 1 ACH or minimum fresh air to suit occupancy	The air conditioning units usually include filtration	24 hours a day in operation
Hospitals and health care	Mechanical ventilation in areas such as operating theatre Natural ventilation in areas such as ward areas	6–15 ACH depending on the buildings functionality of the room	Different classes of filters depending on application The building has an overall positive or neutral pressure	Up to 24 hours a day
Laboratories	Mechanical ventilation	6–15 ACH	HEPA filtration of extract air Negative pressure	Up to 24 hours a day depending on activity
Museums, libraries and art galleries	Mechanical ventilation Air conditioning	Depends on nature of exhibits	Particle and gaseous filtration is recommended	24 hours a day in operation
Schools and educational buildings	Mechanical ventilation Natural ventilation	Classrooms capable of 3 $L \cdot s^{-1}$ per person for design occupancy when unoccupied Capable of 8 $L \cdot s^{-1}$ per person when occupied Minimum 6 ACH in washing areas	None	Variable operation times and periods Mostly daytime during school terms
Shops and retail premises	Mechanical ventilation Air conditioning	5–8 $L \cdot s^{-1}$ per person maximum design occupancy	The building should be maintained under positive pressure	Variable operation times and periods Mostly daytime

Appendix 2: Heat emission for occupants (CIBSE Guide A)

Table 6.1 Heat emission (W) from an adult male body (of surface area 2 m²) and average heat emission per person for a mixture of men, women and children typical of the stated application

Activity	Typical application	Occupancy density (m²/person)	Total, sensible and latent heat emission (W) for stated application and dry bulb temperature (C) for adult male (and average for mixture of men, women and children)										
			Total	15		20		22		24		26	
				Sensible	Latent	Sensible	Latent	Sensible	Latent	Sensible	Latent	Sensible	Latent
Seated, inactive	Theatre, cinema matinee	0.75–1.0[2,3]	115 (100)	100 (87)	15 (13)	90 (78)	25 (22)	80 (70)	35 (30)	75 (65)	40 (35)	65 (57)	50 (43)
Seated, inactive	Theatre, cinema evening	0.75–1.0[2,3]	115 (105)	100 (91)	15 (14)	90 (82)	25 (23)	80 (73)	35 (32)	75 (68)	40 (37)	65 (59)	50 (46)
Seated, light work	Restaurant	1.0–2.0[2,3]	140 (126)	110 (99)	30 (27)	100 (90)	40 (36)	90 (81)	50 (45)	80 (72)	60 (54)	70 (63)	70 (63)
Seated, moderate work	Office	8–39[4–6], 14[4,7]*	140 (130)	110 (102)	30 (28)	100 (93)	40 (37)	90 (84)	50 (46)	80 (74)	60 (56)	70 (65)	70 (65)
Standing, light work, walking	Department store	1.7–4.3[2,3]	160 (141)	120 (106)	40 (35)	110 (97)	50 (44)	100 (88)	60 (53)	85 (75)	75 (66)	75 (66)	85 (75)
Standing, light work, walking	Bank	—	160 (142)	120 (107)	40 (35)	110 (98)	50 (44)	100 (89)	60 (53)	85 (76)	75 (66)	75 (66)	85 (76)
Light bench work	Factory	—	235 (209)	150 (133)	85 (76)	130 (116)	105 (93)	115 (102)	120 (107)	100 (89)	135 (121)	80 (71)	155 (138)
Medium bench work	Factory	—	265 (249)	160 (150)	105 (99)	140 (132)	125 (117)	125 (117)	140 (132)	105 (99)	160 (150)	90 (85)	175 (164)
Heavy work	Factory	—	440 (440)	220 (220)	220 (220)	190 (190)	250 (250)	165 (165)	275 (275)	135 (135)	305 (305)	105 (105)	335 (335)
Moderate dancing	Dance hall	0.5–1.0	265 (249)	160 (150)	105 (99)	140 (132)	125 (117)	125 (117)	140 (132)	105 (99)	160 (150)	90 (85)	175 (164)

* Recommended

Notes:

(1) Figures in parenthesis are adjusted heat gains based on normal percentage of men, women and children for the applications listed. This is based on the heat gain for women and children of 85% and 75% respectively of that of an adult male.

(2) For restaurant serving hot meals add 10 W sensible and 10 W latent for food per individual.

