Case study: Designing out Waste

Southwark Primary School, Nottingham

A design review of the project to build Southwark Primary School in Nottingham identified easy to implement ideas to reduce construction waste with the potential to reduce total project costs by £24,150, reduce the amount of waste produced on site by 14 tonnes and reduce embodied carbon by 260 tonnes.

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CAPITA SYMONDS

Front cover image: Artists impression, Southwark Primary School (Capita Architecture Ltd])

Executive summary

Designing out Waste during the design stage of a construction project presents a significant opportunity to reduce waste from occurring on site, reducing the construction industry's waste burdens and improving the efficiency of material usage. These can provide clear cost savings and reductions in embodied carbon.

Through working with design teams on live projects, WRAP (Waste & Resources Action Programme) has created a series of exemplar case studies which demonstrate the benefits of taking action at the design stage to reduce waste and embodied carbon by making changes that either saved money or were cost neutral based on the five key principles of Designing out Waste:

- Design for Reuse and Recovery;
- Design for Off Site Construction;
- Design for Material Optimisation;
- Design for Waste Efficient Procurement; and
- Design for Deconstruction and Flexibility.

This report describes the work conducted by WRAP with Capita Architecture and Capita Symonds to demonstrate these principles in practice by identifying cost-effective and feasible waste reducing opportunities in the design of Southwark Primary School in Nottingham – part of the Nottingham City Council Building Schools for the Future (BSF) programme.

The Designing out Waste process comprises three stages:

- **Identify** – engagement with the design team in a design review workshop to identify and prioritise opportunities to reduce waste based on the five key principles of Designing out Waste;
- **Investigate** – qualitative and quantitative analysis of prioritised alternative designs compared with the base design, including calculation of savings in cost, waste and carbon; and
- **Implement** – selection of solutions to implement into the design and build based on the outcome of this analysis.

The ideas generated at the workshop were evaluated by the design team in terms of their waste reduction potential and their feasibility for implementation on the project. Because the design review was taking place later in the design process than recommended in the Designing out Waste approach, many of the ideas put forward at the workshop had already been incorporated into the design. Four of these ideas were selected as being the most appropriate for quantitative analysis:

- use of 'standard' carpet tiles in lieu of carpet from a roll;
- use of 'random design' carpet tiles instead of 'standard' carpet tiles;
- leaving the ceiling structure open instead of having suspended ceilings; and
- designing for disassembly of the steel frame to allow elements to be reused rather than recycled at the end of the building's life (i.e. moving up the waste hierarchy).

A comparative assessment of these four opportunities (i.e. base design versus alternative design) to reduce waste was undertaken to determine the difference in the overall construction cost, quantity of waste, embodied carbon, cost of waste disposal and value of material wasted. The table below summarises the results of this assessment for two of the ideas only. The use of random design carpet tiles was rejected by the design team due to its higher cost and, while the quantitative analysis confirmed the environmental benefits of designing the steel frame for disassembly to allow elements to be reused rather than recycled at the end of the building's life, it was difficult to make accurate estimates of the total project costs for this option and so it is omitted from the overall results presented.

Implementing the two alternative designs would:

- reduce total project costs by £24,510;
- reduce waste created on site by 14 tonnes;
- reduce embodied carbon by 260 tonnes;

- reduce waste disposal costs by £414; and
- reduce the value of materials wasted by £9160.

Results of quantitative analysis of design solutions for the Southwark Primary School project

Design solution	Total project cost saving	Reduction in waste (tonnes)	Reduction in embodied carbon (tonnes) [A]	Reduction in waste disposal costs	Reduction in value of materials wasted
Use of standard carpet tiles	£17,090	12.9	239	£182	£8348
Use of open ceiling design	£7420	0.89	21	£232	£812
Total	**£24,510**	**13.7**	**260**	**£414**	**£9160**

A: Resulting from reduced materials used and/or reduced waste created. It does not include carbon contributions from transport of materials and waste.

Contents

1.0 Introduction

The construction industry is the biggest user of materials in the UK economy, consuming more than 400 million tonnes of materials each year. It also generates over 120 million tonnes of construction, demolition and excavation waste each year – over a third of all waste – only half of which is currently recycled or reclaimed back into construction.

The WRAP Construction Programme is helping the construction industry cut costs and increase efficiency through the better use of materials and reduction in waste. It aims to set new standards for good and best practice in resource and waste management in the construction industry, and provides free access to tools and knowledge to allow clients, designers and contractors to increase the materials resource efficiency of their projects and to increase industry awareness of the commercial benefits of doing so.

The best opportunities to reduce materials use and waste in construction occur by working at the earliest stages possible in the construction process. Empowering design teams to identify and act upon these opportunities to design out waste is therefore key to achieving the Government's and industry's commitment to Halving Waste to Landfill by 2012.

Decisions made throughout the evolution of a design can have a major impact on the levels of materials used during a project and waste that arises during the physical construction and future demolition. Often these decisions are made based on considerations such as site constraints, client requirements for improved performance or finish, or compliance with Building Regulations but, currently, these considerations rarely include improving materials resource efficiency or reducing waste.

'Designing out Waste' during the design stage presents a major opportunity to prevent the creation of waste on site thus improving resource efficiency, reducing waste to landfill and saving carbon – and reducing project costs. The five key principles of Designing out Waste are:

- Design for Reuse and Recovery;
- Design for Off Site Construction;
- Design for Material Optimisation;
- Design for Waste Efficient Procurement; and
- Design for Deconstruction and Flexibility.

