Design quality of Scottish schools

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15th November 2007

Client report number 235884

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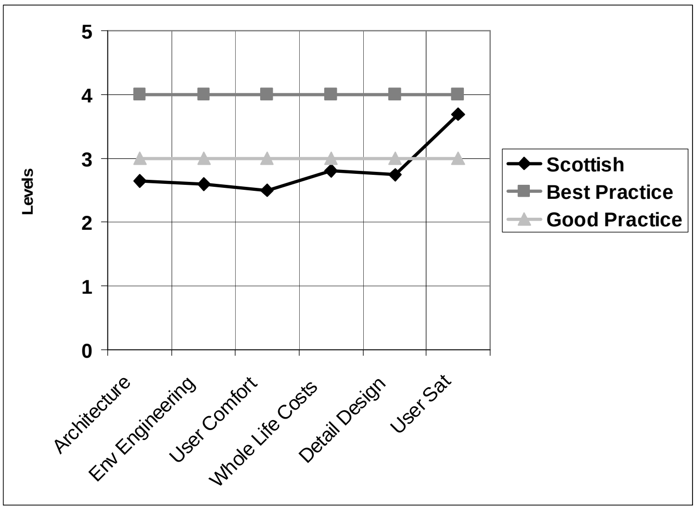
Executive Summary

Audit Scotland have commissioned professional assessments of a sample of twenty schools to develop an independent view of the design quality of new build and refurbished secondary and primary schools in Scotland. The professional assessment method used by BRE in this project was the Design Quality Method (DQM). This method was used in similar projects by the Audit Commission, the Commission Northern Ireland Audit Office and the National Audit Office. The assessment method also included making judgements about the schools in relation to the Scottish Executive's ten features of a well designed school[1]. See Appendix B for a breakdown of how the DQM matrices address the Scottish Executive's ten features of a well-designed school.

A sample of twenty Scottish schools was selected by Audit Scotland. Information relating to the range of schools used in the study can be found in Appendix F. BRE visited the sample in the second-half of April 2007. Two of the schools were older schools that were visited for reference purposes – they were omitted from the sample used for analysis. A total sample of eighteen new build and refurbished schools were used for analysis. Individual school reports have been provided to Audit Scotland but are not included in this report.



Matrix 0: Summary matrix of DQM matrices

Key Findings: -

- The Scottish school estate, judging from this sample, is generally below good practice levels, particularly in the areas of user comfort, environmental engineering and architecture. (Matrix 0)
- Refurbished schools were significantly below good practice in general and poorer than the new build schools in the sample. (See Section 4.1).
- In terms of environmental sustainability, it seems that little attempt was made to design for or mitigate the effects of global warming and climate change. (See Section 3.5 Matrix 2).
- The Scottish sample of new build schools is rated slightly higher than the median of Northern Ireland, England and Wales schools' samples, but followed the same profile. (Section 4.7).

[1] School Design: Building our Future: Scotland's School Estate, Scottish Executive 2003

Contents

1 Introduction

Audit Scotland commissioned BRE to undertake an assessment of the design quality of a sample of new build and refurbished schools in Scotland using their Design Quality Method (DQM). This method was used in similar projects by the Audit Commission. BRE Scotland contacted Audit Scotland to apprise them of the work BRE has done for auditing bodies to assess the value for money and design quality of new build and refurbished schools and hospitals. This includes work done for the Audit Commission[2]; Northern Ireland Audit Office[3]; and the National Audit Office[4] over the past five years. These projects used the BRE's Design Quality Method (DQM) to assess the design quality and value for money of PFI and Non-PFI secondary and primary schools. They represent a body of knowledge which includes the assessment of nearly fifty secondary and primary schools throughout England, Wales and Northern Ireland. The DQM is therefore tried and tested as a methodology for non-intrusive, overview assessments of building design quality

BRE's premise in developing the DQM was that an experienced team of construction professionals could rate operating buildings against objective performance measures. The DQM originated from these Post Occupancy Evaluation (POE) exercises into a 'balanced scorecard' that measures the whole performance of buildings. The Method relies on expert opinion, professional judgement, user opinion, and scientific measurement (e.g. lighting levels, air quality and acoustics etc). The POE DQM surveys are visual and non-intrusive, allowing built asset valuation of large portfolios or samples in an economical manner. Normalisation of the sample results with a larger pool of BRE experts helps to ameliorate subjective value judgements and makes the process as objective as possible. Use of the DQM methodology in both the public and private sectors, over the last five years, at post-occupancy and design stages led to the publication of 'The Design Quality Manual' which is a guide to improving building performance.[5]

[2] *PFI in Schools*. Audit Commission. 2003 http://www.audit-commission.gov.uk
[3] *Building for the future*. Northern Ireland Audit Office. 2004
[4] *Benchmarking PFI hospitals*. National Audit Office. Unpublished draft report. 2006
[5] Martin Cook. *The design quality manual; improving building performance*. Blackwells. Oxford. 2007

2 Description of the project

Audit Scotland commissioned BRE to undertake professional assessments of a sample of approximately twenty schools to develop an independent view of the design quality of new build and refurbished secondary and primary schools. This included making judgements about the schools in relation to the Scottish Executive's ten features of a well designed school;[6] identifying good practice and areas with scope for improvement; and developing a description, with examples, of what the improvements mean for pupils and teachers.

To achieve the objectives set out in the brief BRE used the Design Quality Method (DQM), which benchmarks school designs against Good and Best Practice within the quantified opinion of experienced architects and engineers. The DQM is a tried and tested methodology for the post occupancy evaluation (POE) of schools and hospitals and is used by all auditing bodies in the UK. It consists of visual surveys of premises by a small team of expert architects and engineers, preceded by a semi-structured interview with head teachers. The Method relies on the professional judgement of highly-experienced professionals across a sample of buildings. Their initial field judgements are normalised by peer review by other relevant experts and specialists at BRE, which ameliorates any overly subjective or extreme opinions.

BRE's DQM consists of the following six matrices, over-arched by a summary matrix (See Appendix A):

Matrix 1 - Architecture - covers the relatively subjective area of aesthetic merit, and also the more prosaic qualities of specification, site and space planning. All integrated aspects of a building's artistic and scientific performance are covered by the term 'architecture' – the use of a discrete matrix is not intended to marginalise the term, but establish it as a over-arching definition of design quality.

Matrix 2 – Environmental engineering - more objective and supported by scientifically measurable lighting, noise, temperature, and air-pollution levels. Sympathetic integration of environmental services with architecture is crucial, not to mention appropriateness, maintainability and replacement sourcing.

Matrix 3 - User comfort - internal comfort conditions are also scientifically measurable and links between them and productivity are formally established by peer-reviewed research. Integrating art and science creates ideal environments – e.g. the quality of daylight is just as important as the measurable quantity. For example, optimum environments are critical to successful school design and often reflected in the enhanced educational performance of pupils.[7]

Matrix 4 – Whole life costs - covers the occupancy costs of schools and the potential whole life performance of building fabric, components and services. It provides an analysis of the trade-offs between capital and running costs that affect future building performance.

Matrix 5 - Detail design – failures in building performance are often caused by poor detailed design or bad workmanship. Rectifying and coping with such failures will increase maintenance and occupancy costs.

[6] Scottish Executive. *School design*. 2003

[7] Heschong Mahone Group, *Daylighting and productivity study: daylighting in schools*, USA, August 1999.

Matrix 6 - User satisfaction: a school representative is asked to rate their satisfaction with the building by responding to six structured questions. They are asked to rate each aspect on a scale of one to five (five representing the highest level of satisfaction). [8]

See Appendix B for a breakdown of how the DQM matrices address the Scottish Executive's ten features of a well-designed school.

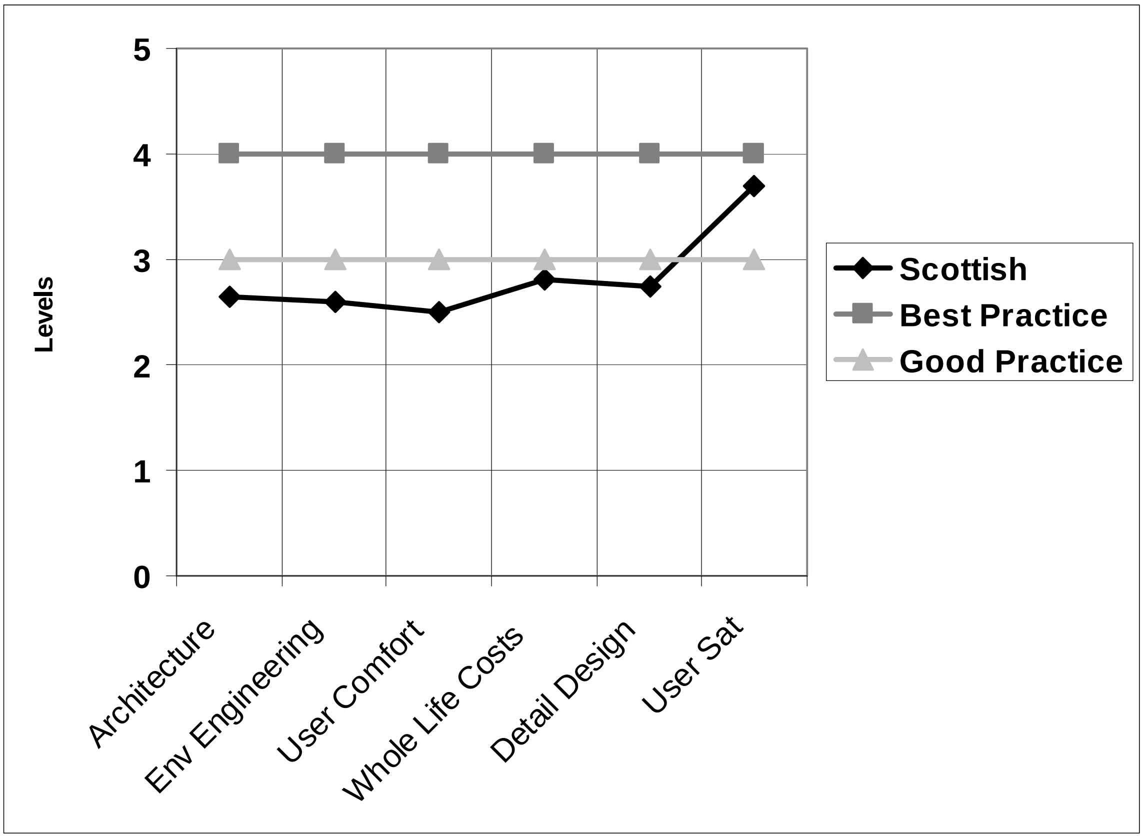
Audit Scotland selected a sample of eighteen new build and refurbished schools, and two historic schools in relatively poor condition. The sample was structured to include a range of PFI and Non-PFI schools, new builds and refurbishments, and primary and secondary schools. BRE visited all twenty schools in the second half of April 2007. The sample of eighteen new build and refurbished schools was used for the analysis in this report, i.e. omitting the two historic schools. The findings relate to the sample only.

[8] Audit Scotland has commissioned separate work to explore the views of pupils, teachers and parents.

3 Findings

The matrices used in the DQMs identify levels ranging from 0 to 5. Level 5 is exemplar; Level 4 is Best Practice; Level 3 is good practice; Level 2 is acceptable; Level 1 is poor; and Level 0 is unacceptable. See Appendix A for matrix definitions. The matrices in Appendix A describe fully good and best practice standards. These standards have been determined by BRE from over 50 years research and investigation into the built environment. These standards are recognised industry wide and are widely used and sourced from organisations such as CABE, DfES, CIBSE, Carbon Trust, Scottish Building Standards Agency and the Department for Community & Local Government amongst others.

Matrix 0 – Summary matrix

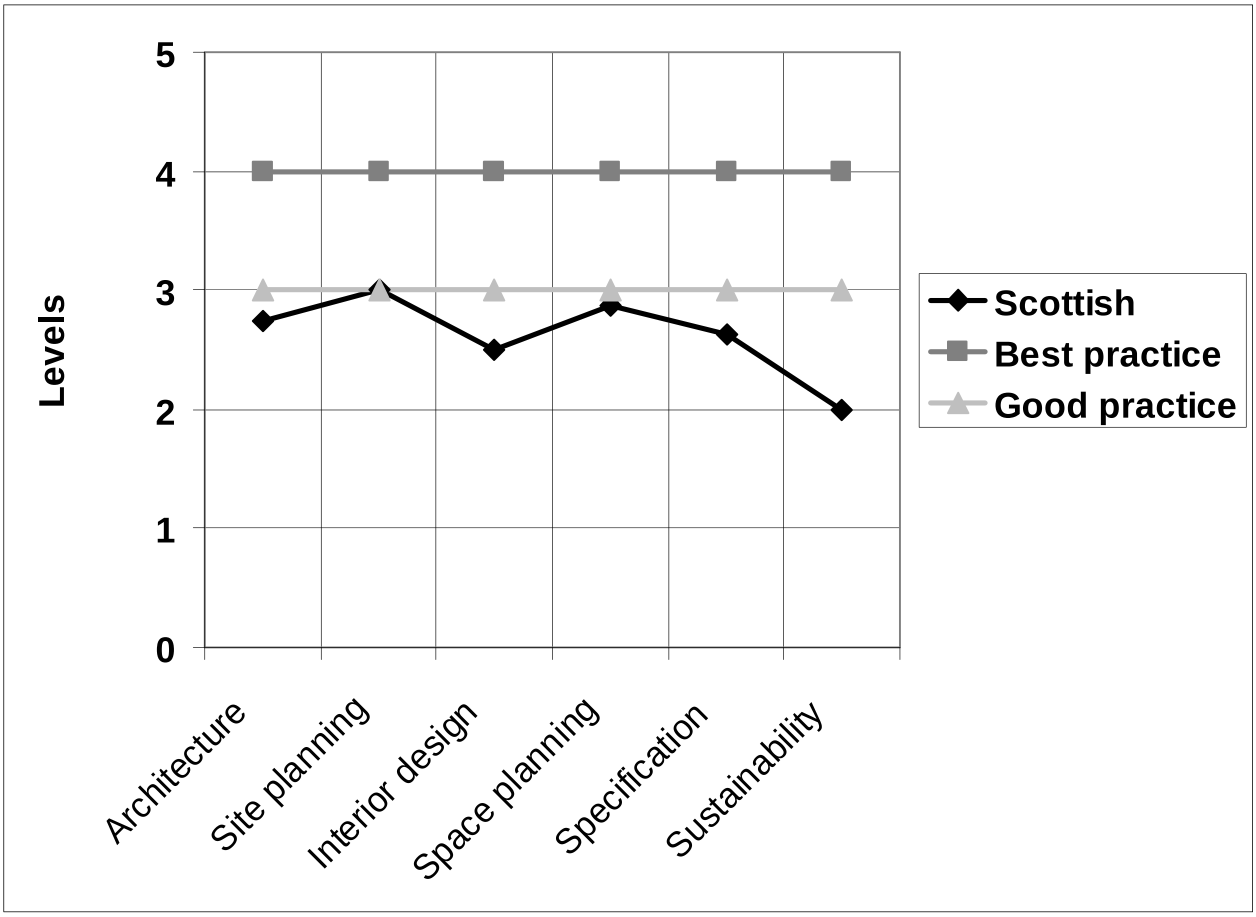


3.1 Matrix 0 – Summary matrix commentary

This is the summary of the six matrices and gives an overview of the results. It shows that user comfort, environmental engineering, and architecture are below good practice. User satisfaction scores are always generally higher as they represent lay opinion and we treat these interviews as anecdotal evidence.

