A Case Study of a FE building

Merton College

PROJECT PART-FINANCED BY THE EUROPEAN UNION

Foreword

This guide is a product of ***Building for the Future*** - an inter-regional collaboration, part-funded by the GROW EU Interreg3C joint programme, which aims to achieve balanced and sustainable economic growth.

The purpose of this guide is to empower colleges to make informed decisions with regard to energy conservation.

By reviewing some of the issues around energy use and sustainable construction, we hope to assist colleges in the formulation of appropriate energy conservation strategies, and to justify the use of sustainable construction techniques.

Every construction project has its own challenges, but the impetus is towards reducing the environmental impact of buildings, both as they are built and as they are used.

AOSEC is very grateful to the partners that have been such an essential support to this project, and so it is with real admiration that I thank the Environment Agency, the LSC and SEEDA.

Dr Anne Murdoch
Chair of Board of AOSEC and Principal & Chief Executive of Newbury College

Other Titles in the Series

This guide is one of a series of 5. The others in the series are on:

- ***Commissioning Sustainable Construction in Further Education Colleges***
- ***Conserving Water in Further Education Colleges***
- ***Case study 1 - a post-occupancy evaluation of a recently-completed FE building***
- ***Case study 2 - a post-occupancy evaluation of a recently-completed Academy building***

The image on the cover page is of Merton College, provided by Nightingale Associates, project architects.

October 2007

Executive Summary

This case study reviews a recently-completed FE building in Merton College, London. The aim of the study is to evaluate the building by undertaking a post-occupancy evaluation and share the evidence-based lessons within the further education sector.

The performance of the building is measured in terms of three parameters of energy use, occupant satisfaction and environmental impact.

The Guide is about:

- **Energy Use in the academy** –how much energy is used and how it compares to other further education buildings.
- **Occupant satisfaction** – the thermal comfort of occupants in the college and how they use the building
- **Environmental impact** – how the college addresses wider environmental concerns at the global to local level ranging from carbon emissions to the internal environment, including issues of water, waste and recycling.

This guide will help:

- **Building managers** to understand the energy and environmental performance to estimate the savings potential that can be achieved.
- **Designers and building managers** to understand how to address user needs more effectively and fine tune the systems to improve efficiency.
- Lessons learnt and feedback can be incorporated to inform the design of new buildings.

Authors

Dr Rajat Gupta and Smita Chandiwala
Oxford Institute for Sustainable Development
School of the Built Environment
Oxford Brookes University
Headington Campus, Gipsy lane
Oxford OX3 0BP
United Kingdom
Tel: +44 (0) 1865 484049
Fax: +44 (0) 1865 483298
Email: rgupta@brookes.ac.uk

Contents

1.1 Building Description

Merton College is a redevelopment of the college's London road campus which comprises of new build and refurbishment spread over nine phases. For the purpose of this study, only the new building on the site has been studied.

The new state of the art building comprises of the IT café and centre, library, bookshop, meeting rooms, laboratories, science and art rooms and administration offices.

Merton College is located in Morden, Surrey and is well connected by public transport including bus, tube and rail.

Fig 1. **Location map**
Source: http://www.multimap.com/

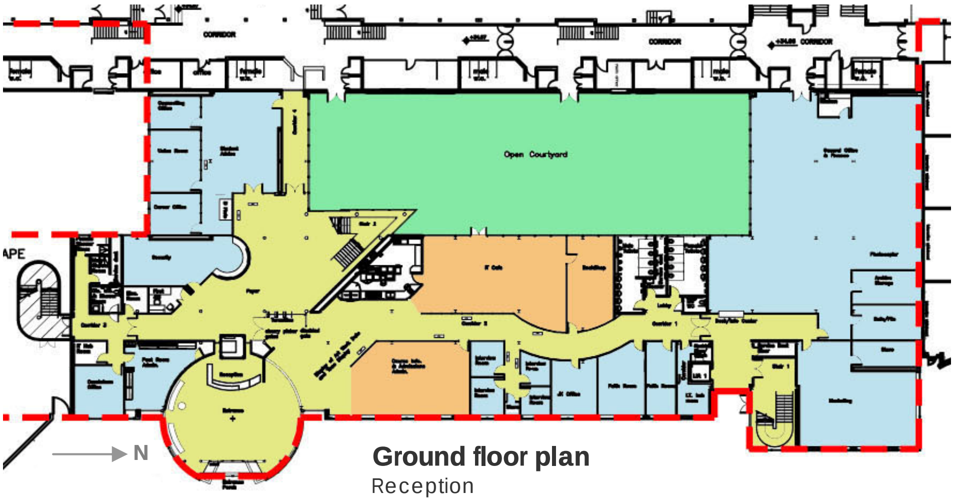
Merton college user group is mostly from 16-19 year old students though there are a large number of mature students. Since the new building is a part of a multi-building site, the number of students can not be accounted for a single site separately.