WRAP has worked closely with the construction industry to develop a simple three-step structured process for 'Designing out Waste' to help design teams apply these principles to reduce the amount of construction waste produced through early changes to design, specification and procurement. A guide, *Designing out Waste: A design team guide for buildings*,[1] presenting this Designing out Waste process was published by WRAP in June 2009 and is recognised by RIBA within its CPD Core Curriculum.

This report describes work conducted as part of a WRAP project to work with the design teams of major live construction projects. The WRAP project had four main objectives:

- to identify opportunities to reduce the amount of construction, demolition and excavation waste produced at the outline design stage;
- to positively influence projects by gaining client, contractor and design team buy in to identify and adopt appropriate waste reduction design solutions;
- to gather evidence of the waste, cost and embodied carbon savings as a result of the adopted solutions; and
- to follow and test WRAP's design guidance and Designing out Waste process.

A number of construction projects were selected to be involved in this WRAP project and to produce exemplar case studies. This report summarises the findings of work by Capita Symonds (on behalf of WRAP) conducted with Capita Architecture to identify and investigate opportunities for Designing out Waste on the project to build Southwark Primary School in Nottingham.

[1] *Available from the WRAP website (www.wrap.org.uk/designingoutwaste)*

1.1 The construction scheme

Southwark Primary School is a new build school undertaken as part of the Nottingham City Council Building Schools for the Future (BSF) programme. Southwark Primary School is a £13 million 'exemplar' primary school designed to accommodate 720 pupils (630 primary and 90 nursery).

The 2.6 hectare site is located in the Old Basford area of Nottingham. Part of the site currently houses Southwark Infants School and the rest of the site is vacated allotments. The site is situated within a primarily residential area with traditional terraced properties. A residential complex for the elderly adjoins the site.

The project is to include innovative new proposals for primary school design, including a 'courtyard' scheme providing a number of unique spaces that will help the school explore a variety of innovative teaching styles. Other measures include large hub spaces, adventure playgrounds, a performance hall and a relaxation area called 'sky rocket'. The building is also designed to maximise natural light and ventilation with the aim of achieving a BREEAM 'excellent' rating. Artists' impressions of the new school are shown in Figures 1 and 2.

The project forms part of a strategy involving 23 pathfinder local authorities across England working alongside the Department for Children, Schools and Families (DCSF) aiming to deliver exemplar primary school projects designed to set a high quality benchmark ahead of major government investment in new primary schools through the Primary Capital Programme. As such, minimising the environmental impact of the construction and operational phases of the project is a high priority and the measures taken in this project may be applied to future new primary schools.

Figure 1 Artist's impression of the new Southwark Primary School (Capita Architecture)

Figure 2 Southwark Primary School, night-time perspective (Capita Architecture)

1.2 The project team

Capita Symonds was contracted by WRAP to:

- facilitate the design review workshop (see section 2);
- carry out the subsequent cost, waste and environmental assessments; and
- develop the exemplar case study.

Capita Architecture, one of the UK's largest architectural practices and the architectural brand of Capita Symonds, supported Capita Symonds in developing the exemplar case study.

Southwark Primary School is being built on Nottingham City Council land and funded under the Nottingham Building Schools for the Future (BSF) programme. The main contractor is Carillion.

2.0 Designing out Waste process

The Designing out Waste process devised by WRAP involves three stages:

1. **Identify** alternative design solutions which reduce materials use and/or creation of waste, and **prioritise** those that will have the biggest impact and be easiest to implement. This stage requires some form of design review, and WRAP's Designing out Waste guide presents the format for a facilitated design review workshop which ensures a robust approach involving all the design team.
2. **Investigate** the prioritised solutions further and **quantify** the benefits in terms of reductions in waste, cost and carbon. This enables evidence-based decision-making on which design solutions to implement.
3. **Implement** the agreed solutions in the project through the plans, specifications and contracts. **Record** the solutions in the Site Waste Management Plan to ensure they are fully communicated to the contractor and the quantified benefits are communicated to the client.

Designing out Waste: a design team guide for buildings recommends undertaking the design review workshop during RIBA Stage C. In the case of Southwark Primary School, the design was already at RIBA Stage E/F and the architects had already implemented a number of ideas to reduce waste. Therefore after listing ideas already incorporated into the design and any additional ideas, it was decided to review those already in place. Thus the third stage of the Designing out Waste process was already in progress separately.

2.1 Design review workshop

The design review workshop was held during RIBA Stage E/F of the project on 11 December 2008 at one of Capita Symonds offices in London. It was attended by:

- Michelle Powers – Capita Symonds;
- Gary Church – Capita Architecture;
- Richard Woods – Capita Architecture;
- David Wilcock – Capita Architecture; and
- Mark Crosby – Capita Symonds.

The workshop had three separate but consecutive sessions:

- Awareness session – review of Designing out Waste principles and summary of the construction project;
- Creativity session – ideas generation; and
- Reasoning session – ideas classification and prioritisation.

2.1.1 Awareness session

The first session included a brief overview of WRAP's construction programme, materials resource efficiency and the aims of the design review workshop. The design team then gave a short presentation on the Southwark Primary School scheme, highlighting some of the specifications from the design brief and project restrictions.

2.1.2 Creativity session

A brainstorming session was then undertaken where all members of the team were encouraged to suggest ideas of how waste could be prevented or reduced. The aim was to create an atmosphere where ideas were stimulated through people thinking 'outside of the box'. Attendees were encouraged to 'brainstorm' a series of design opportunities that would effectively reduce construction waste in the project. The role of the facilitator was to encourage the design team to have a free flow of ideas, and to identify as many opportunities as possible. All ideas, regardless of feasibility, were recorded.

