

Middlehaven Hotel Construction



Design review of the hotel element of BioRegional Quintain Limited's proposed Middlehaven development, in Middlesbrough. Demonstrating waste minimisation opportunities on the project that could reduce waste by 3,140 tonnes saving £397,000 and saving 230 tonnes of embodied carbon.

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Key Facts

- Middlehaven is a 250 acre mixed-use development site situated in central Middlesbrough, adjacent to the River Tees.
- The proposed £200 million regeneration is an exemplar of sustainable development, following the One Planet Living framework¹.
- This study looks at the development of a hotel that will be operated as part of an international chain, one of the elements of the mixed use scheme which comprises residential and commercial buildings and large areas of public realm.
- The project team comprises of BioRegional Quintain Ltd (BQL) (Client), Buro Four (Project Manager), Jestico and Whiles (architects), Martin Stockley Associates (structural engineers), DSSR (mechanical and electrical engineers).
- BQL waste minimisation requirements for all projects on the Middlehaven development:
 - Construction waste to be less than 15m³ per 100m² floor area and less than 0.2% of construction cost.
 - Landscaping levels designed to minimise import/export of soil and fill.
 - Landscape design to make innovative use of recycled and reclaimed materials.
 - Extensive use of on-site demolition arisings.
 - Investigate and promote (as appropriate) construction techniques that are efficient in the use of materials.
- Waste minimisation opportunities already identified on the project:
 - Bathroom pods.
 - Pre-cast lift shafts and stairs.
 - Pre-cast walls and slabs for the guest floors.
 - Standard form, standard layout and standard materials.
 - Reduced design complexity.
- Waste minimisation opportunities to be looked at further during the outline design phase of the project:
 - Pre-cast columns.
 - Rotary displacement piling.
- Potential project cost savings through waste minimisation solutions assessed in this study £397,000.
- Potential project waste savings of 3,140 tonnes, embodied carbon savings of 230 tonnes CO₂.

¹ One Planet Living is a global initiative based on ten principles of sustainability developed by BioRegional and WWF International www.oneplanetliving.org

Overview

A design review of a hotel has been conducted to assess the waste savings available through adoption of appropriate waste minimisation design solutions. The proposed hotel forms a part of the BioRegional Quintain Ltd (BQL) redevelopment of waterfront land at the former Middlesbrough docks in Middlehaven. The project team includes BQL, Martin Stockley Associates, DSSR and Buro Four. The design review was conducted by BioRegional Consulting Ltd.

Middlehaven is a 250 acre site at the heart of Middlesbrough's redevelopment programme. The proposed BQL regeneration forms the first 40 acre, £200m phase and offers a wide variety of residential accommodation, commercial opportunities and community spaces. The proposed hotel reviewed in this project forms part of a later development stage and will be operated as part of an international chain. Stage B² of the project was completed in November 2007 and it is anticipated that Stage C³, outline design, will commence in March 2008. The proposed hotel comprises:

1. Ground and first floor as public areas including lobby, restaurant, kitchen, meeting rooms and back of house areas.
2. Guest floors based on a typical floor plan of 18 rooms per floor, with each room conforming to the operator brand of a bedroom and bathroom.

Key opportunities and benefits

A long list of waste minimisation opportunities was developed specific to the Middlehaven scheme based on WRAP guidance document WAS004-005 'Achieving effective waste minimisation through design'. These options were analysed for their applicability to this project. From the long list, four options were short listed for further discussion and analysis:

1. Modern methods of construction/off site construction (MMC/OSC):
 - a. Bathroom pods.
 - b. Volumetric bed and bathroom pods.
 - c. Pre-cast walls and slabs.
 - d. Pre-cast columns.
2. Foundations.
3. Standard form, standard layout and standard materials.
4. Logistics, supply chain management and packaging.

The summary results for options 1 and 2 are presented in Figure 1 below. Waste minimisation solutions for each of the options had already been considered in the Stage B design, the analysis outlines the potential waste saving that will be achieved through adopting these solutions compared to a traditional construction method. Options 3 and 4 are not quantifiable and have been discussed qualitatively within this document.

Engineering design decisions are made for a number of reasons, waste is intuitive in this decision making process as well as driven by the tools provided by BQL through the One Planet Living⁴ sustainability requirements for the site. Hotels have multiple areas providing identical functions e.g. bedrooms and bathrooms, which lend themselves to a standard form and layout, reduced complexity and the use of modern methods of construction and off site construction. These factors have driven the design solutions adopted by the team. Sustainability drivers which influence the design and materials specification for buildings include acoustic, thermal, air-tightness, certified, locally sourced, Green guide rated etc. The design decisions made at Middlehaven have shown that waste minimisation is optimised within the context of these many multiple drivers.