Building design

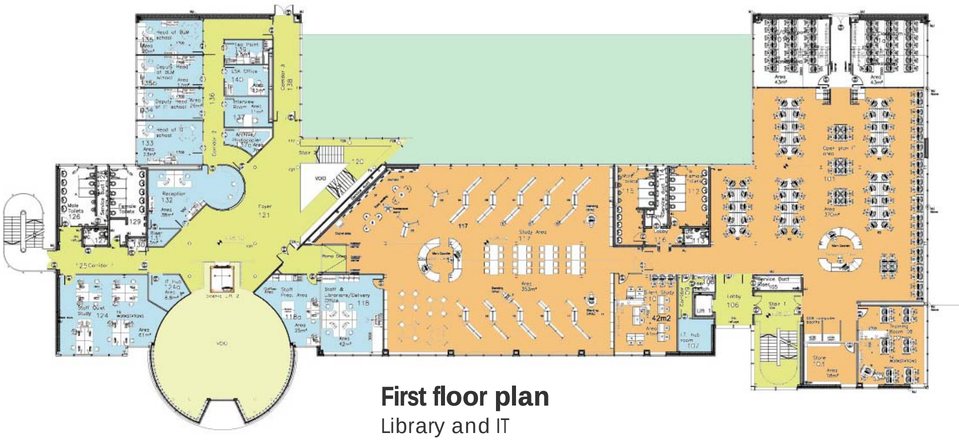
Designed by Nightingale Associates, the new 5600 m^2 three storey college building is built on the overall footprint of the earlier building.

The new building known as 'block A' encloses a courtyard on the west side of the building. The east elevation addresses the main road with a double height reception area. It is marked by an entrance rotunda clad in pre-patinated copper sheet. The rest of the façade is finished in brick and curtain glazing.

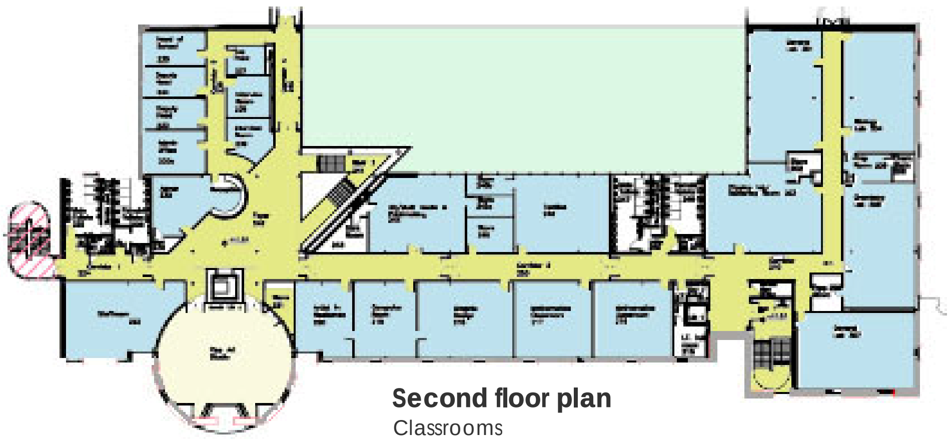
The building was completed in July 2006 and hence, can be assumed to be built with 2002 building regulations. The architects state that the built fabric has increased air tightness levels and thermal mass, with heavyweight concrete floors.



Ground floor plan
Reception
Administrative offices
Cafeteria



First floor plan
Library and IT
Administrative and staff offices



Second floor plan
Classrooms
Administrative and staff offices

2 Methodology

The main aim of the post occupancy evaluation of the academy is to evaluate the performance of the college with respect to energy consumption, environmental impact and occupant satisfaction and share the lessons with other buildings in the further education sector.

Certain preliminary information was collected about the building:

1. Fuel bills
2. Building plans
3. Building functions
4. Occupancy patterns and schedules

Table 1 **POE Methodology**

Required information		**Source**	**Tools**
Design	Design features	Architect, facility manager, media coverage	Interview, e-mail
Energy audit			
Fuel bill analysis	Gas and electricity use	Bills	
Space heating	Boiler specification	Facility manager	Interview
	Controls & BMS	Facility manager	Interview
	Radiators & user controls	Observation	Walk by survey
	Supplementary room heaters	Observation	Walk by survey, interview
Natural Ventilation	Window types & controls	Observation	Walk by survey
		Occupants	Questionnaire
Mechanical ventilation	BMS settings – windows & night time ventilation	Facility manager	Interview
Cooling	Chilled beams	Facility manager	Interview
Lighting	Lights & controls	Facility manager, Observation,	Walk by survey, interview
	Occupancy & daylight sensors		
	Blinds	Occupants	Questionnaire
Environmental Audit			
Internal environment	Temperature, humidity and light (Lux) levels.	Measurement	Data loggers, spot readings taken manually
Water	Water consumption	Bills	
	Rain water harvesting	Facility manager	Interview
Waste	Recycling types	Facility manager, Occupants	Interview, Questionnaire
Travel impact	Travel emissions by users	Occupants	Questionnaire
Occupant Satisfaction Survey			
Comfort	Thermal comfort , Noise, Air & light quality	Occupants	Questionnaire
Controls	Heating, lighting, ventilation	Occupants	Questionnaire

3 Energy Audit

The energy audit of the building comprises of analysing fuel bills to recognise past trends in usage pattern, and comparing it with benchmarks to evaluate the building's performance. It also includes an assessment of the building services.