Appendix 3: Typical benchmarks for hospital wards

Table 6.2 Benchmark allowances for internal heat gains in typical buildings

Building type	Use	Floor area per person / m⁻²	Sensible heat gain / W·m⁻²			Latent heat gain / W·m⁻²	
			People	Lighting*	Equipment†	People	Other
Offices	General	12	6.7	8–12	15	5	—
		16	5	8–12	12	4	—
	City centre	6	13.5	8–12	25	10	—
		10	8	8–12	18	6	—
	Trading/dealing	5	16	12–15	40+	12	—
	Call centre floor	5	16	8–12	60	12	—
	Meeting/conference	3	27	10–20	5	20	—
	IT rack rooms	0	0	8–12	200	0	—
Airports‡ and stations	Airport concourse	0.83	75	12	5	4	—
	Check-in	0.83	75	12	5	50	—
	Gate lounge	0.83	75	15	5	50	—
	Customs/immigration	0.83	75	12	5	50	—
	Circulation spaces	10	9	12	5	6	—
Retail	Shopping malls	2–5	16–40	6	0	12–30	—
	Retail stores	5	16	25	5	12	—
	Food court	3	27	10	†	20	§
	Supermarkets	5	16	12	†	12	§
	Department stores:						
	— jewellery	10	8	55	5	6	—
	— fashion	10	8	25	5	6	—
	— lighting	10	8	200	5	6	—
	— china/glass	10	8	32	5	6	—
	— perfumery	10	8	45	5	6	—
	— other	10	8	22	5	6	—
Education	Lecture theatres	1.2	67	12	2	50	—
	Teaching spaces	1.5	53	12	10	40	—
	Seminar rooms	3	27	12	5	20	—
Hospitals	Wards	14	57	9	3	4.3	—
	Treatment rooms	10	8	15	3	6	—
	Operating theatres	5	16	25	60	12	—
Leisure	Hotel reception	4	20	10–20	5	15	—
	Banquet/conference	1.2	67	10–20	3	50	—
	Restaurant/dining	3	27	10–20	5	20	—
	Bars/lounges	3	27	10–20	5	20	—

Appendix 4: Typical infiltration rate of buildings.

Air permeability of 5m3*h-1/m2 at 50Pa refers to a 'tight' building that complies with the 2013 Part L Building Regulations to ensure compliance with CO2 emission targets (CIBSE Guide A)

Table 4.22 Empirical values for air infiltration rate due to air infiltration for rooms in buildings on normally exposed sites in winter: hospitals and health care buildings; partial exposure

Air permeability / ($m^3/m^2 \cdot h$ at 50 Pa)	Infiltration rate (ACH) for given building size / h–1							
	< 2 storeys; 500 m^2/fl. (25 m × 20 m × 4 m)*		< 4 storeys; 1000 m^2/fl. (40 m × 25 m × 4 m)*		< 8 storeys; 1000 m^2/fl. (40 m × 25 m × 4 m)*		< 12 storeys; 1000 m^2/fl. (40 m × 25 m × 4 m)*	
	Peak	Average	Peak	Average	Peak	Average	Peak	Average
20.0 (leaky)	0.75	0.60	0.65	0.45	0.65	0.45	0.85	0.60
10.0 (Part L (2002))	0.40	0.30	0.35	0.25	0.35	0.25	0.45	0.30
7.0 (Part L (2005))	0.25	0.20	0.25	0.15	0.25	0.15	0.30	0.25
5.0	0.20	0.15	0.15	0.15	0.20	0.15	0.20	0.15
3.0	0.15	0.10	0.10	0.10	0.10	0.10	0.15	0.10
Air change rate at 50 Pa (/ h^{-1})		4.3		2.55		1.95		1.75
ACR_{50} divisor		15.3		11.6		8.8		7.7

* (length × width × height) for each storey

Note: tabulated values should be adjusted for local conditions of exposure

Appendix 5: U-value standards that comply with Building Regulations Part L2B

Table 4 **Standards for new *thermal* elements**

Element[1]	Standard W/(m².K)
Wall	0.28[2]
Pitched roof – insulation at ceiling level	0.16
Pitched roof – insulation at rafter level	0.18
Flat roof or roof with integral insulation	0.18
Floors[3]	0.22[4]
Swimming pool basin	0.25[5]

Notes:

1 'Roof' includes the roof parts of dormer windows, and 'wall' includes the wall parts (cheeks) of dormer windows.

2 A lesser provision may be appropriate where meeting such a standard would result in a reduction of more than 5% in the internal floor area of the room bounded by the wall.

3 The U-value of the floor of an extension can be calculated using the exposed perimeter and floor area of the whole enlarged building.

4 A lesser provision may be appropriate where meeting such a standard would create significant problems in relation to adjoining floor levels.

5 See paragraph 4.14.

Appendix 6: summary of environmental requirements by Health Technical Memorandum 03-01: Specialised Ventilation for Healthcare Premises (Department of Health, 2007)

Application	Ventilation	Air-change rate (ac/h)	Pressure (Pascal – Pa)	Supply filter grade (BS EN 16798)	Noise (dB(A))	Temp (°C)	Comments (for further information see Chapter 8)
General ward (level 0 and 1 care)	S/N	6	–	SUP2	35	18–28	
Communal ward toilet	E	6	–ve	–	45	–	
Single room	S/E/N	6	0 or –ve	SUP2	35	18–28	
Single room WC	E	3	–ve	–	45	–	
Clean utility	S	6	+ve	SUP3	45	18–22	
Dirty utility	E	6	–ve	–	45	–	
Ward isolation room (PPVL)	S	10	Lobby +10 Room 0	SUP2	35	–	See Health Building Note 04-01 (Supplement 1)

Appendix 7. REHVA

For normal areas/patient rooms:

- Normal patient rooms that are not intended for patients with infectious diseases, need at least 4 air changes per hour (ACH).
- If used for airborne precaution, it should be updated to meet the requirement for isolation rooms, where adequate ventilation is considered to be at least 6 ACH (equivalent to 40 L/s/patient for a 4x2x3 m^3 room).