² Stage B Strategic Briefing Preparation of Strategic Brief, as defined by RIBA Plan of work stages

³ Stage C Outline Proposals as defined by RIBA Plan of Works Stages

⁴ One Planet Living is a global initiative based on ten principles of sustainability developed by BioRegional and WWF International www.oneplanetliving.org

	Waste generated	Cost of waste materials	Cost of waste disposal	Embodied carbon of materials and waste	
Traditional construction of elements assessed	4,200 tonnes	£93,600	£366,700	1,950 tonnes	
Waste minimising option	Waste saving	Cost of waste materials saving	Waste disposal cost saving	Embodied carbon saving	Adopted by the project team
1(a) Bathroom pods	45m ³ (90 tonnes)	£13,500	£11,500	23 tonnes	Yes (existing opportunity)
1 (b) Volumetric pods (bed and bathroom)	330m ³ (660 tonnes)	Unknown	£43,250	Unknown	No
1(c) Pre-cast walls and slabs	700 tonnes	£75,500	£45,000	186 tonnes	Yes (existing opportunity)
1 (d) Pre-cast columns	36 tonnes	£4,600	£2,350	13 tonnes	To be investigated at Stage C
2. Foundations	3,850m ³ (2,310 tonnes)	£0	£245,000	3 tonnes	To be investigated at Stage C
Total potential savings⁵	3,140 tonnes	£93,600	£303,900	230 tonnes	
		£397,000			

Figure 1 Summary of the options analysis for the Middlehaven development

Overall the study identified potential for waste savings (through a combination of existing opportunities and opportunities identified during the waste minimisation workshops) of 3,140 tonnes, cost savings of £397,000 and embodied carbon savings of 230 tonnes.

Communications and potential savings across the Middlehaven development

A communications plan and waste minimisation strategy has been developed as a guide for designers in subsequent phases of the Middlehaven development project (residential and commercial units) to adopt waste minimisation solutions in their designs. This document identifies key opportunities and lessons learnt on this project (Appendix 2).

The Middlehaven hotel accounts for approximately 10% of the total works of the development to be carried out by BQL. The other elements of the scheme include residential and mixed use buildings and large areas of public realm. Waste minimisation will be optimised on all of the other scheme elements in the same way that has been seen for the hotel development, due to the approach to sustainability being taken by the developer and design teams. It is not possible to quantify the potential savings across the development as the hotel does not provide a template for the rest of the scheme due to the mixed development types. However it is likely that similar savings could be achieved on each of the future elements using the methodology demonstrated in this study.

⁵ option 1(a) + option 1(c) + option 1(d) + option 2

Lessons learnt

The key lessons learnt on this project are:

1. To be effective, waste minimisation must be an important issue early in options appraisal and the design process of construction projects. Design decisions made at an early stage in the process affect waste production on site.
2. Other factors limiting waste minimisation can be equally if not more important e.g. other sustainability drivers, health & safety, cost, legislative/planning requirements, CO₂ footprint, ongoing maintenance requirements etc.
3. Sustainability, which incorporates resource efficiency, should be a key driver in decision making to ensure waste minimisation is optimised; the carbon impact of transporting pre-cast units long distances, may in some cases outweigh the embodied carbon savings achieved through use of pre-cast units.
4. Waste of time and resources is a bigger cost and risk than waste of construction materials.
5. Waste minimisation of different design options is not easily quantifiable without spending considerable resources on detailed planning of multiple design solutions.
6. Design decisions made at an early stage in the process affect waste production on site.
7. Good planning and logistics minimise over ordering but some is inevitable to prevent unacceptable levels of risk to programme. Strategies should be in place to ensure the highest use for over ordered materials.
8. Modern methods of construction and offsite construction (MMC/OSC) provide a huge opportunity to save both waste and time on construction projects.
9. WRAP guidance on waste minimisation provides a useful document to support designers consider waste minimisation options. A summary checklist of the generic 'long list' of opportunities would be an important tool to ensure effective design team actions.