3.1 Fuel Use

The building uses two fuels, electricity and gas. Gas is primarily used for space heating and hot water. Electricity is used mainly for lighting and equipment such as computers and smart boards etc.

The new building forms a part of a multi building site with a single meter providing gas and electricity to all buildings. No information was hence, available on the total fuel consumption in the new building. Electricity and gas use has been therefore estimated using typical practice benchmarks.

The following table shows the typical benchmarks(CIBSE 2004) and the total estimated energy use for Merton College

Table 2 **Estimated energy use from typical benchmarks**

	Merton college		**Typical benchmarks**	
Space type/category	**Total electricity kWh/ yr**	**Total fossil fuel kWh/yr**	**Electricity kWh/m²/yr**	**Fossil fuel kWh/m²/yr**
Lecture room arts	72,315.52	114,182.4	76	120
Offices naturally ventilated open plan	299,784.8	532,558.88	85	151
Library naturally ventilated	66,752	167,923	64	161
Catering fast food	22,846.4	64,766.4	218	618
Total energy use	461698.72	711675.6		
Further Education [1]	**82***	**126***	**49**	**216**

1. The overall benchmark for further education represents a small sample collected from 49 colleges during 1992-1994, and may be unrepresentative of the whole sector.

* The overall benchmark for Merton College is derived by adding the total estimated energy use and dividing it by the total area of 5626 m^2.

3.2 Space Heating and Hot water

The space and hot water in the building is provided by two Wessex ModuMax 250/750c condensing gas boilers. Each boiler, has three 250 kW models stacked vertically, which makes it six units in all to serve the entire site. The boiler is floor mounted and has been sized to even include the next phases of construction and refurbishment.

Smaller units in the boiler ensure that the only the requisite number of units work to provide the required heating demand, instead of the entire boiler and hence is more efficient, especially for larger sites. The heating system is connected to a building management system (BMS) which determines the required number of boiler units to provide for the heating load. Hot water is provided through two Dorchester DR-LA range of hot water storage heaters.

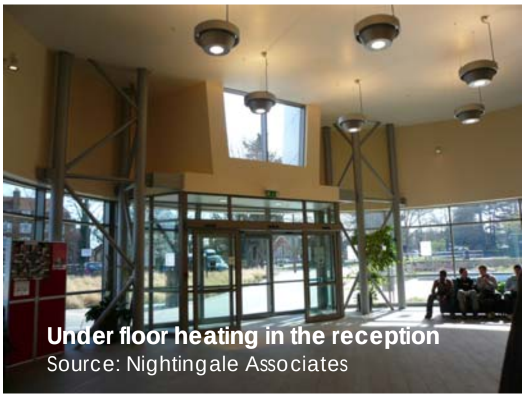
The premises maintenance staff, responsible for the boilers and the BMS system found the heating and water system extremely efficient, suitably adjusting itself to the heating demand.

Boilers for space heating

Hot water storage heaters

Local heating source and controls

Local heating systems have been used to complement the nature of the space and hence, increase efficiency.
The rooms are fitted with wet radiators and thermostatic radiator valves to enable users to partially control the heating in their spaces. The radiators are primarily controlled by the BMS and can be switched on and off through the central control point.



Under floor heating in the reception
Source: Nightingale Associates

The double height entrance lobby area is heated by an under floor heating system, by pipes carrying hot water laid underneath the floor surface. This is an effective system of heating which provides comfortable warmth close to where it is required and avoids heating the entire area. It is specially suited to large spaces where heating the entire space would require a considerable amount of energy.

3.3 Lighting

Daylight

The building appears to be generally well lit with adequate amount of natural light in most spaces. The building is orientated east west with front elevation of the building facing east. All windows except on the north side of the building have interstitial blinds between the two glass panes of double glazed windows. Interstitial blinds reduce the glare and are also more effective at reducing heat gain from outside than internal blinds.
The north side windows have internal blinds.

Interstitial blinds

Artificial lights

The building has energy efficient lighting installed throughout. Dimmer controls have been provided for all lights which allow users to control the level of light in the room. There are also daylight sensors which switch lights off when adequate natural light is available in the room. In addition, occupancy sensors in the building ensure minimum wastage of energy by automatically switching lights off when no user is detected.

Manual controls for lights have been provided as well. Sometimes, occupancy sensors are placed or work in a manner whereby the lights are switched off when it detects no movement for a long time even if the occupants are present in the room. Manual controls allow users to override the sensors and switch lights on and off when they are using the room.

Manual controls

For instances, when users override the controls manually and do not switch them off, the BMS reverts the lights to the automatic settings at around six in the evening which corresponds with the closing time of college. This ensures that any lights left on during the day will be switched off automatically at the end of the work day.

4.3 Ventilation and cooling

The building is naturally ventilated. There are two types of windows in spaces. The lower level large windows are manually operated by users. The windows are designed to be easily operable; however, they only open by a marginal amount. The top level smaller windows are controlled by the BMS to open or close automatically depending on the temperature inside the room. In winters, these windows are used to provide background ventilation without causing cold draughts. Every room has been given a manual override by which the users can choose to open or close the top level windows. However, these controls do not allow controlling the windows individually.