The successive matrices show more detail, particularly aspects of the matrices which influence the median scores in the summary matrix.

3.2 Matrix 1 – Architecture matrix

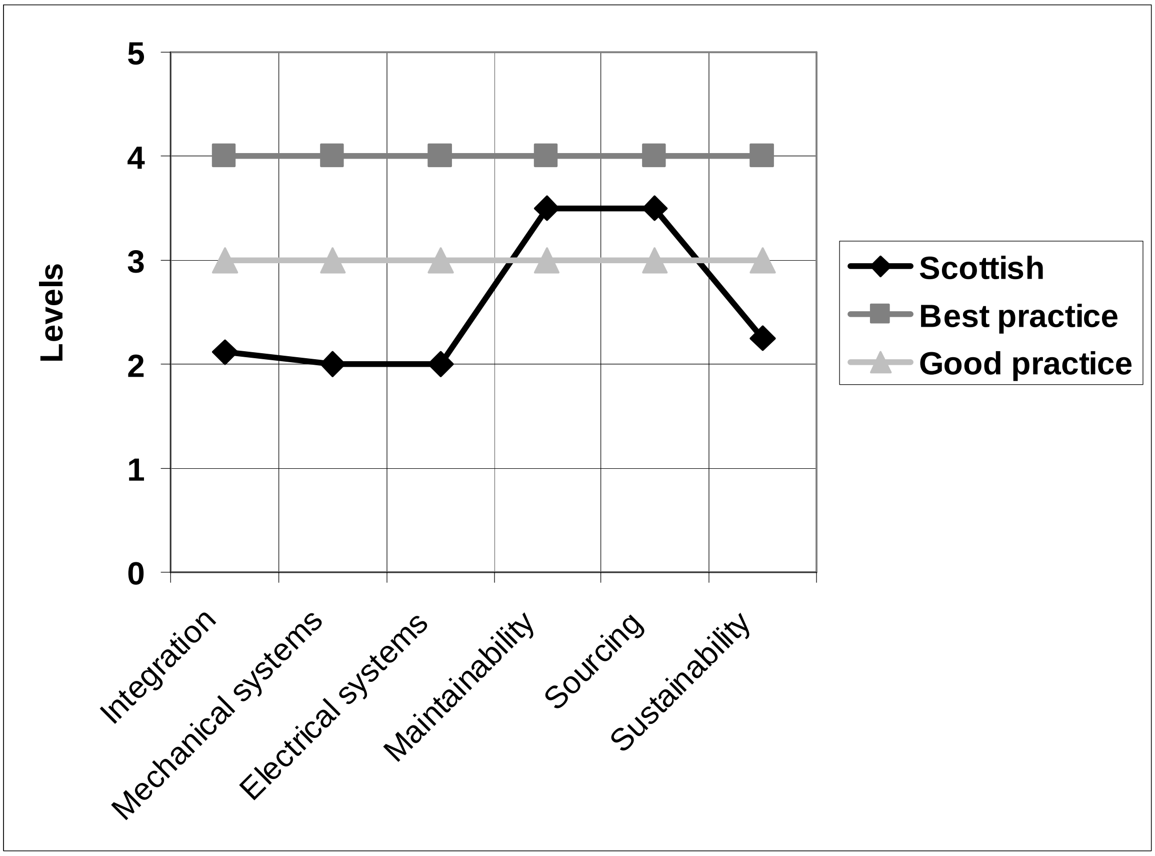


3.3 Matrix 1 – Architecture matrix commentary

Site planning and space planning are at good practice levels. Environmental sustainability is at Level 2, an entire level below good practice. Specification and interior design are other areas of concern, but the poor quality of some of the refurbishments is dragging these aspects and architecture (exterior) down.

There was marked evidence of the implementation of comfort-cooling in certain areas such as computer rooms and libraries – given the trends above, users will increasingly perceive the need for increased mechanical ventilation or even air conditioning, rather than passive means, to furnish them with a well-tempered educational indoor environment that is fit for purpose.

3.4 Matrix 2 – Environmental engineering matrix



3.5 Matrix 2 – Environmental engineering matrix commentary

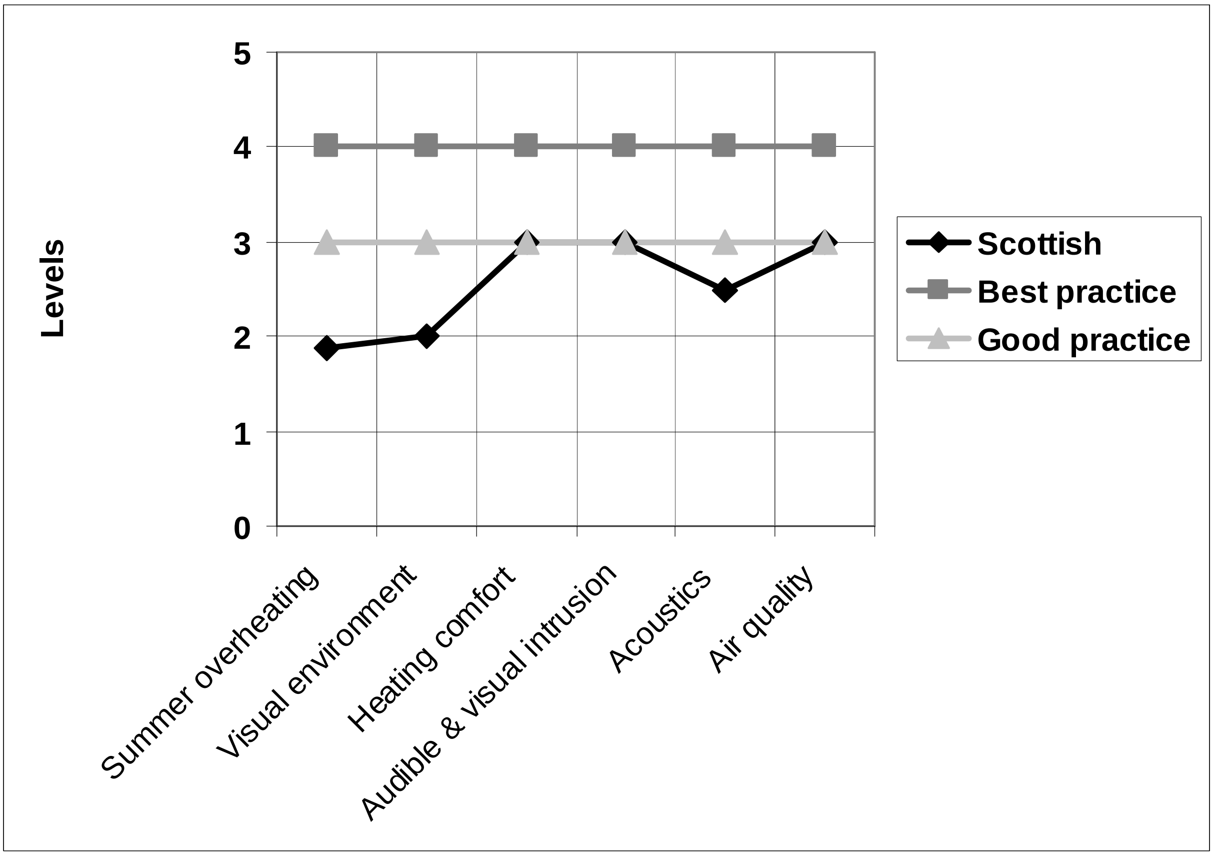
Maintainability and sourcing are between good and best practice, but other aspects are of concern. Sustainability is at a similar level to the architecture matrix score for this aspect. Again, scores at Level 2 are significantly below good practice - in terms of sustainability this represents the difference between a 'Very Good' BREEAM[9] rating (Level 3) and a 'Good' BREEAM rating (Level 2).

BREEAM was developed by BRE in collaboration with DfES as a tool to measure environmental sustainability in schools. It takes a holistic approach and measures sustainability in categories including Energy, Transport, Management, Health & Wellbeing, Ecology, Water, Materials and Pollution. Categories are weighted and assessments are undertaken at design stages and post construction.

The first three elements of the matrix measures how a building's environmental characteristics integrate with the architecture and what mechanical & electrical systems have been installed. This includes an assessment of natural ventilation and daylight strategies, controls, heating and cooling, lighting and equipment and how this has been designed into the building.

[9] BREEAM is the Building Research Establishment's Environmental Assessment Method and it is a requirement for all new schools in England & Wales to achieve a BREEAM Very Good rating. For more information visit www.breeam.org.uk.

3.6 Matrix 3 – User comfort matrix

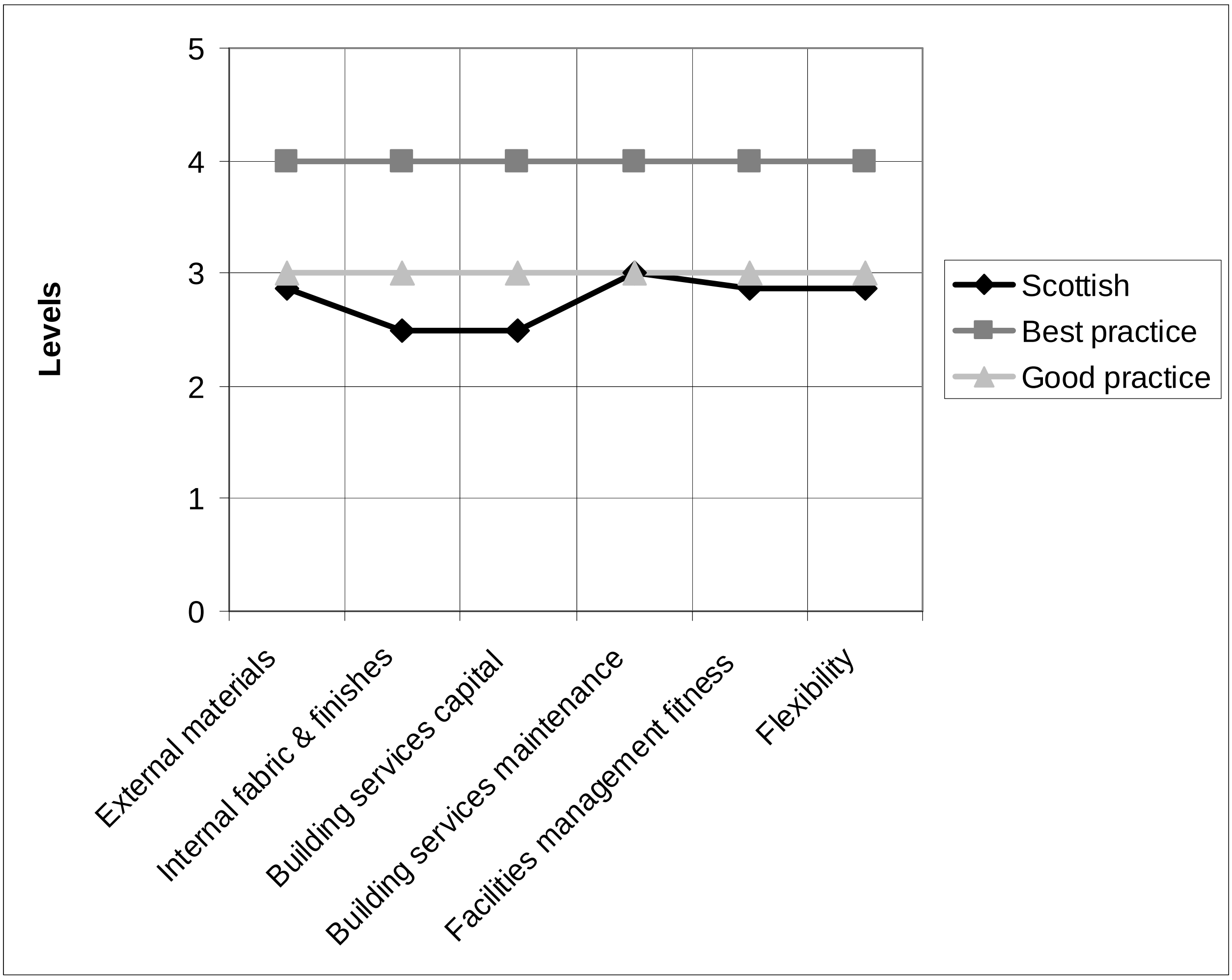


3.7 Matrix 3 – User comfort matrix commentary

Heating comfort; audible and visual intrusion; and air quality are at good practice levels. Summertime overheating is of particular concern, as well as visual environment. Acoustics are below good practice largely due to lightweight construction and hard parallel surfaces. Summertime overheating is a particular problem in lightweight construction where opening windows have not been optimally or even competently placed e.g. at low level for cool air to enter and at ceiling level to allow hot air to escape. There was a distinct trend in the new build sample for non-opening rooflights - this is a lost opportunity in terms of ventilation strategy.