2.1.3 Reasoning session

Following the brainstorming session, the complete list of ideas was reviewed by the whole team with ideas being sorted into those already incorporated into the design (Table 1) and new ideas that were not incorporated (Table 2).

Ideas were then evaluated by the group for their waste reduction potential and their feasibility for implementation on the project in terms of cost, programme and quality. Although a rough initial assessment, this helped to quickly identify the top opportunities with the greatest impact on waste and the most likely to be pursued on the project. All ideas were prioritised by the team by classifying as either A, B, C or D as per the simple 'opportunity' matrix shown in Figure 3:

- Section A – High impact on waste reduction, easy to implement.
- Section B – High impact on waste reduction, difficult to implement.
- Section C – Low impact on waste reduction, easy to implement.
- Section D – Low impact on waste reduction, difficult to implement.

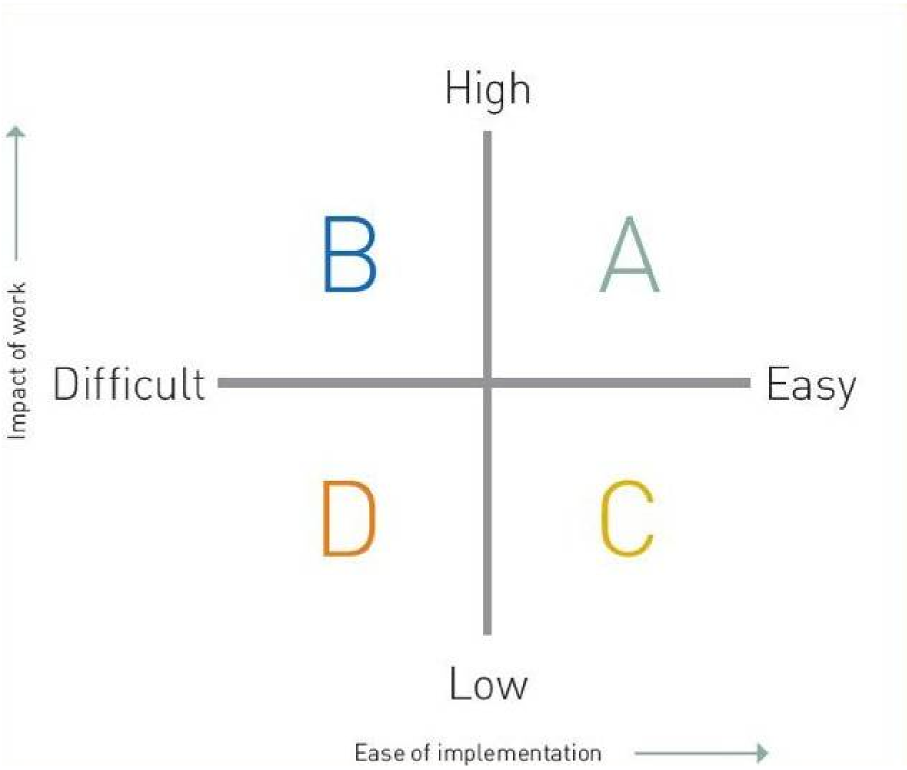

Figure 3 Opportunity matrix used to evaluate waste reduction ideas

Table 1 Ideas already incorporated into the design

Idea	Rating
Design of a spilt level ground floor to accurately balance cut and fill.	A
Prefabricated integrated plumbing systems to the back wall of toilet cubicles.	A
Design of building dimensions to match whole or half cladding panels.	A
Removal of the need for ceiling tiles through an 'open ceiling' design.	A
Sedum roofs used instead of green roofs, reducing the depth of soil required and reducing the loadings exerted by the roof, in turn reducing materials required for the structure.	A
Use of carpet tiles instead of carpet on a roll to reduce the amount of offcuts and need for replacement materials through the building life.	A
Steel frame to be constructed so that it can be unbolted and reused/recycled upon deconstruction.	A

Table 2 Ideas not incorporated into the design

Idea	Rating
Reuse trees to be removed to facilitate development as outdoor furniture and seating within new development.	A
External benches and paving slabs from the old school could be reused in another BSF or local project.	?
Recycling of ceiling and floor tiles via supplier take-back scheme.	A
Reuse of old school furniture through disposal to suitable charity for use in its existing form.	B
Potential for off site fabrication using mechanical and electrical services within wall panelling.	B
Trespa cladding panels to be cut to size off site thereby reducing need for over-ordering and potential for site wastage.	B
Reuse of existing school parquet flooring from main hall, depending on ease of removal.	C
Reuse of demolition materials in other BSF projects, dependent on location and programme/storage constraints.	D
Using wholly integrated plumbing systems (instead of partial) in the back wall of the toilets could be more efficient and reduce waste on site.	D
Replacement of cast in-situ concrete slab to small area of the building with beam and block pre-cast system.	D

The team then created a shortlist of their preferred options (Table 3) with the aim of including up to 10 design solutions with those rated 'A' the most preferable, followed by 'B' and 'C', then 'D'.

Table 3 Shortlist of design solutions

Idea	Rating
Design of a spilt level ground floor to accurately balance cut and fill.	A
Prefabricated integrated plumbing systems to the back wall of toilet cubicles.	A
Design of building dimensions to match whole of half cladding panels.	A
Removal of the need for ceiling tiles through an 'open ceiling' design.	A
Sedum roofs used instead of green roofs, reducing the depth of soil required and reducing the loadings exerted by the roof, in turn reducing materials required for the structure.	A
Use of carpet tiles instead of carpet on a roll to reduce the amount of offcuts and need for replacement materials through the building life.	A
Steel frame to be constructed so that it can be unbolted and reused/recycled upon deconstruction.	A

Further research and discussion helped to refine and clarify the design solutions on the shortlist to decide on those appropriate for quantitative analysis. The following questions were considered:

- Would the design solution satisfy the client's requirements?
- What would be the likely cost (based on previous experience and industry knowledge of the design team)?
- How practical was the solution (based on previous experience, knowledge of the design team and understanding of site constraints in implementing solutions, e.g. storage of components)?