Night time ventilation

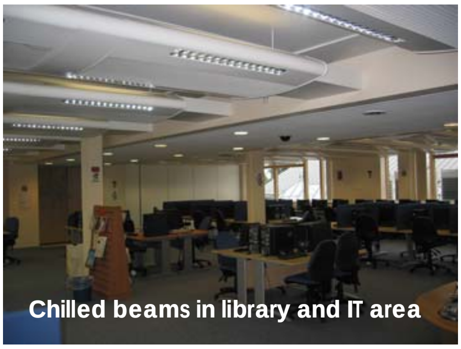
The building is ventilated at night in the summer, to cool the thermal mass. The building has high levels of thermal mass in the form of heavyweight concrete floors which absorb heat during the day, while the internal temperatures remain lower. This heat is released at night, after a time lag. Ventilating the building at night hence, allows the building to cool down before the next day.
The top level windows on the first and second floors controlled by the BMS system are opened at night automatically to enable night purging.

Front elevation with both types of windows
Source: Nightingale Associates

Marginal extent of window opening

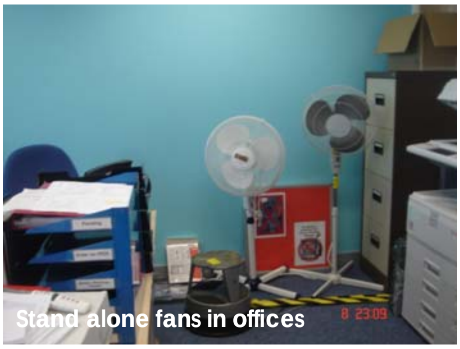
Cooling

The library and IT area on the first floor are cooled using water cooled chillers. The chilled beams are controlled by the BMS and activated when the temperature in the space, reaches beyond the set point.



Chilled beams in library and IT area

Many occupants complained of the ineffectiveness of the chilled beams to cool the space effectively. When the cooling is activated by the BMS, it also automatically closes the top windows. However, the users frequently override the controls and open the windows again. This leads to condensation when the outside warm air comes in contact with the chilled beams and the condensation detector then switches the system off, causing further discomfort in the space.



Stand alone fans in offices

This shows that the effectiveness of technology depends on how users interact with it and should be considered while designing systems. It also shows that people prefer to regulate their immediate environment manually by opening windows and are more forgiving in their expectations from doing so rather than by a centrally controlled system.

Stand alone fans were a common feature in offices to aid in cooling by air circulation.

4 Occupant Satisfaction Survey

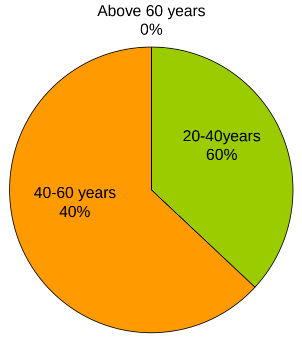
The occupant satisfaction survey was carried out through a questionnaire of thermal and visual comfort, air quality and noise levels in the building. The survey was mostly carried out in person, while some responses were collected at a later date. For a sample questionnaire, please refer to the appendix.

4.1 General

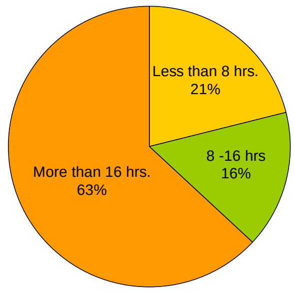
The respondents consisted of mostly staff members of the college ranging from teachers, administrators and estates management team, who had worked in the building for a substantial amount of time to be able to answer the questionnaire.

- There were 19 respondents in all.
- Out of these 14 responses were from female staff and 5 from male staff members.

Average age of respondents



Approximate time spent in college



- Most of the responses are from staff in the age group of 40-60 years.
- More than 60% of the responses are from people who work more than two days in the college in a week and hence could answer the questions about the internal environment of the building.

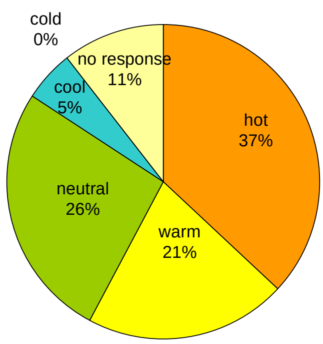
4.2 Comfort

Questions in this section are focused on the perceived comfort levels of the users with the internal conditions such as temperature, light air and noise.

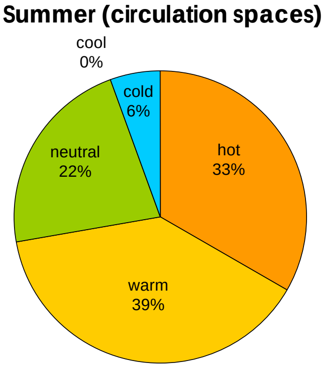
Temperature

The users were asked to rate the temperatures in their space such as classrooms or offices in summer and winter to find out if they associate a particular temperature condition with the space. They were also asked to rate the same for common circulation spaces within the building and specify any space which was particularly uncomfortable.