Typically, there are other inter-related issues, such as the size and geometry of classrooms - e.g. you can not passively light and ventilate a classroom which is deeper than six or seven metres from one external side wall (with a ceiling height of below three metres). Some classrooms in the sample were ten metres deep with low ceiling heights (e.g. 2.8 metres) - the artificial lighting will always be on (with attendant heat generation) and the retrofitting of extract fans does little to alleviate this less than optimal arrangement. The best classroom configuration dated from the 1950s - high ceiling height (about 4 metres); low and high level opening windows with cross-ventilation to the corridor; and heavyweight construction.

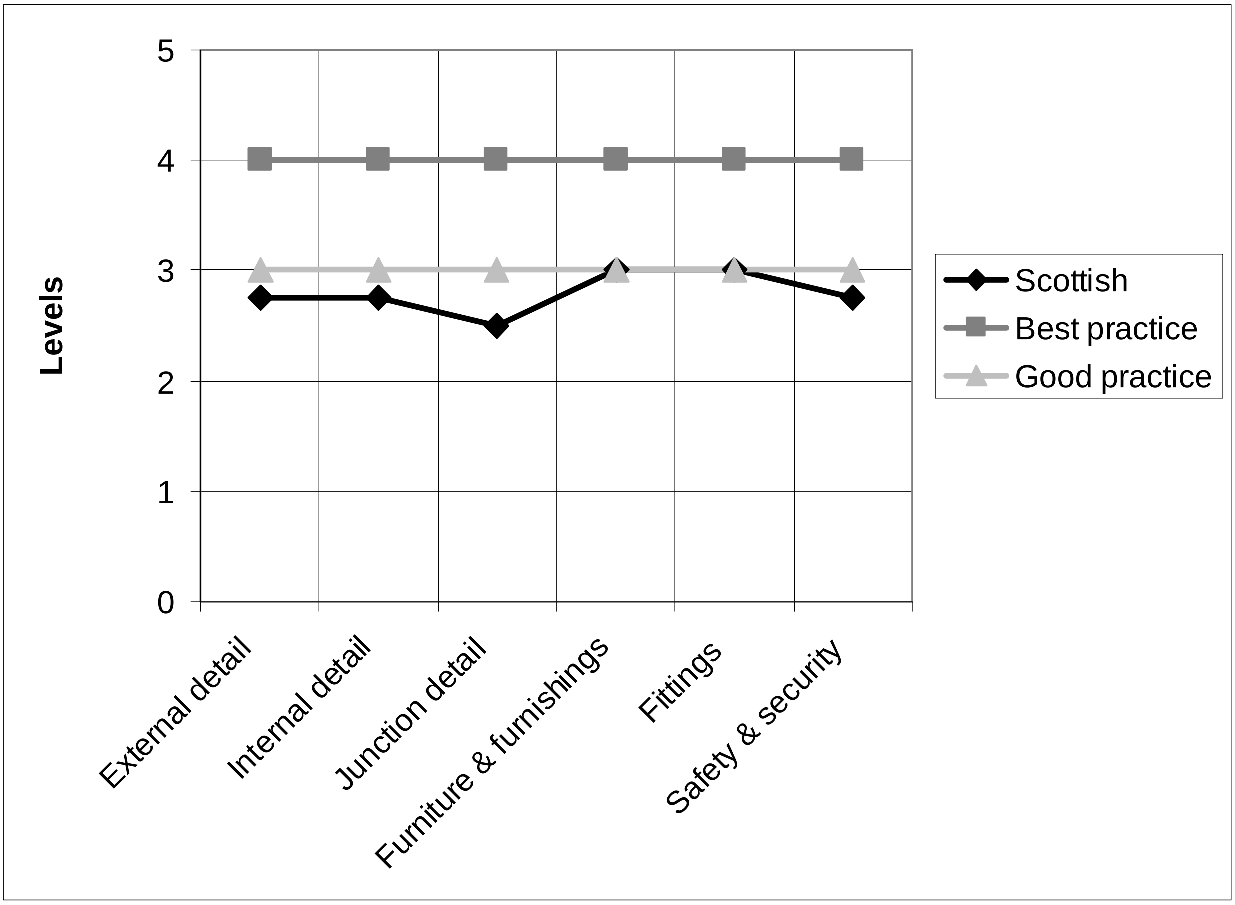
3.8 Matrix 4 – Whole life costs matrix



3.9 Matrix 4 – Whole life costs matrix commentary

Generally at good practice. But internal fabric and finishes are below good practice. Building Services Capital items are also below good practice which links to the low sustainability scores. Although external materials overall score a 3 good practice, one example of deviation from good practice was where Spanish roofing slate was used on a PFI school in the Highlands. The problem is that Spanish (and other overseas countries) roofing slate although cheaper than local materials is usually much thinner than most indigenous slate, achieving a high area of coverage. The school has experienced problems with cracking and falling slates probably due to snow and wind loading, or poor workmanship and inadequate fixings to cope with the micro-climate in the Highlands (as well as problems due to under-specified snow blades). This is a rather depressing example of commercial decisions that ignore the whole life cost argument, not to mention the environmental sustainability argument for local materials.

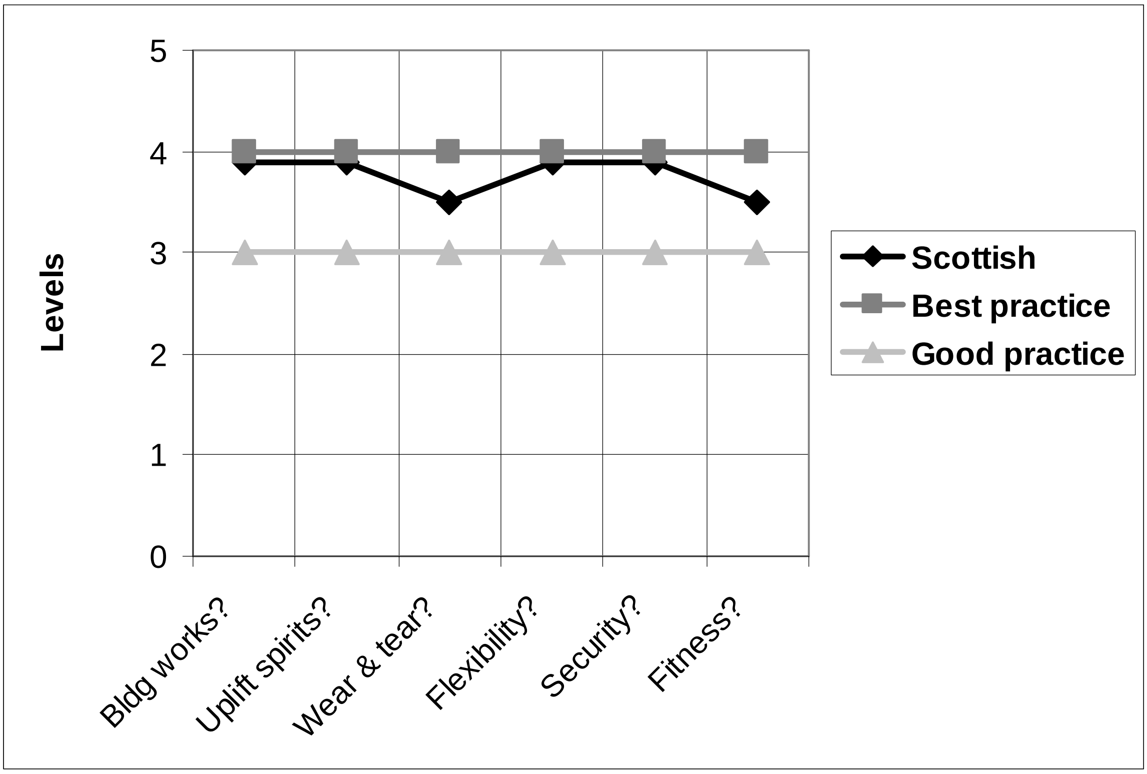
3.10 Matrix 5 – Detailed design matrix



3.11 Matrix 5 – Detailed design matrix commentary

Generally at or approaching good practice, but with some concerns around external (e.g. the snow blades mentioned above); internal and junction details, as well as safety and security. The eaves junction detail, where the external walls meet the roof were particularly poor in some schools, which has led to premature degradation of materials and pigeon roosts. In a few schools in the sample we were able to walk in the front door unchallenged, which is always a good test of security.

3.12 Matrix 6 – User satisfaction matrix

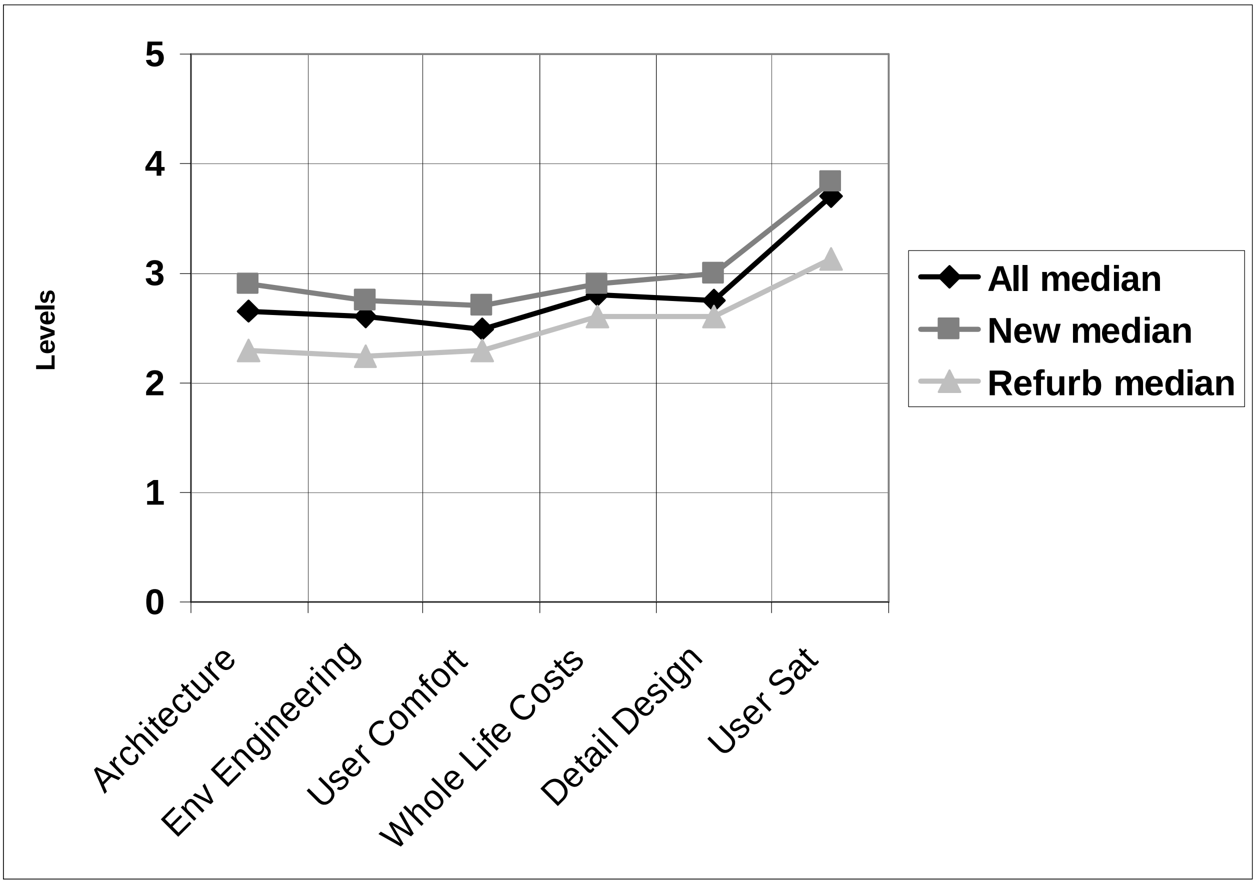


3.13 Matrix 6 – User satisfaction matrix commentary

Generally, we regard this matrix as anecdotal, but the lower scores for 'wear and tear' and 'fitness for purpose of the indoor environment' seems to reflect the concerns raised in these areas in the relevant matrices above.