Based on this discussion, the following conclusions were drawn:

- **Design of a spilt level ground floor to accurately balance cut and fill.** Although cut and fill balance is becoming commonplace in construction to reduce waste exported off site, Capita Architecture has taken this one step further in designing a split level ground floor to closely align the building with the levels already present at the site. While the savings are expected to be greater than a more traditional cut and fill balance, it would be extremely difficult to distinguish accurately between the two.
- **Prefabricated integrated plumbing systems (IPS) to the back wall of toilet cubicles.** At the time of assessment, the extent of IPS to be used was not decided and was in the control of the contractor who was not present at the workshop.
- **Design of building dimensions to match whole or half cladding panels.** Ordering cladding panels manufactured or cut to size off site is commonplace so the 'base design' option was not considered to represent a Standard Practice activity.

- **Removal of the need for ceiling tiles through an 'open ceiling' design.** The concept of removing the suspended ceiling would reduce materials use and therefore reduce waste of those materials. However, increased requirements for acoustically absorptive panels could negate any potential savings. Detailed analysis would confirm this.
- **Sedum roofs used instead of green roofs, reducing the depth of soil required and reducing the loadings exerted by the roof, in turn reducing materials required for the structure.** Accurately calculating the difference in load and therefore structural requirements was considered to require significant effort from the design team which was not practicable within the scope of this project.
- **Use of carpet and rubber flooring tiles instead of carpet on a roll to reduce the amount of offcuts and need for replacement materials through the building life.** Although the use of tiled carpet in a commercial setting is commonplace, recent liaison with Capita Architecture's preferred supplier had suggested the use of 'random design' carpet tiles could reduce waste even further.
- **Steel frame to be constructed so that it can be unbolted and reused/recycled upon deconstruction.** Recycling the steel frame was expected to give rise to a significant saving at the end of the building's life and reuse of the frame would potentially bring revenue. However, any value assigned to the steel at the end of the building's life would be purely speculative.

As a result of this selection process, four alternative design opportunities (Table 4) were taken forward to a full quantitative assessment.

Table 4 Ideas selected for quantitative analysis

Base design	Alternative design
Use of sheet carpet laid over rubber flooring.	Use of 'standard' carpet tiles laid over rubber studded tiles.
Use of 'standard' carpet tiles.	Use of 'random design' carpet tiles.
Use of suspended ceilings.	Leaving ceiling structure open where possible.
Designing for disassembly to allow recycling of elements of the steel frame at the end of the building's life.	Designing for disassembly to allow reuse of elements of the steel frame at the end of the building's life.

2.2 Quantitative analysis

Four design ideas were selected at the workshop for quantitative analysis. The impact of the changes was quantified by comparing the original design (base design) with the alternative design as shown in Table 4. A quantitative analysis was undertaken of the potential cost, waste and embodied carbon savings by changing from the base design to the alternative design.

To provide the most accurate assessment of the actual quantities involved and costs of materials, Capita Symonds cost consultants drew estimates from the latest design drawings and cost plan estimates available at the time of assessment.

2.2.1 Calculate

The first step in the assessment was to calculate:

- **Total construction cost of design** – based on the material composition of the design and the unit rates (including labour, plant and material costs) provided by the surveyor;
- **Quantity of waste created on site** – application of industry material wastage rates (%) to material quantities (m^3) summed to give the volume of waste (m^3) arising from the base design and alternative design. Standard conversion factors applied to convert to mass (tonnes);
- **Cost of waste disposal** – volume of waste (m^3) calculated above multiplied by the unit cost of waste disposal;

- **Value of materials wasted** – material unit rates (£) multiplied by the volume of waste (m^3) to determine the cost.[2] This cost was multiplied by the materials percentage to exclude plant and labour and determine the value of materials wasted (£); and
- **Total embodied carbon** – the sum of the embodied carbon of the materials used for a function in a design and the embodied carbon of the material waste resulting from that design.[3] The savings in the embodied carbon of waste materials was measured by converting the savings in waste materials (m^3) to tonnes of carbon. The Inventory of Carbon & Energy (ICE)[4] developed by researchers at the Department of Mechanical Engineering, University of Bath was used for the conversion.

WRAP's *Net Waste Tool, Guide to Reference Data, Version 1.0* (May 2008)[5] was used to source Good Practice wastage rates, waste disposal costs and materials percentages.

The detailed calculations are presented in Appendix A.

To estimate the quantity of waste diverted from landfill due to the changes in design, recycling/recovery rates would need to be applied to the quantity of waste arising on site. These rates depend on the site waste management strategy chosen for the site, which is usually not fixed at the design stage of the project. WRAP provides guidance on planning and implementing Good Practice site waste minimisation and management projects.[6]

2.2.2 Compare

The second step was to compare for the base design and alternative design of the different ideas on the shortlist:

- total construction cost;
- quantity of waste created on site;
- cost of waste disposal;
- total project cost (total construction cost + cost of waste disposal);
- total embodied carbon; and
- value of materials wasted.

The results of the quantitative analysis of the four waste reducing opportunities are summarised in section 3.