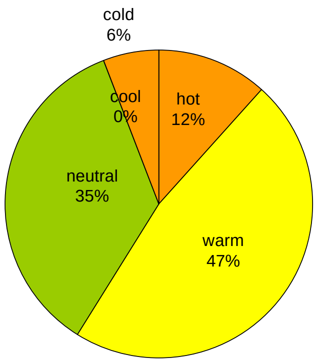
Summer (classrooms/offices)



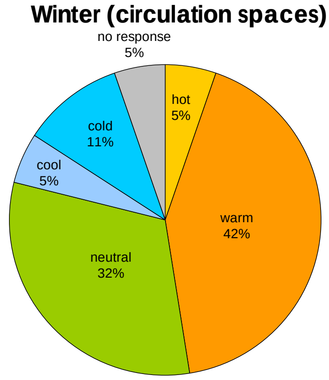
Summer (circulation spaces)



Winter (classrooms/ offices)



Winter (circulation spaces)



- Majority of the respondents find the summer temperatures in the building warm to hot. This shows that the building probably overheats in the summer.
- In winter, the building maintains comfortable temperatures and is generally rated as being right temperature to warm. 16 % of the users find the circulation areas either to be cool or cold.

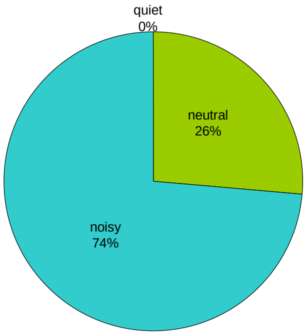
The library and IT centre was mentioned by many people as a space with uncomfortable temperatures. As discussed earlier, the chilled beams are mostly ineffective and do not perform to their capacity because users often override the window controls manually.
The other spaces mentioned for uncomfortable temperatures included the reception and some offices.

Noise

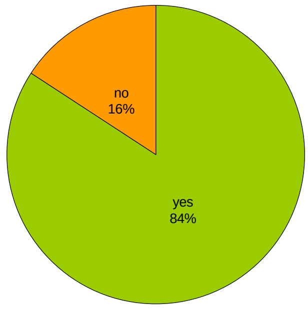
Noise in buildings can be a factor of discomfort in the work space. Although, most people get accustomed to the noise arising out of day to day activities of the college such as noise made by students or by the surrounding traffic, some sounds can affect concentration levels at work.

The users were asked to rate the general noise levels in the building and specify, if they think it affects their ability to concentrate.

General noise levels



Does noise affect concentration?



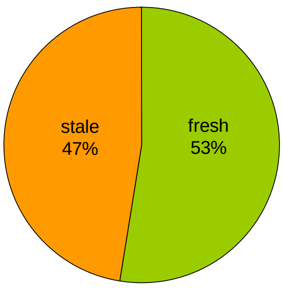
- A very high percentage of users find the noise levels in the building high enough to affect their regular activities in the college. However, most of them also said building works was the main reason for the noise apart from the students. Since the college is being refurbished in stages, there is continuing building work on site which is expected to remain for some time to come.

Air and light quality

Air and light quality in the building most directly affects the health and well being of the users.

Air quality depends on a number of factors such as temperature, humidity, carbon dioxide levels and indoor pollutants. Hence, responses about the air quality can provide clues to discomfort caused by other often ignored factors such as increased carbon dioxide levels due to inadequate air change rates. The occupants were asked to rate the general air quality and movement in their space.

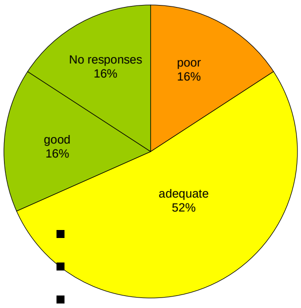
General air quality



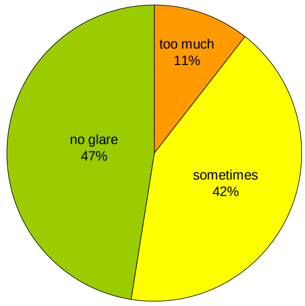
- The responses were almost equally split about the air quality with 47% people dissatisfied with the air quality in their space. The response can be dependant on individual spaces in the building. Also, ongoing building works might be a reason for not opening windows to keep the noise out.
- Only 11% users found the air movement in their space draughty whereas a 26% found the circulation areas draughty.

Availability of natural light and well lit working spaces have been linked to well being in learning environments such as schools and colleges. Users were asked to rate the quality of light and in their space and if there is any glare in the work area.

General light quality



Glare in work place

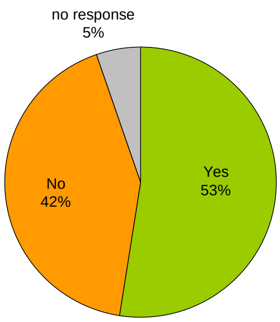


- Light quality is mostly adequate to good in classrooms and offices.
- Almost 90 % said there was some or no glare at all in their work places.