4 Further findings

4.1 New build compared to refurbishment

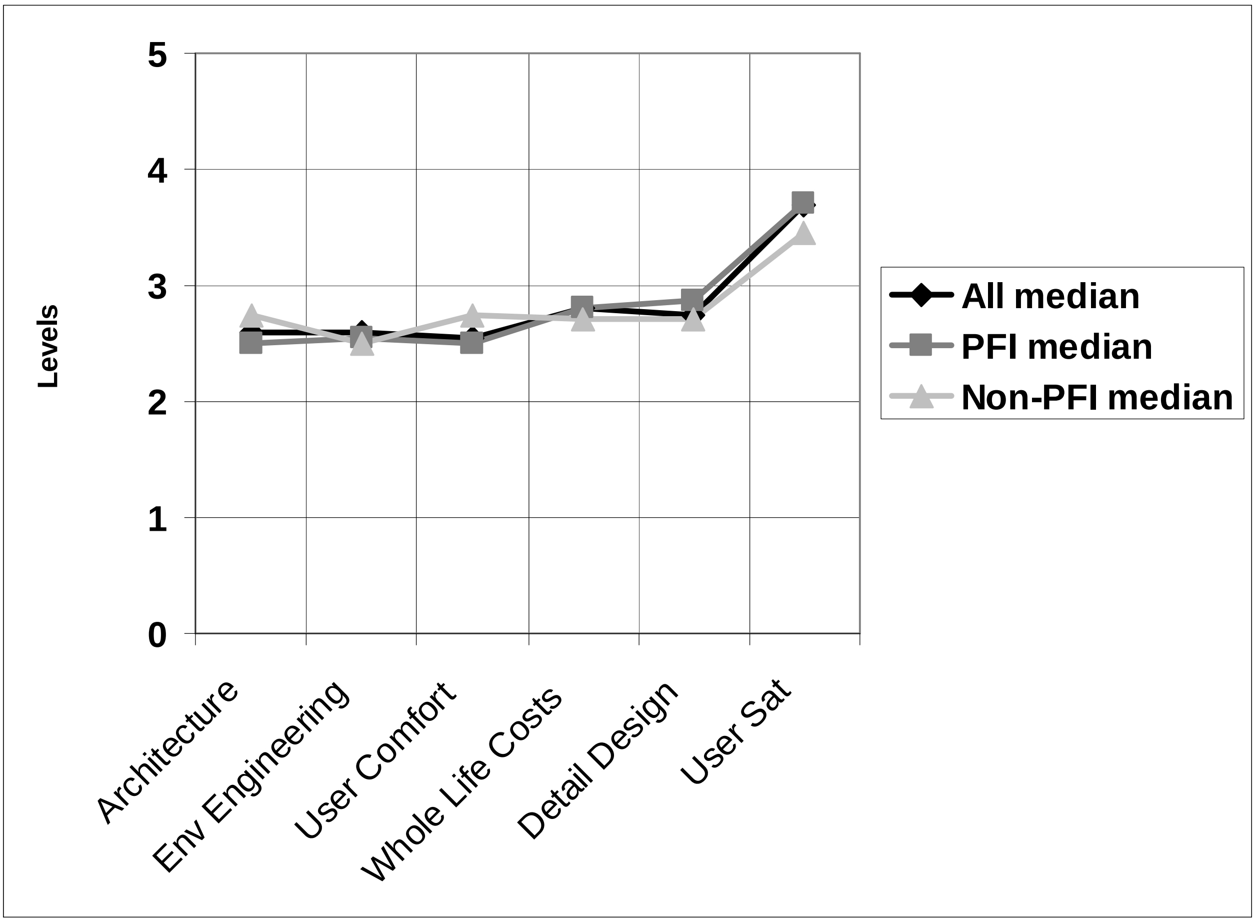


4.2 New build compared to refurbishment commentary

This matrix clearly shows the disparity between the design quality of new build schools as compared to refurbishments. Refurbishments, regardless of the procurement route used, were significantly below good practice across the board. And this is anecdotally corroborated by the difference of nearly an entire level recorded by the users of these schools. There were some extreme examples which reduce the level of the overall median of refurbished schools, however they were all below good practice overall. There were in some cases examples of the refurbishment making some aspects of the schools worse – particularly in terms of ventilation caused by sub-optimal new window arrangements. The new windows were obviously double-glazed replacements for single-glazing, but almost always entailed fewer opening lights in a less than competent arrangement.

The overall trend among the refurbished schools was the prioritisation of Disability Discrimination Act (DDA) compliance. While this is laudable and legally necessary, it often entailed elaborate and expensive retrofitting of thirty or forty year old schools to make them fully accessible. In one case, the refurbishment seemed to consist almost solely of installing a lift to make a four-storey block fully accessible.

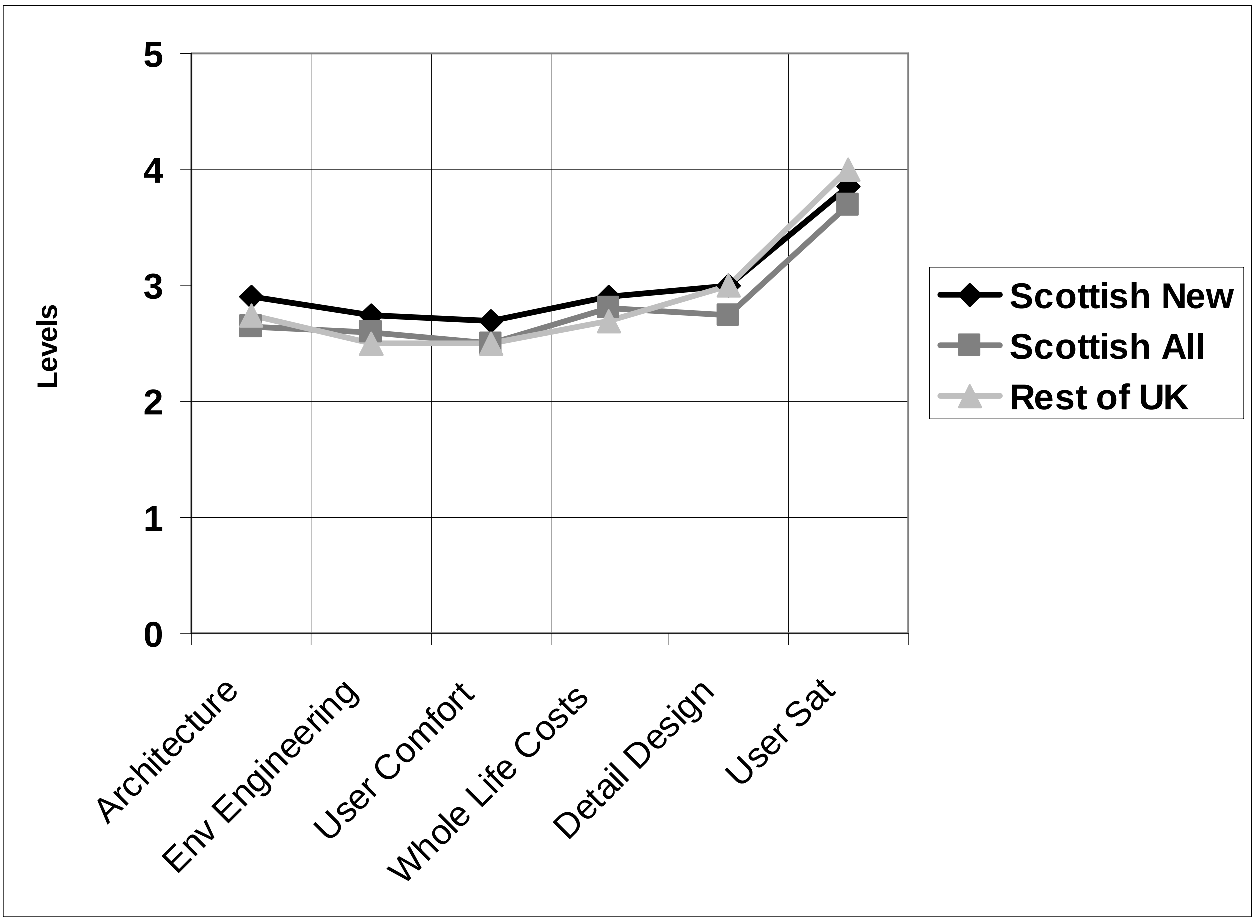
4.3 PFI compared to Non-PFI



4.4 PFI compared to Non-PFI commentary

There appeared to be little difference between PFI and Non-PFI procured schools overall, particularly in regard to the refurbishments. The median of the overall sample is just below good practice, although there were a minority of schools that approached best practice in some aspects and some schools considerably below good practice overall.

4.5 Scottish New Build schools compared to the rest of UK schools



4.6 Scottish schools compared to the rest of UK schools commentary

This matrix shows that the median of the Scottish schools sample follows a very similar profile to that for the rest of UK schools samples that BRE have assessed with the DQM (i.e. England, Wales & Northern Ireland). However, it also shows how the refurbished Scottish schools reduce the overall median of the sample – the new Scottish schools have a slightly higher profile that the rest of the UK median. But, it must be remembered the rest of UK schools' sample dates from surveys undertaken in 2002 and 2003 – in the intervening years building regulations and guidance standards have generally improved. New Build Scottish schools in the sample are approaching good practice levels in all but environmental engineering and user comfort meaning that the refurbishment projects in the sample are

5 Scottish Executive's Ten Features of a Well Designed School

The Scottish Executive's publication 'School Design, Building Our Future: Scotland's School Estate'[10] makes reference to CABE's ten features of a well designed school[11]. This section of the report describes the findings within the context of each of these ten features.

5.1 Good clear organisation…

Site planning and space planning across the sample scored a median of Level 3 which is good practice. Most schools were orthogonally-planned with rectangular wings which are far easier to extend than rigid geometries such as circular or triangular plans – flexibility for change and extension was similarly scored at good practice on average. All other aspects of the matrices that we identified to inform this question were median scored at good practice, apart from interior design which scored between Level 2 and good practice. This was largely due to indoor environment issues arising from the interior design, such as acoustic and daylighting problems.

5.1.1 Good Practice

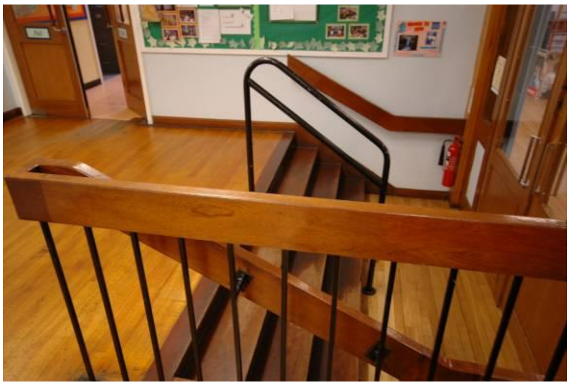
Clear orthogonal ground plan

Academic courtyard formed with extension

[10] Scottish Executive, School Design 2003
[11] CABE: 'Client Guide: Achieving Well Designed Schools through PFI'(2001)

5.1.2 Poor Practice

Constrained and confusing site layout



Ground floor inaccessibility to assembly hall

5.2 Spaces that are well-proportioned…

Most classrooms are naturally ventilated from the window-wall. A floor to ceiling height of 2.8 metres limits the potential for adequate daylight to a room depth of about 5 metres; and adequate single-sided ventilation to a room depth of about 7 metres (with optimum opening window arrangements, such as top and bottom opening windows within an overall window height of 1.5 metres) [12]. Some classrooms surveyed were 10 metres deep – giving poor daylight and ventilation in a single-sided, window-wall arrangement.

Some schools had generous entrance and reception spaces and one school had a dramatic hall which included a mezzanine space. However, the acoustics in many assembly and sports halls were poor. Reverberation times were too long, with sound including speech perceptibly echoing around the room – leading to poor intelligibility.

Staff rooms were often undersized – often due to extension and the introduction of auxiliary teaching staff.

5.2.1 Good Practice

Well-proportioned entrance lobby

Well-proportioned classroom c1950

[12] BRE Digest 399. *Natural ventilation in non-domestic buildings*. BRE. 1994

5.2.2 Poor Practice

Poorly-proportioned entrance lobby

Poorly-proportioned classroom

5.3 Circulation that is well-organised…

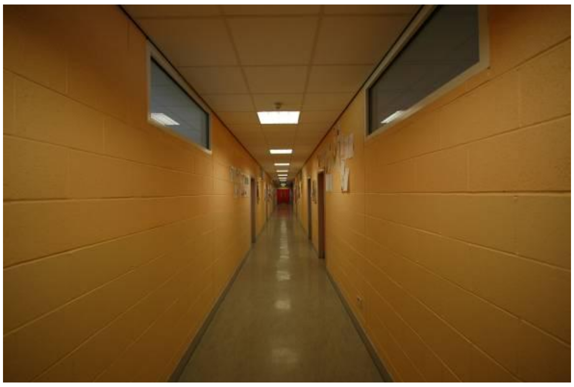
Corridors were often too narrow. This was sometimes associated with a school being extended. Several schools had imposed a one-way system for safety reasons – this increases travel time between classes and reduces teaching time. Many corridors were lengthy and dim without a relieving window at the end. Some corridors and circulation spaces were generous, articulated and with rooflights and glazing at the ends.

5.3.1 Good Practice

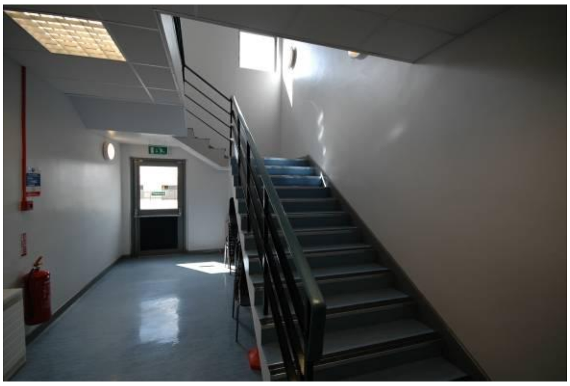
Generous and well-daylit corridor

Generous and well-daylit corridor

5.3.2 Poor Practice



Mean, dingy, long and narrow corridor



Restricted headroom – less than 2 metres

5.4 Good environmental conditions throughout…

A significant trend was the installation of quite generous fixed-rooflighting to corridors and sometimes at the back of classrooms, with no opening-windows. This is a lost opportunity to benefit from passive ventilation via the stack effect of hot air rising, particularly where the school is predominately constructed of thermally-lightweight materials (e.g. internal partitions of plasterboard) and will almost certainly overheat in summer.