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Glossary

- BCL BioRegional Consulting Limited
- BQL BioRegional Quintain Limited
- MMC Modern Methods of Construction
- OPL One Planet Living
- OSC Offsite construction
- PC Pre-cast concrete
- PT Post tension
- RC Reinforced concrete
- SPONS Architect’ and Builders’ Price Book 2007 and Civil Engineering and Highway Works Price Book 2007, Davis Langdon
- Stage B Strategic Briefing Preparation of Strategic Brief, as defined by RIBA Plan of Work Stages
- Stage C Out line proposals as defined by RIBA Plan of Works Stages
- WRAP Waste & Resources Action Programme

1.0 Background

WRAP have produced guidance on designing out waste for construction clients, design teams and contractors called 'Achieving effective waste minimisation through design' (WAS004-005). WRAP have commissioned a number of design review projects to assess their guidance document, this report is one of a number of similar reports.

1.1 The Project – The Middlehaven Development

Middlehaven is a 250 acre site at the heart of Middlesbrough's redevelopment programme. The site is centrally located, adjacent to the Middlesbrough railway station in the West and Middlesbrough football ground in the East.



Figure 2 The Middlehaven site.

The proposed 40 acre, £200m regeneration by BQL offers a wide variety of residential accommodation, commercial opportunities and community spaces. It will be constructed over a number of stages, the first two cubed residential blocks comprising of 170 apartment units have been designed and work commenced on site in January 2008.

The next stage of the Middlehaven programme is the development of a hotel that will be operated as part of an international chain. Stage B⁶ of the project was completed in November 2007 and it is anticipated that Stage C⁷, outline design, will commence in March 2008. The proposed hotel comprises:

1. Ground and first floor as public areas including lobby, restaurant, kitchen, meeting rooms and back of house areas.
2. Guest floors based on a typical floor plan of 18 rooms per floor, with each room conforming to the operator brand of a bed room and bathroom.

The proposed Stage B design comprises of the following items:

- piled foundations;
- ground and first floor constructed from a traditional reinforced concrete frame with post tensioned concrete slabs;
- ground and first floor glazed external façade onto public area, block construction used for back of house walls;
- upper hotel floors comprise pre-cast concrete walls and slabs;
- vertical stability achieved through a combination of core and shear walls around the lift and stair areas;
- lift shaft and stairs manufactured from pre-cast concrete; and
- pre-cast concrete flat roof construction.

⁶ Stage B Strategic Briefing Preparation of Strategic Brief, as defined by RIBA Plan of work stages

⁷ Stage C Outline Proposals as defined by RIBA Plan of Works Stages

BQL won the tender to develop the whole Middlehaven site following the sustainability principles of One Planet Living⁸. The ten sustainability principles are outlined in Figure 3. Using the One Planet Living principles a Sustainability Action Plan has been developed, which sets out specific targets for the project.

Zero Carbon	Sustainable Water
Zero Waste	Natural Habitats and Wildlife
Sustainable Transport	Culture and Heritage
Local and Sustainable Materials	Equity and Fair trade
Local and Sustainable Food	Health and Happiness

Figure 3 The ten One Planet Living principles

All of the consultants and contractors working on the project are required to attend a One Planet Living induction and sign up to deliver the targets outlined in the Sustainability Action Plan, as defined in their tender documents. Of particular relevance to this project is the Zero Waste principle, the targets identified under this principle include:

- Construction waste to be less than 15m³ per 100m² floor area and less than 0.2% of construction cost.
- Landscaping levels designed to minimise import/export of soil and fill.
- Landscape design to make innovative use of recycled and reclaimed materials.
- Extensive use of on-site demolition waste.
- Investigate and promote (as appropriate) construction techniques that are efficient in the use of materials.



Figure 4 The Middlehaven site, July 2007 credit BCL

2.0 Project Structure

The project team comprises;

- BioRegional Quintain Limited – Client,
- Buro4 - Project Manager,
- Jestico and Whiles – Architects,
- Martin Stockley Associates –Structural engineers, and
- DSSR – Mechanical and electrical engineers.

⁸ One Planet Living is a global initiative based on ten principles of sustainability developed by BioRegional and WWF International www.oneplanetliving.org

BioRegional Consulting Ltd (BCL) held two waste minimisation workshops (in January 2008) with the project team to discuss options and prioritise opportunities. Between the workshops BCL conducted a period of analysis of potential waste savings for the options presented here.