4.3 Controls

The questions in this section focus on the controls provided to users to adjust services such as heating, lighting and ventilation in their workspace. Discomfort in the space can be caused sometimes by not being able to regulate your surrounding environment to one's needs. Even when controls are provided, sometimes users are not aware about them or they are difficult to use leading to their infrequent use.

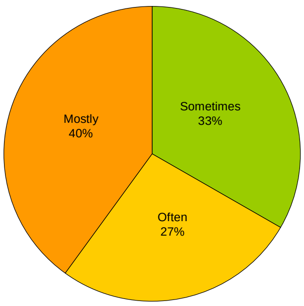
Are light sensors effective?



Lighting

- 84% of the respondents agree to have manual control over lights in their space and also find it easy to use the blinds.
- Just over half the respondents find the automatic daylight and occupancy sensors work well while 42% believe they aren't effective.

How often do you override the controls and open windows manually?



Ventilation

- 84% find the windows easy to operate and 88% of these manually open the windows to cool the room or for the breeze.
- Almost two thirds of the respondents override the controls by manually opening the windows. This shows that probably the BMS in not fine tuned to meet the requirements. Additionally, the set points for temperature might require readjustment to be more effective.

Users were also asked to specify which measure they were most likely to adopt to attain comfortable conditions in their room.

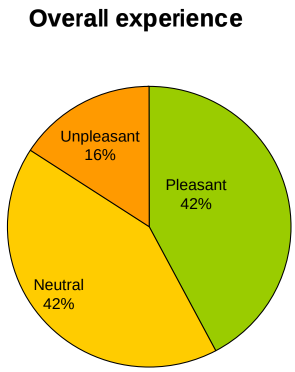
- Most people opted for opening windows and adjusting blinds to attain comfortable temperatures. Some other responses that people mentioned included calling up the premises manager to change settings or to install a fan or air-conditioning unit.

Heating

- 95% of the respondents say they have no control over the heating in their space. This is probably because the BMS controls when the heating system is switched on or off by set point temperatures in the room. However, all radiators have been provided with thermostatic radiator valves which can be adjusted to reduce or switch off heating in the immediate area.

4.4 Overall experience

User were finally asked to rate their overall experience in the college. This is indicative of the satisfaction levels of people with their environment.



Majority of the respondents rated their experience in the college neutral to pleasant with only 16% finding the experience unpleasant.

Common reasons for a pleasant experience

- Airy and natural light
- Pleasant working environment
- More facilities

Common reasons for an unpleasant experience

- Noisy environment and too much echo
- Stale air leading to headaches
- Too hot

Changes you would like to make to your environment in the college:

- More control
- Windows should open wider and individually
- More effective air cooling systems as present one causes a draft
- Reduce noise

5 Environmental Audit

The environmental audit of the building was carried out to assess the impact of the building on its internal conditions of temperatures, light and humidity and wider environmental issues of the site concerning water use and travel.

5.1 Internal Environment

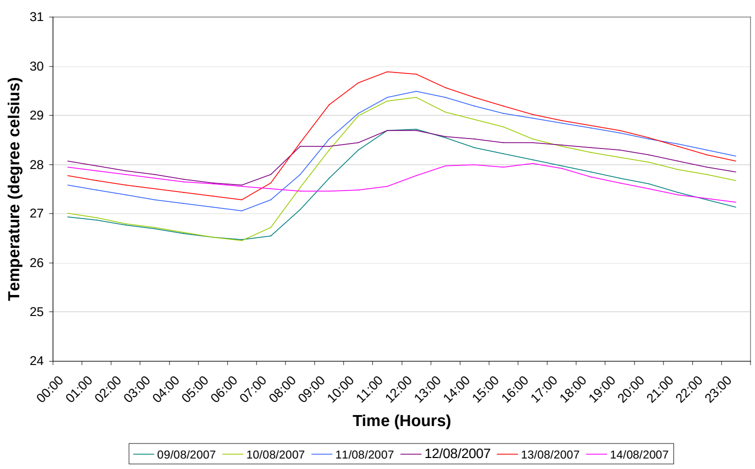
The internal environment of the building is most directly related to how the users feel inside the building and provides important clues to evaluate the building's performance. The internal environment audit was carried out through a series of measurements taken for temperature, relative humidity and light levels in the building by installing data loggers.

Temperature

Temperature was measured over a week in august by two data loggers. One data logger was placed in the IT area of the library. This is the only area in the building where the chilled beams are and also has a high heat load due to computers. The second data logger was placed in a top floor east facing classroom. Due to building works, access to any west facing room was not allowed.