The ventilation of teaching spaces was usually poor due to sub-optimal opening-window arrangements which usually consisted of a single row of opening windows in the horizontal centre of the window arrangement – rather than the optimal top and bottom opening-window arrangements. It seems that ventilation arrangements in many refurbished schools were made worse with the introduction of double-glazing with fewer opening windows, in a sub-optimal arrangement as described above. Presumably, a commercial decision was made to specify fewer opening-windows than the original and traditional, albeit single-glazed, arrangements. The best classroom configuration dated from the 1950s, with a high ceiling height (about 4 metres); low and high level opening windows with cross-ventilation to the corridor; and thermally-heavyweight construction.

5.4.1 Good Practice

Cross-ventilated and daylit classroom c1950

Well-daylit sports hall c1960

5.4.2 Poor Practice

Poor opening window arrangement

Poor glazing ratio to classroom

5.5 Attractiveness in design…

Architecture in the new schools is approaching good practice, but nearer to Level 2 in the refurbishments. External architectural appearance is often viewed as a subjective matter, but the DQM architecture matrix broaches many other more prosaic matters such as specification quality. There was evidence of a consistently attractive approach in most of the new schools, in terms of external materials, finishes and fittings – these were often the product of a standardised approach, such as plan templates for different sizes of schools.

Refurbished premises of some decades vintage are often at a disadvantage in terms of their appearance, but to the trained eye the evidence of durability and wearing well with age is often a feature of attractiveness. Recent interventions were often the reason for doubts about refurbished premises, such as crudely retrofitted glazing. Many of the older schools benefited from good daylighting as a result of their original designs, and the best classroom configuration dated from 1950 – e.g. internal spatial proportions in plan and section, such as generous space, storage and ceiling heights.

5.5.1 Good Practice

Dramatic new entrance

Dramatic assembly hall

5.5.2 Poor Practice

Low-key entrance only signified by signage

Smooth low level cladding encourages graffiti*

**a roughly textured finish such as brickwork at low level would be more difficult to vandalise.*

5.6 Good use of the site…

One new Non-PFI procured school achieved Best Practice in terms of exterior architecture and space planning – in terms of good use of the site and public presence as a civic building.

5.6.1 Good Practice

Best practice urban design

Dynamic canopy gives civic presence

5.6.2 Poor Practice

Lack of civic presence – office block?

Unimaginative hard surfacing

5.7 Attractive external spaces…

Some external spaces and courtyards were attractive with generous proportions and landscaping, while a few were far from attractive, with mean dimensions and consisting of little more than hard-landscaping.

5.7.1 Good Practice

Generous and landscaped courtyard

Attractive foreground to school entrance

5.7.2 Poor Practice

Mean and hard-surfaced courtyard

Extensive tarmac foreground to school entrance

5.8 A layout that encourages broad community access…

The best example of this was a new Non-PFI primary school in which this criterion was clearly evident in the brief. It was achieved by planning a separate annexe for community use to the opposite side of the entrance hall from the school.

5.8.1 Good Practice

Division of use – community to the left

Extensive sports facilities

5.8.2 Poor Practice

Constrained and confusing site layout

Sports hall with minimal daylighting

5.9 Robust materials that are attractive…

There were examples of the use of robust, environmentally-friendly materials, such as the use of sustainable and low-maintenance cedar cladding to walls. However, there were also examples of commercially-led specification decisions, such as the use of exotic roofing slates in a school in the Highlands, which showed signs of beginning to fail after a few years either due to the thinness of the slate in a harsh micro-climate or due to poor workmanship and inadequate fixings – or a combination of all of these factors.

5.9.1 Good Practice

Cedar cladding to a school extension

Robust external materials and detailing

5.9.2 Poor Practice

Exotic roofing slates in the Highlands

Poor detailing to roof eaves

5.10 Flexible design that will facilitate changes…

Most schools were orthogonally-planned with rectangular wings which are far easier to extend than rigid geometries such as circular or triangular plans – flexibility for change and extension was similarly scored at good practice on average. There were some good examples of generous space and storage standards, particularly in some of the vintage schools. But many staffrooms were undersized and took little account of the increase in teaching assistants and other auxiliary staff. The full triumvirate of long-life; loose-fit; and low energy was not achieved in any single school in the sample.

School designs which are not environmentally sustainable will not be able to respond to changes brought about by climate change as they are not flexible enough to respond to future climatic changes over the course of their sixty-year life cycle. Increasing energy prices and changes in local mirco-climates (i.e. rising temperatures) in coming decades may render badly designed schools uninhabitable.

5.10.1 Good Practice

Good storage allows for change

Good storage allows for expansion

5.10.2 Poor Practice

Poor natural daylighting - more electric lighting

Fixed rooflights do not encourage natural ventilation

6 Conclusion and recommendations

We are of the opinion that the Scottish school estate, judging from this sample, is generally below good practice levels, particularly in the areas of user comfort, environmental engineering and architecture. Refurbished schools were significantly below good practice in general, often in spite of competent original designs and configurations of some vintage, largely due to recent interventions – particularly changed glazing arrangements. The indoor environment of many refurbished schools has been worsened due to poorer opening window configurations and less openable windows (top and bottom) than were in place originally. Also, the installation of suspended ceilings decouple the thermal mass of the original concrete ceiling slab - all of which create summertime overheating in classrooms.

New-build schools were nearer to good practice than the refurbishment projects. The Scottish sample of schools is rated very slightly higher than the median of Northern Ireland, England and Wales samples - but we should bear in mind that the latter samples were procured several years before the Scottish sample. Regulations, standards and guidance have obviously improved in the intervening time, and possibly some of the feedback from earlier schemes is improving later ones.

In terms of environmental sustainability, it seems that little attempt was made to design for or mitigate the effects of global warming and climate change. Daylight should be the prime means of lighting classrooms.[13] This problem is acute in refurbished schools where retrofitting of double-glazing has often resulted in poorer opening-window arrangements which will lead to increased summertime overheating and poor air quality, with obvious effects on user comfort and educational attainment.[14] Although double glazing will improve heat losses and save energy in the winter, this energy saving will be dwarfed by the energy required to combat overheating and poor ventilation if the window configurations are badly designed. Even new schools were almost exclusively fitted with fixed rooflights and most were also thermally-lightweight with low ceiling heights (below 3 metres). Dense materials, particularly internally, are also needed to provide satisfactory acoustical conditions. [15]

There was marked evidence of the implementation of comfort-cooling in certain areas such as computer rooms and libraries – given the trends above, users will increasingly perceive the need for increased mechanical ventilation or even air conditioning, rather than passive means, to furnish them with a well-tempered educational indoor environment that is fit for purpose (See Appendix D for further technical trends). Operational, maintenance and repair costs will potentially increase as a result.

6.1 Top ten successes

- Clear orthogonal ground plans were widespread – good site planning and space planning
- Good storage was observed in some new schools and many older schools
- Good potential maintenance and ease of sourcing of environmental engineering spares and components

[13] BB 90. *Lighting design for schools*. DfES. 1999.
[14] Scottish Executive. *School design – Optimising the internal environment.* 2007. Aspires to teaching spaces with no more than 40 hours above 25 degrees Centigrade, and no more than 5 degrees above the external air temperature.
[15] BB 93. *Acoustic design of schools: A design guide*. DfES. 2003

- Good overall user satisfaction with new schools.
- Vandalism only apparent in existing and refurbished schools. Notable reduction in vandalism reported in new schools.
- New build schools were better than refurbishment projects overall and Scottish new build schools performed better than other new build schools in the UK.
- A few examples of good daylighting strategies.
- One authority achieved consistency across schools, and presumably economy of scale, in terms of attractiveness of external architecture and quality of fittings and furniture
- One school was a Best Practice example of architecture and urban design
- An ideal classroom configuration was observed in a school dating from 1950

6.2 Top ten problems

- Overall design quality of schools in Scotland has room for improvement, particularly refurbishments
- Poor internal environments were widespread, particularly in refurbishments.
- Fixed rooflights in new build schools
- Generally poor integration of environmental engineering with architecture
- Poor summertime overheating, visual environment and acoustics
- Environmental sustainability is not really on the agenda
- Major opportunities exist to improve energy efficiency
- Inept retrofitted glazing arrangements in many refurbishments
- User's doubts over the durability; ease of maintenance and fitness for purpose of their schools
- Poor internal fabric and finishes, and junction details

Appendix A – Design Quality Matrices

BRE *DQM*	**Architecture** *Generic*	*NB: This form must be adapted to appropriate building type before use*		*Design Quality Method*		**MATRIX ONE** **1**
Level	***Architecture - exterior***	***Site planning***	***Interior design***	***Space planning***	***Specification***	***Sustainability***
5	*Exemplary*					
4 **best practice**	Excellent firmness, commodity and delight without architectural conceit or excess. Excellent materials selection with provision for weathering and maintenance. Users respect the building	Excellent displacement of built elements optimises site geometry. Good orientation and access. Space for extension.	Excellent design with clarity with appropriate scale and size. Excellent daylight, acoustics and colour. Robust finishes.	Excellent use of space with good juxtaposition of key spaces. Imaginative use of servant to service space. Good social space. Sound ergonomic design.	Excellent component selection and abutment. Excellent detailing and maintenance provision. Long-life materials selected for low maintenance.	Minimal impact on the environment, in balance with social and economic factors. Excellent energy efficiency in components and materials. Excellent BREEAM rating.
3 **good practice**	Good design with minor shortcomings. Good use of all materials. Some maintenance difficulties and weathering discrepancies .	Good site planning but some failures to achieve best practice. Constrained site reduces extension.	Good design, but with compromised proportions. Minor problems with daylight, acoustics and finishes.	Good space planning. A few departures from best practice in terms relationships of served to servant space.	Good specification in general, but with a few minor deviations from best practice. Some access difficulties.	Good consideration of environmental issues, and related social and economic aspects. Good energy efficiency. Very Good BREEAM rating.
2	Design is mediocre and uninspiring, but functional. Adequate materials, but poor weathering and maintenance.	Site plan is competent, but uninspired. Access and extension difficulties.	Interior design is competent, but uninspired. At least one major failure in daylight, acoustics etc	Adequate space plan, but with clear relationship problems in at least one space. Circulation space problems.	Adequate spec, but with deficiencies immediately obvious to informer users. Some short life materials.	Some sustainability issues addressed in an adhoc way. Little consideration of energy efficiency. Good BREEAM rating.
1	Mundane design with some functionality problems. Short-life materials and predictable weathering and maintenance problems.	A few significant operational difficulties due to poor site planning. No possibility of extension.	A few significant, or several minor failures in daylighting, acoustics, colour, or finishes	A few significant, or several minor operational difficulties due to inadequate planning. Lack of consideration for intended use. Inadequate circulation space	A few significant, or several minor specification deficiencies – obvious to informed users. Many short life materials and components.	Token sustainability. Energy efficiency not apparent in operating data – eg typical consumption figures. Pass BREEAM rating.
0	Banal architecture with many functionality problems. Use of inappropriate materials eg school that resembles an industrial shed. Weathering and maintenance very poor.	Major operational difficulties arising from poor site planning, inadequate space and difficult access.	Internal finishes and materials utilitarian, inappropriate for use, or inadequate. Poor acoustics, lighting etc	Substantial difficulties obvious in use, due to inadequate planning, or consideration for intended use. Wholly inadequate circulation.	Specification deficiencies obvious to users. Design life of most components and materials inadequate to ensure minimum design life of building.	Sustainability not on the agenda or in the brief. Energy consumption above typical levels for the building type. No energy management apparent. No BREEAM rating.

BRE *DQM*	**Environmental Engineering** *Generic*	*NB: This form must be adapted to appropriate building type before use*			*Design Quality Method*	**MATRIX TWO** **2**
Level	***Integration with architecture***	***Mechanical system design***	***Electrical system design***	***Maintain-ability***	***Sourcing of repairable items***	***Sustainab-ility of bldg services***
5	*Exemplary*					
4 **best practice**	Environmental engineering design is sympathetic to, and optimises, all aspects of the architecture. Consideration of thermal, lighting and acoustic issues. No intrusion of services into occupied spaces.	Robust best practice using the most appropriate components, integrated into efficient and reliable systems. Includes heating, ventilation, cooling and plumbing. Nil acoustic intrusion.	Robust best practice using the most appropriate components, integrated into efficient and reliable systems. Includes internal & external lighting, communications and any other systems. Component selection supports architecture.	Maintenance facilities and access are designed to optimise use, and time to clean and repair. Specialised access for replacement avoided. All service data widely available.	All repairable and replaceable items are selected for wide availability and compliance with well-known standards. Design has avoided the use of specially manufactured items with long future order times and high replacement costs.	Environmental engineering components, system arrangements and controls selected and commissioned to minimise environmental impact. Equivalent to BREEAM Excellent rating
3 **good practice**	One or two minor departures from ideal as defined in Level 4. No deficiencies related to thermal and lighting issues.	One or two minor departures from ideal as defined in Level 4. No deficiencies related to efficiency of heating, lighting and cooling	One or two minor departures from ideal as defined in Level 4. No deficiencies related to lighting control or adequate ICT provision.	One or two minor departures from ideal as defined in Level 4. Limited revenue maintenance to some items can be excepted.	One or two minor departures from ideal as defined in Level 4. No deficiencies related to essential services, such as back-up generation in a health facility.	One or two minor departures from ideal as defined in Level 4. Equivalent to BREEAM Very Good rating
2	Good design at a visual level. Some minor technical deficiencies related to ventilation, thermal and lighting aspects. Component location in occupied spaces is not good.	One or two minor departures from Level 4. Minor departures from good practice related to efficiency and operation of heating, lighting and cooling.	One or two minor departures from Level 4. Some deficiencies related to lighting control or ICT provision. Visible components do not clash with environment.	Some significant cost and availability impacts due to inadequate design consideration. Access equipment and specialist tools needed for maintenance.	One or two minor departures from Level 4. Some deficiencies related to selection and specification of components. Some spare parts are difficult and/or costly to obtain.	Some obvious failures by designers and cost consultants to properly consider long-term environmental impact. Equivalent to BREEAM Good rating
1	Component selection, positioning, safety, thermal, and lighting issues not thought through. Services noticeably intrude into occupied spaces.	Design approach is compliant with design codes, but not optimised for efficiency. Component selection is not good for noise and reliability	Design approach has one or two major deficiencies. Compliant with design codes but obviously uses lowest cost components.	Significant cost and availability impacts due to inadequate design consideration.	Many deficiencies related to selection and specification of components. Many spare parts are difficult to obtain. Sourcing of spares a significant problem.	Widespread minor and some major failures to consider environmental impacts. Equivalent to BREEAM Pass.
0	Frequent and obvious clashes between services and architecture. Significant failures on thermal and lighting issues.	Design marginally sized. Concerns over component suitability. Not properly commissioned. Users aware of problems.	Arbitrary design approach that has obviously failed to consider users views. Components and fittings under specified in many cases.	Minimal consideration given to maintenance at design stage. Maintenance costs higher due to access costs.	Widespread use of components with limited availability. Maintenance staff have to spend considerable time to obtain replacement items.	Widespread major failures to consider environmental impacts. Equivalent to no BREEAM rating.