3.0 Cost, waste and carbon reductions from selected solutions

3.1 Use of carpet tiles

Two options involving carpet tiles were considered:

- **Tiles instead of carpet:** use of 500 × 500mm carpet tiles installed in a uniform manner (monolithically) over rubber-studded tiles rather than use of rolls of broadloom carpet and rubber flooring; and

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[2] The value of materials wasted provides a measure of a component of the total construction cost which is spent but does not form a useful function in the finished building. It also represents a measure of unnecessary depletion of finite natural resources which could be avoided by reducing waste through the alternative design change.

[3] These are assessed independently as although a reduction in waste from a design change will also reduce the embodied carbon of the waste impact, the alternative design may itself have a higher embodied carbon than the original design. For example, a design manufactured off site may produce less waste than the traditional in situ solution and thus the embodied carbon impact of waste may be less, but it may use materials with a higher embodied carbon or a more carbon intensive manufacturing process.

[4] www.bath.ac.uk/mech-eng/sert/embodied/

[5] www.wrap.org.uk/nwtool

[6] www.wrap.org.uk/construction/tools_and_guidance/waste_minimisation_and_management/waste_man_guidance.html

- **Random design rather than uniform carpet tiles:** use of 500 × 500mm carpet tiles[7] installed in a non-uniform manner (non-directionally) rather than 500 × 500mm carpet tiles installed in a uniform manner (both installed over rubber-studded tiles).

In all cases the flooring will be laid over a cement and sand base.

3.1.1 Use of 'standard' carpet tiles rather than broadloom carpet

The wastage rate for both 'standard' carpet tiles and rubber-studded tiles is 5% compared with 20% for sheet carpet and rubber flooring on rolls.

The financial impact to the project of using standard carpet tiles rather than carpet on a roll would be a saving in the total project cost of £17,090 (Table 5). There would also be environmental benefits in terms of:

- a total reduction in waste created on site of 13 tonnes; and
- a total reduction in embodied carbon of 239 tonnes.

The saving in waste disposal costs would be £182 and the saving in the value of materials wasted £8348.

Table 5 Using 'standard' carpet tiles rather than carpet from a roll – results of quantitative analysis

	Base design	Alternative design	Reduction
Total project cost [A]	£65,562	£48,472	£17,090
Waste created on site	14.0 tonnes	1.13 tonnes	12.9 tonnes
Embodied carbon in materials	279 tonnes	90.4 tonnes	188 tonnes
Embodied carbon in waste [B]	55.7 tonnes	4.52 tonnes	51.1 tonnes
Total embodied carbon	334 tonnes	94.9 tonnes	239 tonnes
Cost of waste disposal	£233	£51	£182
Value of materials wasted	£10,294	£1946	£8348

A: Includes cost of waste disposal.

B: Does not include carbon impact of transporting waste or recycling/recovery/disposal method.

3.1.2 Use of 'random design' carpet tiles rather than 'standard' carpet tiles

The use of random designed carpet tiles reduces the amount of waste (from 5% to 1%) as they can be installed in any direction. It also reduces the number of tiles that need to be purchased. However, the cost per m^2 of the random design carpet tiles is greater than that for the standard carpet tiles. This means the construction cost of the alternative design is higher than that for the base design.

The use of random design tiles also reduces waste throughout the life of the carpet as replacement tiles will fit seamlessly into the installation even if they are ordered years later. This additional benefit could not be quantified.

The financial impact to the project of using random design instead of standard carpet tiles would be an increase in the total project cost of £5617 (Table 6). However, there would be environmental benefits in terms of:

- a total reduction in waste created on site of 1 tonne; and
- a total reduction in embodied carbon of 6 tonnes.

The saving in waste disposal costs would be £40 and the saving in the value of materials wasted £1360.

[7] *This option involved a carpet tile range more suited for laying in a random design.*

Table 6 Using random design carpet tiles rather than standard carpet tills – results of quantitative analysis

	Base design	Alternative design	Reduction
Total project cost [A]	£48,472	£54,089	(£5617)
Waste created on site	1.13 tonnes	0.3 tonnes	0.83 tonnes
Embodied carbon in materials	90.4 tonnes	87.3 tonnes	3.13 tonnes
Embodied carbon in waste [B]	4.52 tonnes	1.20 tonnes	3.32 tonnes
Total embodied carbon	94.9 tonnes	88.5 tonnes	6.45 tonnes
Cost of waste disposal	£51	£11	£40
Value of materials wasted	£1946	£586	£1360

A: Includes cost of waste disposal.

B: Does not include carbon impact of transporting waste or recycling/recovery/disposal method.

3.2 Open ceiling design

The financial impact to the project of an open ceiling design rather than a suspended ceiling would be a saving in the total project cost of £7420 (Table 7). There would also be environmental benefits in terms of:

- a total reduction in waste created on site of 1 tonne; and
- a total reduction in embodied carbon of 21 tonnes.

The saving in waste disposal costs would be £232 and the saving in the value of materials wasted £812.

Table 7 Use of open ceiling design – results of quantitative analysis

	Base design	Alternative design	Reduction
Total project cost [A]	£61,609	£54,189	£7420
Waste created on site	1.02 tonnes	0.13 tonnes	0.89 tonnes
Embodied carbon in materials	20.82 tonnes	1.19 tonnes	19.63 tonnes
Embodied carbon in waste [B]	1.63 tonnes	0.06 tonnes	1.57 tonnes
Total embodied carbon	22.45 tonnes	1.25 tonnes	21.2 tonnes
Cost of waste disposal	£241	£9	£232
Value of materials wasted	£2166	£1354	£812

A: Includes cost of waste disposal.