Appendix 8: summary of environmental requirements by Health Technical Memorandum 03-01: Specialised Ventilation for Healthcare Premises (Department of Health, 2007), chapter 8, Table 2

Application: Bronchoscopy, Endoscopy, Dental and General treatment facilities		
Area/zone	**Reason for ventilation**	**Typical design factors**
Bronchoscopy procedure room	Control of exposure of staff to airborne pathogenic material discharged by the patient e.g. multi-drug-resistant tuberculosis (MDR-TB) during the procedure being undertaken. (COSHH Regs) Control of exposure of staff to waste anaesthetic agents when used. (COSHH Regs)	Establish a clean airflow path – Supply terminal at high level at foot end of patient's chair/couch and extract terminal at patient's head level behind the chair/couch. Design parameters Air change: 10 per hour Pressure regime: –5 Pa to corridor Noise level: 40 d(B)A Temp range: 20 to 25°C BMS control Humidity: Floating; max 70%RH Air quality: BS EN 16798 - SUP2 Extract discharge – Discharge in safe position away from people or open windows. If no suitable position available treat the discharge in the same way as a LEV with a discharge stack 3 m above the roof line.
Endoscopic procedure room	As above and odour control	
Dental treatment room	Control of exposure of staff to airborne pathogenic material discharged by the patient during the procedure being undertaken. (COSHH Regs) Control of exposure of staff to waste anaesthetic agents when used. (COSHH Regs)	Establish a clean airflow path – Supply terminal at high level and extract terminal at low level near patient's chair/couch. Design parameters Air change: 10 per hour Pressure regime: Neutral to corridor Noise level: 40 d(B)A Temp range: 20 to 25°C BMS control Humidity: Floating; max 70%RH Air quality: BS EN 16798 - SUP2
Emergency department resuscitation room	As above	
General treatment room	Comfort conditions only	

All of the above rooms are suitable for aerosol-generating procedures (AGPs)

Appendix 9: Formula of natural ventilation calculations

The ventilation area required to give a ventilation rate q for a specified value of ΔC_p is given by:

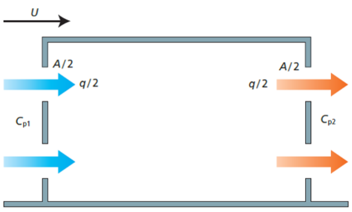


Figure 4.12 Case 4: crossflow ventilation driven by wind alone

$$A = q\left(C_d\, U \sqrt{\frac{\Delta C_p}{2}}\right)^{-1} \qquad (4.14)$$

where A is the total ventilation area (each wall) (m^2) and ΔC_p is the difference between the wind pressure coefficients C_{p1} and C_{p2}.

Note: in cases 1 and 4 it is assumed that the openings are identical; different equations will apply if the openings have different areas or discharge coefficients (see the examples in CIBSE Guide A[6] and BS 5925[62]).

See 'Wind pressure coefficients' tab for tables on pressure coefficients.

Appendix 10. Wind pressure coefficient table

Appendix 4.A1: Basic pressure coefficient data

The following tables are reproduced from *A Guide to energy-efficient ventilation* (Liddament, 1996).

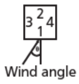
Table 4.A1.1 Wind pressure coefficient data

Low–rise buildings (up to 3 storeys)

Length to width ratio: 1:1

Shielding condition: exposed

Wind speed reference level: building height



Location		Wind angle							
		0°	45°	90°	135°	180°	225°	270°	315°
Face 1		0.7	0.35	–0.5	–0.4	–0.2	–0.4	–0.5	0.35
Face 2		–0.2	–0.4	–0.5	0.35	0.7	0.35	–0.5	–0.4
Face 3		–0.5	0.35	0.7	0.35	–0.5	–0.4	–0.2	–0.4
Face 4		–0.5	–0.4	–0.2	–0.4	–0.5	0.35	0.7	0.35
Roof (>10°)	Front	–0.8	–0.7	–0.6	–0.5	–0.4	–0.5	–0.6	–0.7
	Rear	–0.4	–0.5	–0.6	–0.7	–0.8	–0.7	–0.6	–0.5
	Average	–0.6	–0.6	–0.6	–0.6	–0.6	–0.6	–0.6	–0.6
Roof (11–30° pitch)	Front	–0.4	–0.5	–0.6	–0.5	–0.4	–0.5	–0.6	–0.5
	Rear	–0.4	–0.5	–0.6	–0.5	–0.4	–0.5	–0.6	–0.5
	Average	–0.4	–0.5	–0.6	–0.5	–0.4	–0.5	–0.6	–0.5
Roof (>30° pitch)	Front	0.3	–0.4	–0.6	–0.4	–0.5	–0.4	–0.6	–0.4
	Rear	–0.5	–0.4	–0.6	–0.4	0.3	–0.4	–0.6	–0.4
	Average	–0.1	–0.4	–0.6	–0.4	–0.1	–0.4	–0.6	–0.4