BRE *DQM*	**User Comfort** *Generic*	*NB: This form must be adapted to appropriate building type before use*			*Design Quality Method*	**MATRIX THREE** **3**
Level	***Summertime overheating***	***Visual Environ-ment***	***Heating comfort***	***Audible and visual intrusion***	***Acoustics quality***	***Air quality (internal)***
5	*Exemplary*					
4 **best practice**	Building interior unlikely to experience more than 30 hours/year above internal environmental temperature >27ºC. Occupants have very limited beam radiation from sun. Adequate summertime ventilation.	Daylight and artificial lighting sources entirely appropriate for task and promote a cheerful but non-distracting atmosphere. Full compliance with Work-place	Internal air temperatures within – 1.5ºC to +2.0ºC of target temperature. No 'Monday morning' discomfort with intermittent heating. Adequate ventilation – no noticeable draughts in winter.	No interference to work or leisure from background noises in interior or exterior occupied spaces. No unwanted or noticeable visual intrusion.	All occupied areas free from acoustic features that act to the detriment of efficient working and enjoyment of the building. Covers, reverberation time, intelligibility of speech and music.	No noticeable odour, dust, allergic or health symptoms from contaminants such as micro-organisms, organic or non-organic compounds. Satisfactory humidity in all spaces.
3 **good practice**	Same as Level '4' with the exception that not more than 50 hours/year above >27ºC. No hot air pockets at ceiling level. Eg high-level opening lights in fenestration.	Few minor departures from Level '4' standards. Daylighting sensibly even over whole usable area, Good use of colour. Very few reflections on VDU screens.	A few areas non-compliant with Level '4' standards. Minimal problems from asymmetric radiation. Occasional under-heat on Monday mornings.	Very occasional slight intrusion to internal activities from background noise. Occasional visual intrusion from passing pedestrians & vehicles.	Most large and/or heavily used areas compliant with Level '4'. Compliance with relevant acoustics good practice guidance.	Minimal problems due to non-compliance with Level '4'. Most occupants unable to recall any problems related to air quality.
2	Occupants report summertime overheat as an occasional problem. Possibly some discomfort from beam radiation from the sun. Ceilings trap hot air.	Significant departures from Level '4' standards in one or two spaces. Daylighting sensibly even. Good use of colour. Very few VDU screen reflections.	Majority of areas compliant with Level '4' temperature control. Occasional reports of discomfort from uneven heating and cold Monday mornings.	Occupants notice noise and visual intrusion. Insufficient to disturb activity. Either due to insufficient isolation or inappropriate planning adjacencies.	A noticeable number of spaces are not ideal acoustically - to the extent that speech levels have to be raised occasionally, and/or words repeated	Some occupant can recall air quality related issues when questioned. Probably no noticeable impact on occupant health or productivity
1	Summertime overheat a frequent problem. Users known to move away from sun path. Fans in use. Ceilings 'hot'. Inadequate ventilation.	Many instances of departure from Level '4' standards. Inadequate daylighting. A number of dark corners. Veiling reflections in VDUs.	Some obvious failures to control temperatures. Building noted as cold on Monday mornings when cold outside. Some cold draughts.	Noise and visual intrusion occasionally disturbs task in hand. . Eg rain drumming on metal roofs in a school suspending teaching.	Many spaces are not ideal acoustically, to the extent that speech levels have to be raised occasionally, and/or words repeated.	A few occupants comment on indoor air quality. Noticeable odour on first entering building. Some complaints of nasal and throat irritation.
0	Summertime overheat a major problem. Users try to avoid use of hot areas. Hot areas have fans, some permanently fixed.	Many instances of poor day-lighting, distracting glare, veiling reflections in VDU screens, poor colour co-ordination.	Widespread overheat / under-heat. Users report cold feet. Monday morning heating timed early to avoid heating problems.	Noise and visual intrusion frequently disturbs task in hand. Building functionality severely impaired.	Much of building has unsatisfactory acoustics that obviously impact on efficiency of working or on social conversation.	Obvious problems. If asked, many occupants note that the building seems 'sick'. Some occupants link heath problems to air quality.

BRE *DQM*	**Whole Life Costs** *Generic*	*NB: This form must be adapted to appropriate building type before use*			*Design Quality Method*	**MATRIX FOUR** **4**
Level	***External materials***	***Internal fabric & finishes***	***Building services – capital items***	***Building services – revenue***	***Facilities management - fitness***	***Flexibility – change & extension***
5	*Exemplary*					
4 **best practice**	All components selected for installed to achieve lowest cost of ownership. All have good resistance to vandalism, sun, wind and rain. Graceful degradation of appearance with wear. Detailing to best practice.	Fabric and finishes chosen for lowest cost of ownership. Properties include ease of routine and special cleaning. Graceful degradation of appearance with wear – easy repair and replacement	All components chosen for minimum cost of ownership. Adequate space for minor and major maintenance. Design enables most service activities to be undertaken during occupation.	All components selected for minimum cost of ownership. Component arrangement and availability good. Easy maintenance access. Most service activities possible during occupation.	All architectural fittings, furniture and furnishings selected for minimum cost of ownership and support to organisational objectives. All items eminently suitable for purpose. Average repair time is short.	Building plan, site planning, construction and materials make future adaptation and extension easy. Extension possible without excessive cost and disturbance to occupiers. Long life, loose fit, low energy.
3 **good practice**	Level 4 requirements largely satisfied. But a few minor shortfalls leading to the appearance of premature aging in some limited areas.	Level 4 requirements largely satisfied. But a few minor failures leading to the appearance of premature aging in some limited areas.	Level 4 requirements satisfied for all major components. All components selected for highest appropriate operating efficiency. Some minor shortfalls.	Level 4 requirements satisfied for all major items. Some minor shortfalls, possibly involving long order periods for replacements.	Level 4 requirements satisfied for all major components. Some minor shortfalls, possibly involving costly replacement eg scaffolding needed for access.	Level 4 requirements satisfied in most areas. Some minor shortfalls. Balance between functionality and flexibility achieved.
2	Level 4 requirements satisfied for most but not all major components, and for most minor components. Some obvious failures to achieve good practice.	Level 4 requirements satisfied for most but not all major components, and for most minor components. Some obvious failures to achieve good practice.	Level 4 requirements satisfied for most but not all major components. Some failures to specify and properly install components with the appropriate efficiency. Some areas less than good practice.	Level 4 requirements satisfied for most but not all major components. Some failures to specify components with optimum running and replacement costs.	Level 4 requirements satisfied for most but not all major components. Some under-specification and less than optimum running costs. Some obvious failures to achieve good practice	Level 4 requirements satisfied for most but not all major areas. Minor difficulties identified on less important items. Minor impact on future costs and functionality.
1	More than a few obvious failures to specify suitable materials and install them with good detailing.	More than a few obvious failures to specify suitable materials. Service life impaired.	More than a few obvious failures to specify suitable components. Service life impaired. Notably high costs of ownership.	More than a few obvious failures to specify and install suitable components. Impact on costs of ownership.	More than a few obvious failures to specify and install suitable components. Impact on costs of ownership.	Future adaptation and extension may be limited by site planning and space planning. Major impact on costs and functionality..
0	Many obvious failures to specify and properly install robust materials. Frequent and obvious examples of unsatisfactory details.	Many obvious failures to specify and install suitable materials. Many obvious examples of unsatisfactory details.	Many obvious failures to specify and install suitable and efficient components. Service life significantly impaired with associated costs.	Many obvious failures to specify and install suitable and efficient components. Service life significantly impaired with associate costs.	Many obvious failures to specify and install suitable and efficient components. Service life significantly impaired with associated costs.	Future adaptation almost rendered impossible, or severely limited – and potentially very costly, due to plan configuration and/or construction.

BRE *DQM*	**Detail Design** *Generic*	*NB: This form must be adapted to appropriate building type before use*		*Design Quality Method*		**MATRIX FIVE** **5**
Level	***External detail***	***Internal detail***	***Junction details***	***Furniture & furnishings***	***Fittings***	***Safety & security***
5	*Exemplary*					
4 **best practice**	All materials and components selected and installed for good resistance to sun, wind, rain and vandalism. Graceful degradation of appearance with wear, ageing and use. All detailing to best practice	Good functional and aesthetic detailing. All internal materials and components appropriate for function. Easy maintenance and replacement. Minimal need for access equipment. Graceful degradation.	All architectural junctions detailed to best practice with good workmanship. Aesthetically pleasing and unlikely to suffer premature failure during predicted life or from vandalism.	All furniture and furnishings selected for ability to retain good appearance and minimum cost of ownership. All seating comfortable for expected occupancy – and with low VOC emission.	All architectural fittings suitable for purpose and aesthetically pleasing. Anthropomorphic-ally acceptable. Correctly sized, robust and solid. Suitable provision for disabled persons use and access.	Detailed architecture to best practice and safe. Design accords with *Secure by design* guidance. Security management and operating costs minimised. All significant safety hazards competently addressed.
3 **good practice**	Level 4 requirements satisfied for all materials and major components, and for most of the minor components. Minor discrepancies.	Level 4 requirements satisfied for all materials and major components, and for most of the minor components. Minor discrepancies.	Level 4 requirements satisfied for all materials and major components, and for most of the minor components.	Level 4 requirements satisfied for all widely-used furniture, and furnishings, and for most of the other furniture and furnishings.	Level 4 requirements satisfied for most widely-used fittings, and for most other fittings. Minor discrepancies.	Level 4 requirements satisfied for all most major issues, and for most of the less significant issues. Minor discrepancies.
2	Level 4 requirements satisfied for most, but not all, major components, and for the great majority of minor components	Level 4 requirements satisfied for most, but not all, major components, and for the great majority of minor components	Level 4 requirements satisfied for most, but not all, important material junctions, and for the great majority of minor details.	Level 4 requirements satisfied for most widely-used furniture and furnishings, and for the great majority of other items.	Level 4 requirements satisfied for most widely-used fittings, and for the great majority of other items.	Level 4 requirements satisfied for most major issues, and for the great majority of less important issues.
1	A few obvious failures on major materials and components, and/or multiple failures on minor details	A few obvious failures to specify suitable major materials and components, and/or multiple failures on minor details.	A few obvious failures to specify and install suitable details on widely-used junctions, and/or multiple failures on minor details.	A few obvious failures to select widely-used items compliant with Level 4 requirements, and/or multiple failures on less widely-used items.	A few obvious failures to satisfy Level 4 requirements on widely-used and/or important fittings. Multiple failures on less widely-used items.	A few obvious failures to satisfy Level 4 requirements on important issues. Multiple failures on less important issues.
0	Many failures to properly specify and detail materials and components.	Many failures to properly specify and detail materials and components.	Many failures to specify and install suitable details on widely-used and on minor junctions.	Many failures to address Level 4 requirements on widely-used and/or other items.	Many failures to address Level 4 requirements. Many failures on less widely-used items.	Many failures to address Level 4 requirements on important issues. Many failures on minor issues.

Matrix 6: User satisfaction

Initial interviews with principals and directors of educational facilities are structured with six questions, which they are asked to rank in terms of their satisfaction, on a scale of one to five (with five representing maximum satisfaction). The six questions are:

- **One**: Does the building work well?
- **Two**: Does the building lift the spirits?
- **Three**: Will the building weather well, withstand wear and tear, and be easily maintained?
- **Four**: Is the building flexible?
- **Five**: Is the building secure?
- **Six**: Is the indoor environment of the building fit for purpose, in terms of daylighting, heating, ventilation and acoustics?

Further user satisfaction questions commentary

Audit Scotland requested three questions be added to the six questions we normally ask as part of the user satisfaction interview at the beginning of each survey – they were:

- How good is physical accessibility for disabled pupils? Any issues? (16/18 responses)
- How easy is it to get basic repairs/maintenance/changes done (e.g. putting up pinboards, getting electrical sockets moved, getting broken things fixed or replaced)? (16/18 responses)
- Were you consulted about the design of the school? How? At what stage in the process? How much influence would you say you had on the design? This question was only to be asked if the Head or Depute was interview – many were unable to comment as they were not in post when the school was procured. (10/18 responses)

Appendix B – DQM and SE's ten features

Good clear organisation, a clear plan, and full accessibility

Matrix 1 – Site planning; interior design; space planning

Matrix 4 – Flexibility for change and extension

Matrix 5 – Safety and security

Matrix 6 – Does the building work well? Is the building flexible?; Is the building secure?