B: Does not include carbon impact of transporting waste or recycling/recovery/disposal method.

Although the reductions in waste and embodied carbon are small, the open ceiling design increases resource efficiency by reducing the quantity of materials used in construction from 14 tonnes to 3 tonnes. This saving will be seen at the end of the building's life in deconstruction.

3.3 Reuse of steel frame at end of building's life

There would be significant environmental benefits from designing the steel frame for disassembly so that elements could be reused at the end of the building's life rather than being recycled. This is embodied in the Designing out Waste principle of Design for Deconstruction and Flexibility. The design suggested that potentially most of the steel frame (274 tonnes) frame could be reused, although it was not possible to quantify the benefits as there are too many variables associated with the future end-of-life scenario.

4.0 Discussion

4.1 Potential savings

The design team confirmed that the following design solutions would be implemented:

- use of standard tiled carpets;
- use of open ceiling design; and
- design of the steel frame for deconstruction.

The use of random design carpet tiles was not selected for use at Southwark Primary School because, although there were environmental benefits from their use and replacement of a single tile would be easier, their provision would be cost significantly more.

Table 8 shows the significant benefits to the project of implementing the first two design opportunities. The figures exclude the benefits from reusing rather than recycling the steel frame as they could not be quantified accurately, only being achieved at the end of the building's life.

The total project cost saving is £24,510 of which £414 is due to savings in waste disposal costs and £9160 is due to a saving in the total value of materials wasted.

The environmental benefits are also significant; the reduction in waste created on site is 14 tonnes and the total reduction in embodied carbon is 260 tonnes

Table 8 Potential savings from the two design solutions investigated

Design solution	Total project cost saving [A]	Reduction in waste (tonnes)	Reduction in embodied carbon (tonnes) [B]	Reduction in waste disposal costs	Reduction in value of materials wasted
Use of standard carpet tiles	£17,090	12.9	239	£182	£8348
Use of open ceiling design	£7420	0.89	21	£232	£812
Total	**£24,510**	**13.7**	**260**	**£414**	**£9160**

A: Cost of construction + waste disposal cost

B: Total of embodied carbon in materials and waste.

4.2 Comments on the Designing out Waste process

Because the Southwark Primary School project was subject to the Designing out Waste process at a later stage than recommended (i.e. RIBA Stage D/E and not RIBA Stage C), the design was not informed by its conclusions. However, the results of the quantitative analysis and the list of ideas from the design review workshop already incorporated into the design demonstrate that the designers have been successful in reducing the amount of waste that would be produced on site. In designing the steel frame for disassembly, the designers have also enabled the future team responsible for demolition to reuse materials.

Appendix A Quantitative analysis results

Use of 'standard' carpet tiles

- **Base design:** use of carpet and rubber flooring from rolls.
- **Alternative design:** use of 'standard' carpet tiles and rubber tiles.

Table A1 Base design – quantification of waste

Material	Quantity	Unit	Other dimension (thickness)	Density (tonnes/m^3)	Volume of material (m^3)	Tonnes of material	Wastage rate	Quantity of waste (m^3)	Quantity of waste (tonnes)
Broadloom carpet installed from rolls to cement and sand base	2022	m^2	0.0078	4.3	15.77	67.8	20%	3.15	13.56
Rubber flooring installed from rolls to cement and sand base	221	m^2	0.0025	4.3	0.55	2.38	20%	0.11	0.47
Total								**3.26**	**14.04**

Table A2 Alternative design – quantification of waste

Material	Quantity	Unit	Other dimension (thickness)	Density (tonnes/m^3)	Volume of material (m^3)	Tonnes of material	Wastage rate	Quantity of waste (m^3)	Quantity of waste (tonnes)
500 × 500 carpet tiles installed monolithically to cement and sand base	1769	m^2	0.0078	1.5	13.80	20.69	5%	0.69	1.03
Rubber studded tiles fixed with adhesive to cement and sand base	193	m^2	0.0025	4.3	0.48	2.07	5%	0.02	0.10
Total								**0.71**	**1.13**

Table A3 Base design – cost of waste disposal

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m³)	Total cost of waste disposal
Broadloom carpet installed from rolls to cement and sand base	m^3	3.15	0.5	Mixed waste	£36	£225.44
Rubber flooring installed from rolls to cement and sand base	m^3	0.11	0.5	Mixed waste	£36	£7.89
Total						**£233.33**

Table A4 Alternative design – cost of waste disposal

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m³)	Total cost of waste disposal
500 × 500 carpet tiles installed monolithically to cement and sand base	m^3	0.69	0.5	Mixed waste	£36	£49.32
Rubber studded tiles fixed with adhesive to cement and sand base	m^3	0.02	0.5	Mixed waste	£36	£1.73
Total						**£51.04**

Table A5 Base design – value of materials wasted

Material	Quantity (m^2)	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate	Value of wasted materials
Broadloom carpet installed from rolls to cement and sand base	2022	29.04	£58,707	80%	£46,966	20%	£9393
Rubber flooring installed from rolls to cement and sand base	221	30	£6622	68%	£4503	20%	£901
	Cost of base design		**£65,329**	**Total value of wasted materials**			**£10,294**

Table A6 Alternative design – value of materials wasted

Material	Quantity (m^2)	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate	Value of wasted materials
500 × 500 carpet tiles installed monolithically to cement and sand base	1769	24.40	£43,163	82%	£35,394	5%	£1770
Rubber studded tiles fixed with adhesive to cement and sand base	193	27.23	£5258	67%	£3523	5%	£176
	Cost of alternative design		**£48,421**	**Total value of wasted materials**			**£1946**