All measurements were taken during the vacation period in august, when there were no students and the school was not in use. This implies that internal gains due to people occupying and using the space and from equipment such as computers have not been accounted for.

classroom temperatures over a week

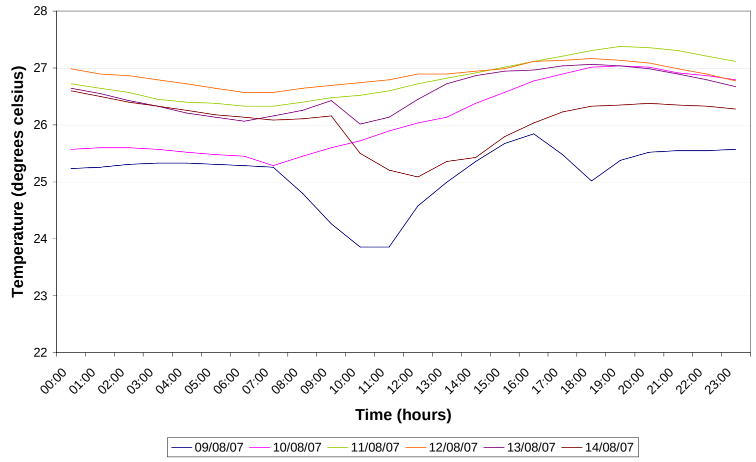


- The east facing room receives early morning sunshine and experiences a steady temperature rise from 6am and reaches the peak at around noon.
- The room temperature during the day frequently reaches to about 27°-30° with not much fluctuation in day and night temperatures.

The room was not being used and hence not being ventilated during the day, probably leading to constant temperatures inside.

- The graphs do not provide clues to the effectiveness of night time ventilation as there is an average drop of one degree in temperature from six in the evening when the windows are opened till the beginning of the next day at 7 am.

Temperature in the library and IT area over a week in august

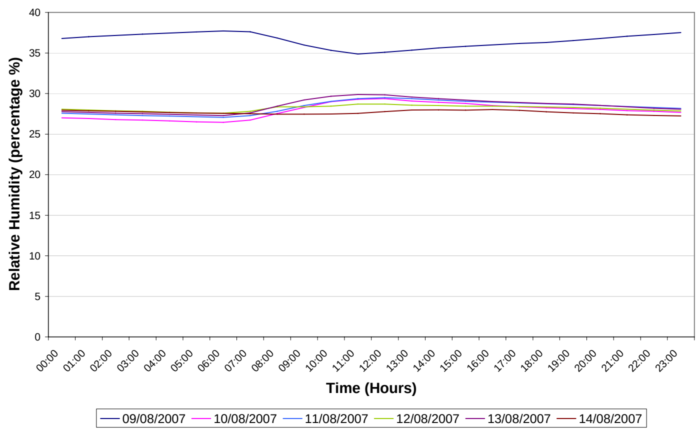


- The temperature in the IT area remains relatively constant throughout the day during the weekend (11 and 12 august) when there is probably no cooling or ventilation.
- On most weekdays, the graph shows a decrease in temperature probably when the chilled beams are working. The temperature rises once the cooling stops in the evening. On an average, the chilled beams are able to reduce the temperature by one degree.

Relative humidity (RH)

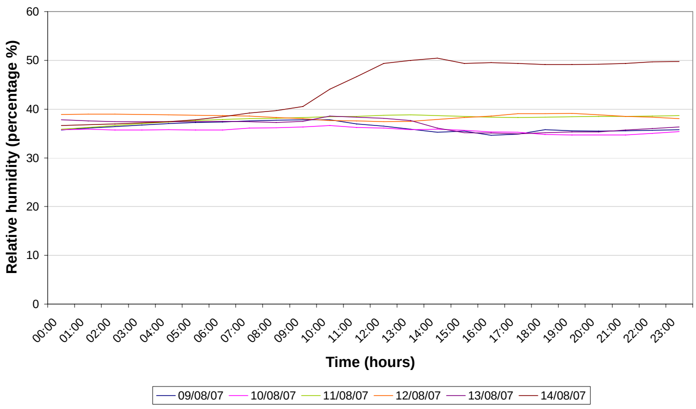
Relative humidity level in the space is also linked to comfort. Very high humidity encourages microbial growth while low humidity might lead to excessive dryness in the air resulting in certain health issues such as eye irritation. A generally recommended value for spaces with controlled internal conditions is around 30- 60% relative humidity. Relative humidity was measured through loggers during the vacations when the room was not in use.

Relative humidity in classroom over a week in august



- RH levels are mostly between 25-30% and remain well within the comfortable range.

Relative humidity in library and IT over a period of one week in august

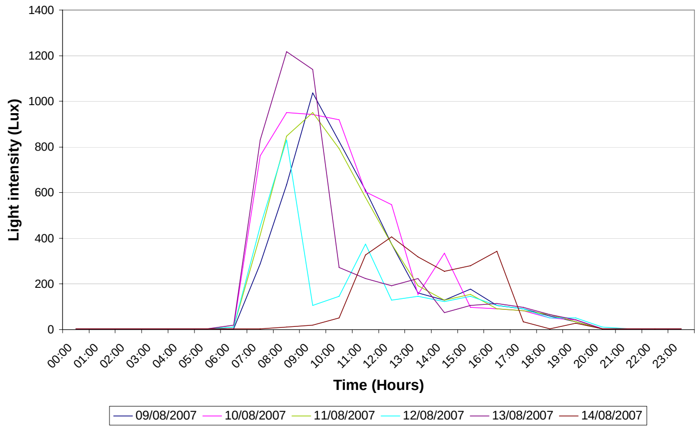


- The IT area has higher RH levels than the classroom of about 38%, but remains well within the comfortable range.