Spaces that are well-proportioned, efficient, fit for purpose and meet the needs of users

Matrix 1 – Architecture (exterior); site planning; interior design; space planning; specification

Matrix 4 – Flexibility for change and extension

Matrix 5 – Furniture and furnishings; fittings

Matrix 6 – Does the building work well? Is the building flexible?; Is the building secure?

Circulation that is well organised, and sufficiently generous

Matrix 1 – Site planning; space planning; interior design; flexibility for change and extension

Matrix 5 – Safety and security

Matrix 6 – Does the building work well?

Good environmental conditions throughout, including appropriate levels of natural light and ventilation

Matrix 1 – Interior design; Sustainability

Matrix 2 – Entire matrix

Matrix 3 – Entire matrix

Matrix 6 – Is the indoor environment of the building fit for purpose, in terms of daylighting, heating, ventilation and acoustics

Attractiveness in design, comparable to that found in other quality public buildings

Matrix 1 – Entire matrix

Matrix 5 – Entire matrix

Matrix 6 – Does the building lift the spirits?

Good use of the site, and public presence as a civic building

Matrix 1 – Entire matrix

Matrix 5 – Entire matrix

Matrix 6 – Does the building lift the spirits? Will the building weather well, withstand wear and tear, and be easily maintained?

Attractive external spaces with a good relationship to internal spaces and offering appropriate security and a variety of different settings

Matrix 1 – Architecture (exterior); site planning;

Matrix 5 – Safety & security

Matrix 6 – Is the building flexible? Is the building secure?

A layout that encourages broad community access and use out of hours, where appropriate

Matrix 1 – Entire matrix

Matrix 6 – Does the building work well? Is the building flexible? Is the building secure?

Robust materials that are attractive, that will weather and wear well, and that are environmentally friendly

Matrix 1 – Interior design; specification; sustainability

Matrix 4 – External materials; internal fabric and finishes;

Matrix 5 – Entire matrix

Matrix 6 – Will the building weather well, withstand wear and tear, and be easily maintained?

Flexible design that will facilitate changes in policy and technology and which allows expansion or contraction in the future, where appropriate

Matrix 1 – Site planning; interior design; space planning; specification

Matrix 2 – Entire matrix

Matrix 4 – Flexibility for change and extension

Matrix 6 – Is the building flexible?

Appendix C – Technical summary

There were widespread departures from what must be considered good design practice. The key observations were:

1. **Gas boilers**, even when recently replaced or in new build, were not (apart from one school) condensing.
2. **Heating emitter systems** should be designed to fully utilise condensing mode operation.
3. **Whiteboards**, where installed, were often washed out by daylight. This leads to the environmentally unfriendly blinds-down, lights-on operating mode. None of the design professionals were aware of brightness management. Needs guidance.
4. **There was minimal use of light controls.** Partly due to the architecture giving poor daylighting, but also because ‘it is not the way we do things’. This is not good practice in sustainability terms.
5. **Sports halls** tended to be black-box, or with minimal daylighting. Lighting was needed during occupancy, but many instances were found of lights-on (except for safety lights) with prolonged nil-occupancy. When property design personnel were present, almost all were unaware of the Sport Scotland guidance that recommends north-light roof construction and wall colours to enable good vision of shuttlecocks and balls.
6. **Sports hall safety** requires no sharp projections into the playing space, and especially in to the run-off areas of courts. There were several instances of fire-call boxes, fire extinguishers and 13A mains sockets projecting from walls. These were all avoidable.
7. **Daylight levels** in the great majority of schools were below 1% average daylight factor. This needs artificial lighting to provide acceptable internal conditions, even on bright days. Many school classrooms would be un-occupiable if there was a power-cut during daytime, even on bright days. Minimum average daylight factors need to be 2-4% to start to displace paid-for lighting energy. Daylight design must achieve adequate useable daylight without disability glare to occupants.
8. **Ventilation via windows** – there was little understanding, even in new build schools, of the need for competent design of windows. Design factors must include adequate ventilation during occupied hours under all weather conditions (has strong links to thermal comfort / cold draughts).
9. **The majority of classrooms did not have opening windows**, or ventilation paths close enough to ceiling level to avoid hot ceilings in summertime. This needs to be complemented by adequate inlet area for incoming ventilation air. Opening restrictors precluded adequate ventilation air, leading to inadequate ventilation and loss of pupil cognitive function (levels commonly measured indicate 5% to 10% loss of cognitive function as being commonplace).

10. **Many assembly halls** did not have ventilation air paths for both air inlet, and exhaust. Where the identified solution was to open the external doors, this would give unacceptable thermal comfort in cold weather. Ventilation air inlet paths need to be tempered to ensure thermal comfort. Ventilation volumes adequate for spaces used as exam halls need to be three to five times large than for sports use – evidence of adequate volume was not seen. This can lead to lower cognitive function and impair exam results.

11. **Room depth for classrooms** – most rooms were naturally ventilated from the window wall. Typically, adequate daylight with floor to ceiling heights of 2.7m is only available to a room depth of 5m (with light-coloured interiors), and adequate ventilation is only achievable to 7m deep with competent window arrangements. Thus room depths should not exceed 7m in naturally-ventilated spaces. Many rooms were 10m deep – giving obviously (by measurement of carbon dioxide levels) poor ventilation.

12. **Ventilation of teaching spaces** – many measurements were taken of atmospheric carbon dioxide levels in the 2200 to 3500ppm range. This indicates ventilation rates much below the minimum recommended by the World Health Organisation. 2200ppm equates to a ventilation rate of 2.6litres/second per person, and 3500ppm equates to 1,5litres/second per person. The WHO recommendation for schools is for an average level of 1000ppm (equates to 8litres/second per person), with only brief excursions up to 1500ppm. Levels above 2500ppm are considered by the WHO to be in a region of health hazard.

13. **Acoustics** in many assembly and sports halls were poor. Reverberation times were too long, with sound including speech ‘rattling’ around the room. None of the design professionals were familiar with Speech Transmission Index design or measurement. In a number of instances, the clarity of speech, such as during assembly or sports lessons would be too poor to understand what was said, even for pupils without hearing disabilities. Thus compliance with Disability Discrimination Act requirements was unlikely to be achieved.

14. **Corridors were often too narrow. I**n some instances this was associated with a school being extended. For safety reasons, several schools had imposed one way corridors. This increased transit time between classes, and thus loss of lesson time.

15. **Overall**, the Scottish Executive School Estates needs to urgently review its design standards to address all the above issues. This is so that school buildings do not impede the process of delivering education. The standards must apply to refurbishment works as well as new build.

Appendix D – Technical aspects of an ideal school

No	Aspect	Educational issues	Sustainable design	Examples
1	**Daylight quantity**	Lisa Heschong identified the benefits of high levels of daylight levels to students. End of year exam results (14% to 23% improvement), and to general productivity (0.5% to 1.0%) in her 'Re-analysis Report 2002'.	Daylight displacement of artificial lighting starts at 2% average daylight factor, and is significant at 4% average daylight factor. Sustainable operation requires daylight design to satisfy visual comfort requirements – brightness Cd/m^2 for room surfaces to be within the range of 30 to 700, with the maximum to minimum ratio no more than 10:1.	See images below and in Appendix 'F'.
2	**Daylight quality including visual comfort**	Absence of distracting glare within the visual field. Sources of glare include very bright surfaces, reflections on table tops. Disabling glare causes occupants to look away from the immediate task, with resulting loss of productivity. Visual comfort requires adequate visibility / absence of veiling reflections of projected images, and of ICT screen images. Unified Glare ratio should be 19 or better.	Failure to design the space for adequate visual comfort is likely to lead to 'blinds-down, lights-on'. Check window facades, especially south facing, for extent of blinds down. The ensuing use of artificial lighting will use electrical energy with its associated carbon impact.	See images below and in Appendix 'F'.
3	**Whiteboard image visibility in daylight**	With typical whiteboard peak white image brightness of 150 to 200 $Candelas/m^2$ (Cd/m^2), daylight screen brightness (projector off) above $500Cd/m^2$ will result in difficulty in seeing the image (daylight washout). Projector images with dim bulbs can have peak white levels of 20 to 30 Cd/m^2 which makes image visibility considerably worse.	Whiteboard images washed out by daylight will lead to occupiers going blinds-down, lights-on. The ensuing use of artificial lighting will use electrical energy with its associated carbon impact	Whitecross School, Hereford is a superb example of best practice in classroom daylighting and brightness management. The window wall adjacent to the whiteboard on the party wall shields the whiteboard with 1.5m to 2m of opaque fabric. (This design approach also inherently allows spacing between blocks to be reduced as most daylight comes via clerestorey lights, and thus not reliant on low-angle daylight for lighting the rear of the room.)
4	**Artificial lighting quantity**	CIBSE (Chartered Institution of Building Services Engineers) and DfES (Department of Education & Skills) both provide guidance for specific space types.	Over provision of light levels increases capital costs, and if no lighting controls are fitted or they are not in competent working order, increases revenue costs and carbon impact.	None found. (A possible reason for this is that the average daylight factor in many schools was below 1%, thus requiring lights to be on almost all occupied hours. Thus there was little need for light level controls, and none were installed

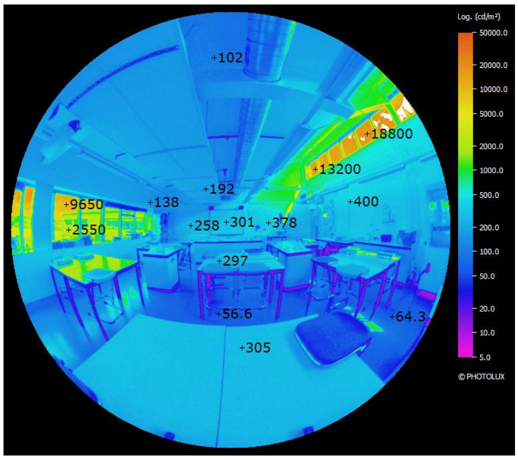
No	Aspect	Educational issues	Sustainable design	Examples
5	**Artificial lighting quality including visual comfort**	Existing design processes comply with CIBSE and DfES guidance that provides satisfactory conditions including freedom from glare.	Needs appropriate selection of luminaires, good positioning of luminaires with respect to whiteboards and writing boards.	No comment.
6	**Artificial lighting controls**	The light-level control operation should not be unduly noticeable by occupants, and occupancy sensing should use sufficiently sensitive sensors to avoid unwanted loss of light. May be necessary to use multiple light-level and occupancy sensors in a space to avoid adverse user reaction.	Artificial lighting controls should be installed in all but the smallest spaces. Light level controls adjust output from artificial lighting to enable daylight to displace paid-for lighting energy. Occupancy controls minimise lighting energy consumption when spaces are not occupied. Will also reduce the running hours of luminaires and thus facilitate longer lamp replacement cycles.	Many of the images in Appendix 'F' show lights on when daylight levels are obviously adequate. This is both a technical issue for lighting controls, and needs management by occupiers.
7	**Whiteboard image visibility in artificial lighting**	Light from incorrectly positioned or the inability to separately switch luminaires can wash-out projected images and increase time to recognise information on the whiteboard.	Wasteful operation of a lamp with associated impacts on operating cost and carbon impact.	Good practice seen in numerous locations. Also, too many examples of bad practice especially when lights shine onto the whiteboard and wash-out the projected image.
8	**ICT equipment visual comfort**	ISO 9241 makes a number of recommendations; especially associated with sequential viewing of ICT screens, work documents and keyboards. The recommended maximum brightness range is 10:1. At 100:1, it states that there is a 'small but noticeable reduction in productivity'. Black keyboards are frequently more than 100:1 less bright than the ICT screen, and thus not ideal for maintaining productivity. ICT screen surrounds should not present a sudden change in brightness from the screen. Neutral colours such as beige, silver and grey are preferred, and dark surrounds including black avoided.	Lack of compliance will lead to occupants' behavioural need for better quality lighting, such as artificial lighting with its higher carbon impact.	Positioning of ICT screens with backs to windows is not good practice when the daylight level within peripheral vision causes glare
9	**Ventilation (occupied hours) in summertime**	Minimisation of summer overheat on hot days requires both radiant and air temperatures to be minimised. CIBSE Guide A (2006 Edition) identified 5% to 10% loss of productivity at an operative temperature of 27ºC.	The passive performance of the space relating to overheat needs to be optimised. A well designed space (including fully occupied classrooms) will exhibit a mid-afternoon internal operative temperature no more than 2ºC above the outside air temperature on at least 60% of hot summer days. Air temperature is reduced by sufficient and adequately distributed ventilation to remove heat	No comment.