Table A7 Base design – impact on CO_2 emissions

Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material CO_2 impact (tonnes)	Waste CO_2 impact (tonnes)
Broadloom carpet installed from rolls to cement and sand base	67.81	13.56	3.97	269.22	53.84
Rubber flooring installed from rolls to cement and sand base	2.37	0.47	3.97	9.42	1.88
Total				**278.64**	**55.73**

Table A8 Alternative design – impact on CO_2 emissions

Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material CO_2 impact (tonnes)	Waste CO_2 impact (tonnes)
500 × 500 carpet tiles installed monolithically to cement and sand base	20.70	1.03	3.97	82.17	4.11
Rubber studded tiles fixed with adhesive to cement and sand base	2.08	0.10	3.97	8.24	0.41
Total				**90.42**	**4.52**

Table A9 Summary

	Base design	Alternative design	Reduction
Cost of design	£65,329	£48,421	£16,908
Cost of waste disposal	£233	£51	£182
Total project cost	£65,562	£48,472	£17,090
Total waste arisings	14.04 tonnes	1.13 tonnes	12.91 tonnes
Value of wasted material	£10,294	£1946	£8348
Material CO_2 impact	278.64 tonnes	90.42 tonnes	188.22 tonnes
Waste CO_2 impact	55.73 tonnes	4.52 tonnes	51.21 tonnes
Total CO_2 impact	334.37 tonnes	94.94 tonnes	239.43 tonnes

Use of 'random design' carpet tiles

- **Base design:** use of 'standard' carpet tiles.
- **Alternative design:** use of 'random design' carpet tiles.

Table A10 Base design – quantification of waste

Material	Quantity	Unit	Other dimension (thickness)	Density (tonnes/m³)	Volume of material (m³)	Tonnes of material	Wastage rate	Quantity of waste (m³)	Quantity of waste (tonnes)
500 × 500 carpet tiles installed monolithically to cement and sand base	1769	m^2	0.0078	1.5	13.80	20.69	5%	0.69	1.03
Rubber studded tiles fixed with adhesive to cement and sand base	193	m^2	0.0025	4.3	0.48	2.07	5%	0.02	0.10
Total								**0.71**	**1.13**

Table A11 Alternative design – quantification of waste

Material	Quantity	Unit	Other dimension (thickness)	Density (tonnes/m³)	Volume of material (m³)	Tonnes of material	Wastage rate	Quantity of waste (m³)	Quantity of waste (tonnes)
500 × 500 carpet tiles installed non-directionally to cement and sand base	1702	m^2	0.0078	1.5	13	20	1%	0.13	0.20
Rubber studded tiles fixed with adhesive to cement and sand base	193	m^2	0.0025	4.3	0.48	2.07	5%	0.02	0.10
Total								**0.16**	**0.30**

Table A12 Base design – cost of waste disposal

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m³)	Total cost of waste disposal
500 × 500 carpet tiles installed monolithically to cement and sand base	m^3	0.69	0.5	Mixed waste	£36	£49.32
Rubber studded tiles fixed with adhesive to cement and sand base	m^3	0.02	0.5	Mixed waste	£36	£1.73
Total						**£51.04**

Table A13 Alternative design – cost of waste disposal

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m³)	Total cost of waste disposal
500 x 500 carpet tiles installed non-directionally to cement and sand base	m^3	0.13	0.5	Mixed waste	£36	£9.49
Rubber studded tiles fixed with adhesive to cement and sand base	m^3	0.02	0.5	Mixed waste	£36	£1.73
Total						**£11.21**

Table A14 Base design – value of materials wasted

Material	Quantity (m^2)	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate	Value of wasted materials
500 × 500 carpet tiles installed monolithically to cement and sand base	1769	24.40	£43,163	82%	£35,394	5%	£1769.68
Rubber studded tiles fixed with adhesive to cement and sand base	193	27.23	£5258	67%	£3,523	5%	£176.15
	Cost of base design		**£48,421**	**Total value of wasted materials**			**£1,945.83**

Table A15 Alternative design – value of materials wasted

Material	Quantity (m^2)	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate	Value of wasted materials
500 x 500 carpet tiles installed non-directionally to cement and sand base	1702	28.69	£48,819	84%	£41,008	1%	£410.08
Rubber studded tiles fixed with adhesive to cement and sand base	193	27.23	£5258	67%	£3523	5%	£176.15
	Cost of alternative design		**£54,077**	**Total value of wasted materials**			**£586.23**

Table A16 Base design – impact on CO_2 emissions

Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material CO_2 impact (tonnes)	Waste CO_2 impact (tonnes)
500 × 500 carpet tiles installed monolithically to cement and sand base	20.70	1.03	3.97	82.17	4.11
Rubber studded tiles fixed with adhesive to cement and sand base	2.08	0.10	3.97	8.24	0.41
Total				**90.42**	**4.52**

Table A17 Alternative design – impact on CO_2 emissions

Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material CO_2 impact (tonnes)	Waste CO_2 impact (tonnes)
500 × 500 carpet tiles installed non-directionally to cement and sand base	19.91	0.20	3.97	79.04	0.79
Rubber studded tiles fixed with adhesive to cement and sand base	2.08	0.10	3.97	8.24	0.41
Total				**87.29**	**1.20**

Table A18 Summary

	Base design	Alternative design	Reduction
Cost of design	£48,421	£54,077	(£3656)
Cost of waste disposal	£51	£11	£40
Total project cost	£48,472	£54,089	(£5617)
Total waste arisings	1.13 tonnes	0.30 tonnes	0.83 tonnes
Value of wasted material	£1946	£586	£1360
Material CO_2 impact	90.42 tonnes	87.29 tonnes	3.13 tonnes
Waste CO_2 impact	4.52 tonnes	1.20 tonnes	3.32 tonnes
Total CO_2 impact	94.94 tonnes	88.49 tonnes	6.45 tonnes

Open ceiling design

- **Base design:** use of suspended ceilings.
- **Alternative design:** leaving ceiling structure open where possible.