Light Levels

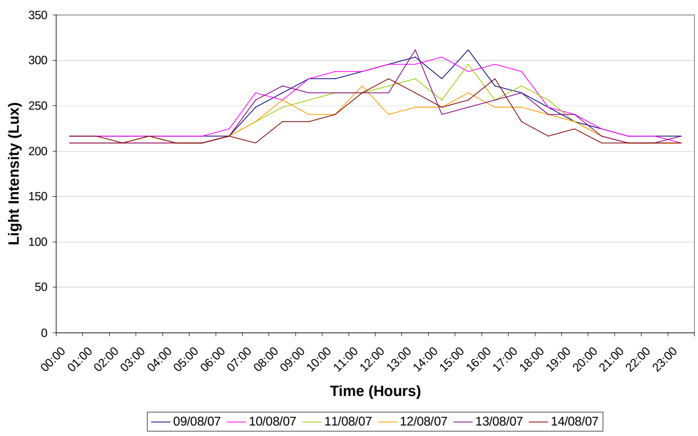
The recommended light level (including electric lights) in classrooms is in between 300-500 lux depending on the nature of the task.

Light (Lux) levels in classroom over a week in august



- The room is east facing and therefore has very high lux levels in the morning from sunrise till 9 am when the room must be receiving direct sunlight. After noon the light levels are close to 300 lux.

Light (Lux) levels in the library and IT over one week in august



- The light levels in the library and IT area are generally between the ranges of 250-300 lux during the day.
- The light level of about 200 lux even during the night suggests, that there are probably security lights switched on in the area.

5.2 Local environment indicators

Water Use

Information about the total water use in the new college building was not available. As with other services, water is metered for all the buildings on the site together and it was not possible to disaggregate the water use.

Rain water harvesting

The college harvests rain water from landscaped areas on the ground floor. The water is collected in an underground tank where two levels of disinfection and treatment is carried out. It is then pumped to an overhead tank and distributed for toilet flushing and landscape irrigation.

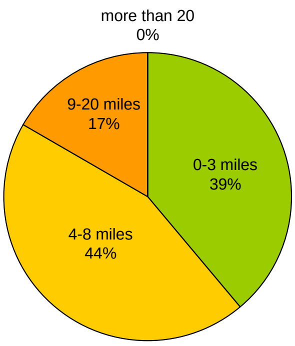
Harvesting rainwater helps in reducing the mains water consumption. Additionally, it avoids excessive run-off into site water drainage systems during heavy rainfall.

Transport

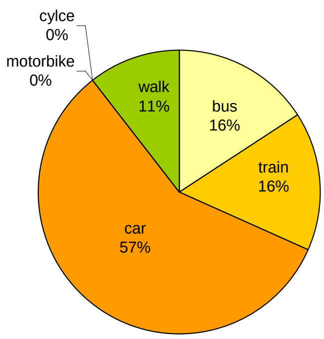
Merton College is located within easy access of public transport links with the nearest bus stop located within 500 meters of the college. Morden underground tube station and Morden south mainline train stations are also within walking distance. The architects have provided 40 cycle parking spaces on the site and introduced showers to encourage the use of cycles for traveling. Car parking spaces are provided on the campus and though there are plans to introduce a green travel plan, the college is also looking at the possibility of additional parking in the adjacent public parking bays.

The feasibility of any of these schemes depends on the user support. The graphs below are based on the responses received in the occupants' survey. The respondents were asked to specify the distance they travel to reach the college and the mode of transport.

Distance traveled



Mode of travel



- Majority of the staff, about 87% live within 8 miles of the college which is easily accessible by public transport.
- However, the preferred mode of transport is a private car followed by train and bus.

6 Conclusions

Design

The college building has been designed to incorporate passive design measures and sustainability strategies.

a. Built fabric – increased thermal mass and air tightness levels.
b. Daylight - provision for adequate natural light in spaces with different sun shading techniques depending on the orientation.
c. Artificial lighting is controlled by automatic daylight and occupancy sensors. There are dimmers for lights in classrooms and other work areas and all controls can be manually operated as well.
d. Ventilation – the building is naturally ventilated with large manually operable windows. There are top level windows controlled by the BMS for maintaining comfort conditions, though manual controls for users have also been provided.
e. Night time ventilation – to cool the thermal mass.
f. Cooling – chilled beams to provide low energy cooling.
g. Rain water harvesting – to reduce dependence on mains water supply.
h. Building Management System – to control temperature and ventilation rates in spaces.

Chilled beams

A low energy system to provide cooling has been used in the library and it. The performance however, has not been as expected due to problems with users frequently overriding controls manually. It highlights the problems with new technologies and the user interface. It also shows that people prefer to regulate their immediate environment manually by opening windows and are more forgiving in their expectations of comfort from doing so rather than by a centrally controlled system.

Occupant comfort and controls

Building management system controls the heating, lighting and ventilation in the space. Users have also been provided with manual controls to override lighting and ventilation controls.

However, majority of the users felt that they had no control over the heating in their space and had to frequently call the site services to change temperature settings.

A substantial number of users did not find the air quality in their space satisfactory and would prefer the large lower level windows to open wider and be able to individually control the top level windows.

A Case Study of a FE building

Merton College

ISBN 978-1-873640-62-3