No	Aspect	Educational issues	Sustainable design	Examples
			gains. Radiant temperature in naturally ventilated buildings is reduced by ensuring that hot air is not trapped at ceiling level (needs >1.2% of floor area free-area ventilation within the first 200mm below the ceiling to be effective). Full advantage should be taken of passive cooling approaches such as the use of cool borehole water, and/or earth tubes.	
10	**Ventilation (occupied hours) in spring + autumn**	Generally no impact as thermal comfort, especially associated with cold draughts, is not perceived as a problem,	No comment for most spaces. ICT rooms and communication rooms must be designed for good passive performance before any consideration is given to the introduction of mechanical cooling. A well designed space will exhibit a mid-afternoon internal operative temperature no more than 2ºC above the outside air temperature on at least 60% of hot summer days.	No comment.
11	**Ventilation (occupied hours) in cold weather**	CIBSE Guide A (2006) and CIBSE KS:6 Comfort both identify loss of productivity at operational temperatures below 20ºC. Incoming ventilation air therefore needs to be tempered (warmed) before it impinges on occupants.	Heat loss from ventilation air exhaust can be a major (in modern well insulated buildings can be >75% of total) heat loss. Mechanical ventilation with wheel type heat exchangers can recover the majority of this heat (cross-plate heat exchangers are less efficient).	No comment.
12	**Summertime overheat - insolation**	Minimisation of summer overheat on hot days requires both radiant and air temperature s to be minimised. CIBSE Guide A (2006 Edition) identified 5% to 10% loss of productivity at an operative temperature of 27ºC. An important contributor to this is insolation (beam radiation from the sun) either heating the room or impinging on people in the space.	Beam radiation from the sun should be limited to less than 25W/m^2 averaged over the whole room area. Shading must be by devices outside the room so that hot shading surfaces do not contribute	No comment.
13	**Summer overheat – cool fabric reduction of radiant temperature during occupied hours**	Minimisation of summer overheat on hot days requires both radiant and air temperature s to be minimised. CIBSE Guide A (2006 Edition) identified 5% to 10% loss of productivity at an operative temperature of 27ºC.	With thermally heavyweight fabric, cool night-time air can be used to pre-cool the fabric. Needs at least 6 air changes per hour (ac/h). Above 10ac/h not much improvement in benefit. This is one of the techniques that can avoid the need for mechanical cooling.	No comment.
14	**Acoustics – classroom reverberation time and intelligibility of speech**	CIBSE and DfES both provide guidance for specific space types	Acoustic tiles can adversely impact on heat transfer into and out of thermally heavyweight fabric. Non-parallel rooms surfaces help –	No comment.

No	Aspect	Educational issues	Sustainable design	Examples
			eg. a sloping ceiling	
15	Acoustics – classroom background noise level	CIBSE and DfES both provide guidance for specific space types	No comment.	No comment.
16	Acoustics - assembly hall reverberation time and intelligibility of speech	CIBSE and DfES both provide guidance for specific space types	No comment.	No comment.
17	Acoustics – dining hall reverberation time and intelligibility of speech	CIBSE and DfES both provide guidance for specific space types	No comment.	No comment.
18	Acoustics – sports hall reverberation time and intelligibility of speech	CIBSE and DfES both provide guidance for specific space types	No comment.	No comment.
19	Acoustics – corridor noise level during class change	Experience suggests that once noise level gets to 60dBA, occupiers have difficulty hearing people close to them. Raised voices to restore audibility then take the noise level to circa. 70dBA.	No comment.	No comment.

Whitecross School, Hereford – ideal natural lighting conditions in a classroom


Typical classroom – ideal daylight conditions



Ideal range 30-300 Cd/m2

Whitecross School, Hereford – commentary

Good visual comfort is obtained within the range of 30-300 Cd/m2 and can still be acceptable at 700 Cd/m2. Below 30 Cd/m2 and conditions become too dim for comfort and artificial lighting will be switched on. Whitecross School has little need for artificial lighting for much of the school year – clerestorey lighting, at a high enough enough level not to cause glare to occupants, makes a significant contribution to these ideal conditions.

The classrooms at this school are exemplars. Mechanically ventilation ensures thermal comfort under all outside temperature conditions. On hot days, the interior temperature using passive measures only was 26.5ºC with a mid-afternoon outside air temperature of 33ºC. On cold days, heat recovery lowers the heating energy and cost to just over half of the energy used by typical schools – and maintains good thermal comfort. Mechanical ventilation also very effectively addresses classroom acoustics issues. Construction costs were less than 1% above a naturally ventilated school.

Appendix E – Daylight analysis of Scottish schools

Introduction

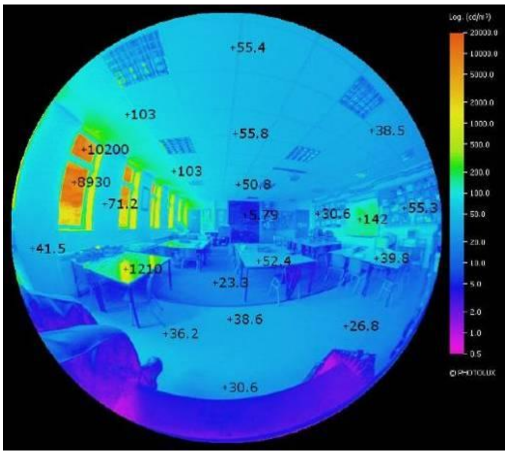
In the images below, brightness mapping was used to identify visual comfort. The measurements are of luminance, in Candelas per m^2 (Cd/m^2). This is a measure of how bright the eye perceives a surface to be. It is important to avoid confusion with illuminance, measured in Lux, which is the level of light falling on a surface. The false-colour images below used a calibrated digital camera and lens combination, and were processed using specialist software. The numbers on the false colour images are brightness in Cd/m^2 at the '+' sign to the left of each number.

Human eyes prefer a room interior surface brightness within the range of 30 to 200/300 Cd/m^2. Surfaces below 20 Cd/m^2 are perceived as being dim – the human behavioural instinct is to correct this by turning on the artificial lighting. Very bright sources and surfaces are satisfactory providing they are outside the eye's prime and peripheral vision areas, and thus not 'seen' when working.

These measurements are of the built environment. Designers can model and visualise these spaces using 'Radiance' based design tools.

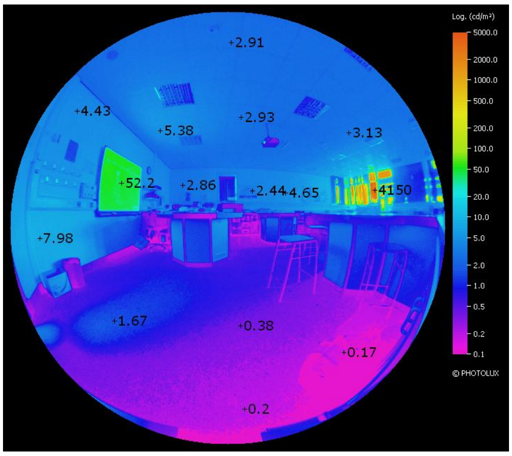
Good brightness management facilitates better workplace productivity, and reduces the occupants' behavioural need to use artificial lighting with its generally good visual comfort. This is important for sustainable and low carbon impact operation of schools.

Good Practice daylight to classroom



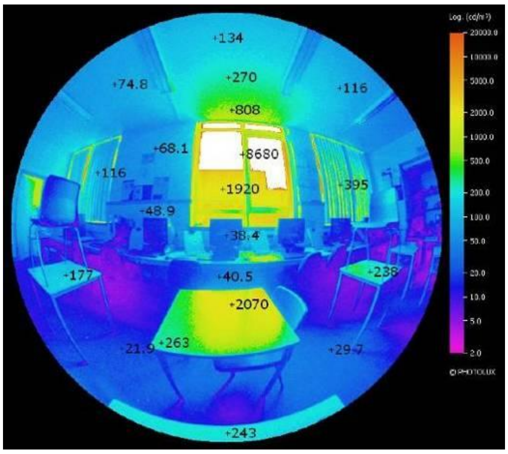
Note the room fabric brightness levels are mainly within the preferred 30Cd/m^2 to 300Cd/m^2 range. This room has little need for artificial lighting on the majority of days.

Bad Practice daylight to classroom



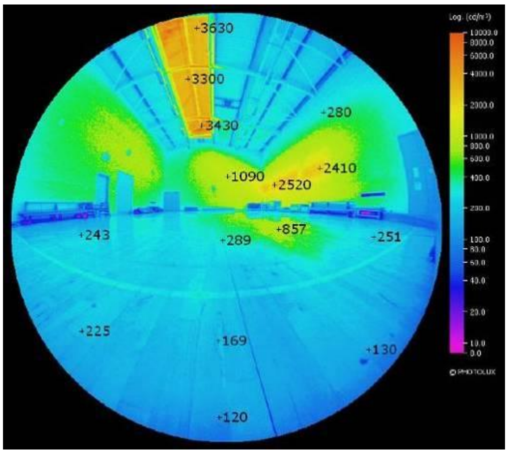
Note the room fabric brightness levels are way below the preferred 30Cd/m^2 to 300Cd/m^2 range. This room will need artificial lighting on the majority of days. Due to the dark interior, the small windows are an effective but unwanted source of disabling glare.

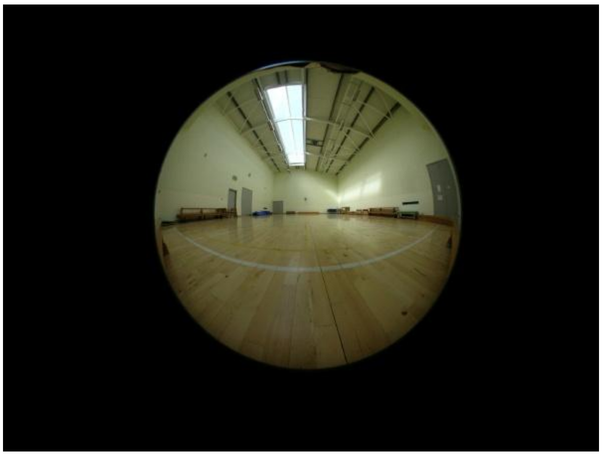
Bad Practice daylight to computer room



The daylight from the window is a major source of glare. The glossy table-top has a brightness from window glare that will very effectively cause unacceptable glare with the prime visual field for anyone working at that table.

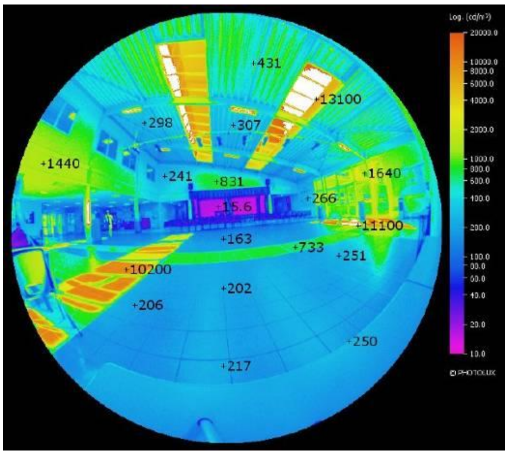
Good Practice daylight to sports hall

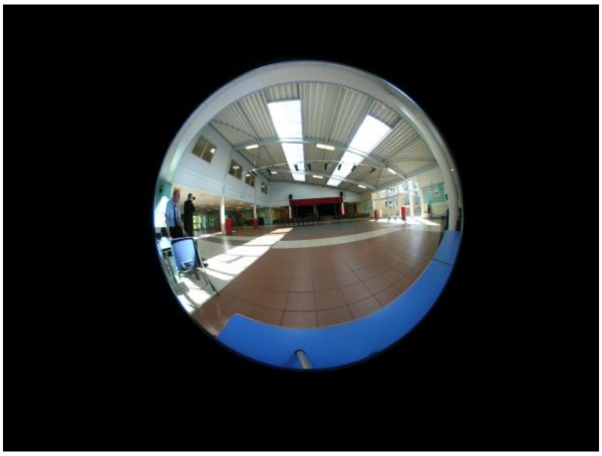




Very even daylighting at an entirely adequate level. Note that if fabric colours (wall and ceiling) were to Sport Scotland recommendations, the overall brightness levels would be 20% to 30% down, and would warrant additional daylight.

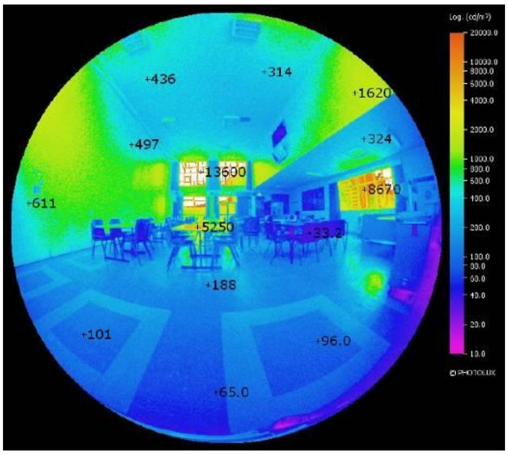
Good Practice daylight to dining hall





This dining hall has extensive daylight from the rooflights.This provides a bright evenly-lit area that shows the joy of good daylight. Note the artificial lighting is on – at these levels of daylight this will have minimal impact on brightness levels.

Good Practice daylight to dining hall



This dining hall is lit from both sides from large high-level windows. The resulting daylight level is more than adequate to displace the need for artificial lighting, and is visually comfortable. This school dates from 1970.

Appendix F - Study Sample

Schools sample selected by Audit Scotland

	PFI/Non-PFI	If PFI, earlier or later phase	Primary or secondary	Size/location	New-build or refurbished	Number of schools in sample
1	PFI	Phase 1 (earlier: opened 2000 – 2003)	Primary	Larger/urban	New-build	P
2					Refurb	P
3				Smaller/rural	New-build	P
4			Secondary		New-build	P P
5					Refurb	P
6		Phase 2 (later: opened 2003 – 2006)	Primary	Larger/urban	New-build	P P
7					Refurb	
8				Smaller/rural	New-build	
9			Secondary		New-build	P
10					Refurb	P
11	Non-PFI		Primary	Larger/urban	New-build	P
12					Refurb	P
13				Smaller/rural	New-build	P
14					Refurb	P
15			Secondary	Larger/urban	New-build	P
16					Refurb	P
17				Smaller/rural	New-build	
18					Refurb	P P

19	Historic	Primary	-	Condition C/D	
20		Secondary	-	Condition C/D	P P

Notes:

1) The two historic schools are not used in the analysis of results.
2) Where no schools are sampled in a category (e.g. PFI primary school refurbishment) this is because there are no, or there are very few, schools in this category. Instead, there are two schools sampled in categories where there are a relatively large number of schools (e.g. PFI new-build secondary schools).