Table A19 Base design – quantification of waste

Material	Quantity	Unit	Other dimensions (m)			Item weight (kg)	Volume of material (m³)	Tonnes of material	Wastage rate	Quantity of waste (m³)	Quantity of waste (tonnes)
Dune Max Board, 600 × 600 × 18	6890		0.018	0.6	0.6	1.55	44.65	10.66	7.5%	3.35	0.80
Prelude 24 Main runner	575		0.043	0.024	3.6	0.88	2.14	0.50	7.5%	0.16	0.04
Prelude 24 XL Cross tee	3446		0.024	0.038	1.2	0.30	3.77	1.04	7.5%	0.28	0.08
Prelude 24 XL Cross tee unslotted	3446		0.03	0.024	0.6	0.14	1.49	0.48	7.5%	0.11	0.04
Wire hangers	2007		0.01	0.48	0.01	0.04	0.10	0.09	7.5%	0.007	0.006
Painted shadowline 20 × 20 × 20mm	276		0.20	0.2	3	1.64	33.12	0.45	7.5%	2.484	0.034
Acoustic boards	120	m²	0.05			0.085	6	1	5%	0.30	0.03
Total										**6.7**	**1.02**

Table A20 Alternative design – quantification of waste

Material	Quantity	Unit	Other dimension (m)	Density (tonnes/m³)	Volume of material (m³)	Tonnes of material	Wastage rate	Quantity of waste (m³)	Quantity of waste (tonnes)
Acoustic boards	602	m²	0.05	0.085	30	3	5%	1.51	0.13
Total								**2**	**0.13**

Table A21 Base design – cost of waste disposal

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m³)	Total cost of waste disposal
Dune Max Board, 600x600x18	m³	3.3	0.5	Mixed waste	£36	£239.34
Prelude 24 Main runner	m³	0.2	0.5	Metal	£0	£0.00
Prelude 24 XL Cross tee	m³	0.3	0.5	Metal	£0	£0.00
Prelude 24 XL Cross tee unslotted	m³	0.1	0.5	Metal	£0	£0.00
Wire hangers	m³	0.01	0.5	Metal	£0	£0.00
Painted shadowline 20 × 20 × 20mm	m³	2.5	0.5	Metal	£0	£0.00
Acoustic boards	m³	0.0	0.5	Mixed waste	£36	£1.84
Total						**£241.18**

Table A22 Alternative design – cost of waste disposal

Material	Unit	Quantity of waste	Bulking factor	Material type	Unit cost of waste disposal (£/m³)	Total cost of waste disposal
Acoustic boards	m^3	0.13	0.50	Mixed	£36	£9.14
Total						**£9.14**

Table A23 Base design – value of materials wasted

Material	Quantity (m^2)	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate	Value of wasted materials
Demountable suspended ceiling	2408	21	£50,568	50%	£25,284	7.5%	£1,896.30
Acoustic boards	120	90	£10,800	50%	£5400	5%	£270.00
	Cost of base design		**£61,368**	**Total value of wasted materials**			**£2,166.30**

Table A24 Alternative design – value of materials wasted

Material	Quantity (m^2)	Unit rate (£)	Cost	Materials percentage	Value of materials	Wastage rate	Value of wasted materials
Acoustic boards	602	90	£54,180	50%	£27,090	5%	£1,354.50
	Cost of alternative design		**£54,180**	**Total value of wasted materials**			**£1,354.50**

Table A25 Base design – impact on CO_2 emissions

Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material CO_2 impact (tonnes)	Waste CO_2 impact (tonnes)
Dune Max Board, 600 × 600 × 18	10.66	0.80	0.24	2.56	0.19
Prelude 24 Main runner	0.50	0.04	8.53	4.29	0.32
Prelude 24 XL Cross tee	1.04	0.08	8.53	8.87	0.68
Prelude 24 XL Cross tee unslotted	0.48	0.04	8.53	4.09	0.34
Wire hangers	0.09	0.01	8.53	0.77	0.09
Painted shadowline 20 × 20 × 20mm	0.45	0.03	n/a		
Acoustic boards	0.51	0.03	0.47	0.24	0.01
Total				**20.82**	**1.63**

Table A26 Alternative design – impact on CO_2 emissions

Material	Quantity materials (tonnes)	Quantity of waste (tonnes)	CO_2 equivalents (tonnes)	Material CO_2 impact (tonnes)	Waste CO_2 impact (tonnes)
Acoustic boards	2.56	0.13	0.47	1.19	0.06
Total				**1.19**	**0.06**

Table A27 Summary

	Base design	Alternative design	Reduction
Cost of design	£61,368	£54,180	£7188
Cost of waste disposal	£241	£9	£232
Total project cost	£61,609	£54,189	£7420
Total waste arisings	1.02 tonnes	0.13 tonnes	0.89 tonnes
Value of wasted material	£2166	£1354	£812
Material CO_2 impact	20.82 tonnes	1.19 tonnes	19.63 tonnes
Waste CO_2 impact	1.63 tonnes	0.06 tonnes	1.57 tonnes
Total CO_2 impact	22.45 tonnes	1.25 tonnes	21.2 tonnes

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