3.0 Waste minimisation 'long list' opportunities

3.1.1 Design Development Opportunities

During the development of the design it is important to raise the profile of waste, the long list opportunities are:

Middlehaven hotel Opportunity/Issue
<p>Change management:</p> <ul style="list-style-type: none"> ■ The design team plans to identify design freezes in Stage C to enable Off-site Construction (OSC).
<p>Design with existing resources</p> <ul style="list-style-type: none"> ■ Extra capacity has been designed into the Energy Centre for the first two buildings to supply heating to the hotel in the later development stage. This eliminates the need for additional infrastructure. ■ The designs propose using spoil arisings from piles onsite under buildings and hard standing.
<p>Design for site conditions:</p> <ul style="list-style-type: none"> ■ The dockside location enables delivery of large items, such as volumetric pods, by water that may be harder and/or more costly by road. ■ Transporting materials by water results in large carbon savings when compared with transporting them by road.
<p>Putting waste on the agenda:</p> <ul style="list-style-type: none"> ■ This is an exemplar sustainable development following the One Planet Living (OPL) framework and waste has been on the agenda from the start.

3.1.2 Design options

As the project is moving into the outline design stage (RIBA Plan of Works Stage C), many of the design elements are not fixed. However waste is integral to the OPL framework and so many of the minimisation opportunities have already been considered.

Middlehaven hotel Opportunity/Issue
<p>Fundamental design decisions</p> <ul style="list-style-type: none"> ■ Six structural options were considered within an options and issues exercise for Stage B design development. ■ These options were evaluated against a number of criteria including Offsite Construction, the materials used and wastes generated. ■ The criteria were considered collectively and precast concrete (PC) panels were identified as the most suited for this element of the building.
<p>Design complexity</p> <ul style="list-style-type: none"> ■ This was another criterion of the structural options analysis. ■ Precast concrete option was identified as a means of reducing complexity of design.
<p>On site reuse of materials</p> <ul style="list-style-type: none"> ■ There will be no demolition arisings. ■ Opportunity to use recycled aggregates and cement substitutes in concrete.
<p>Standardised form and layout</p> <ul style="list-style-type: none"> ■ The precast guest rooms are of uniform dimension and standardised layout. See MMC below.

Middlehaven hotel Opportunity/Issue

Standardised building materials

- Guest floors – precast concrete panels and structural steel.
- Ground and first floors – insitu concrete floor and columns, concrete blockwork, plasterboard partitions and curtain walling.
- Opportunity to specify the same materials as those used on later stages of the development so that excess materials can be reused.

Modern methods of construction

Considered in Stage B:

- Pre-cast concrete panels – being taken forward;
- Tunnel form – rejected;
- Light Steel Frame – rejected;
- Ship container guest room units – not in keeping with clients brand and considered less sustainable option;
- prefabricated bathroom pods – being taken forward;
- Pre-cast staircases and lift modules - being taken forward.
- pre-cast cladding – being taken forward;

Additional opportunities discussed in the workshop:

- Prefabricated commercial kitchen pod;
- Precast concrete columns;
- Preassembled building services systems;
- Thin joint construction.

Ground works and enabling works

- The site is flat and clear to 1m depth, below which residual contamination exists.
- Innovative piling techniques (e.g. rotary displacement) are being considered to minimise arisings and cost of disposal.

3.1.3 Communication and Procurement

The key to waste reduction is a change in mindset and communication throughout the supply chain. Waste can be reduced through adequate planning and thought throughout the design process.

Middlehaven hotel Opportunity/Issue

Appointments

- BQL puts sustainability 'at the centre' of their operations. Waste minimisation is considered as a part of their standard approach and contractual obligations reflect this.
- All designers and contractors are required to sign up to the OPL framework and have a day of OPL training.
- Waste is one of the ten OPL principles. The Middlehaven Sustainability Action Plan identifies construction waste targets of 15m³ per 100m² floor area and less than 0.2% of construction cost.

Early contractor involvement:

- No contractor appointed as yet. Although contractors and suppliers for the first two buildings could be used to bring lessons learnt into the hotel development and subsequent projects.

Middlehaven hotel Opportunity/Issue

Procurement:

- Opportunity to engage with the supply chain and develop waste minimisation strategies to reduce packaging and excess orders, especially as this is a phased project over a number of years.
- Appropriate delivery and storage times, quantities and methods will be supported by BQL's proposed logistics plan and consolidation yard adjacent to the development site.
- Excess materials can be stored in the warehouse for use on the subsequent phases of the Middlehaven development.

4.0 Revised list of solutions

The long list of options was discussed with the project team in a waste minimisation workshop. A number of specific options were discussed in greater detail and short listed:

1. Modern methods of construction/off site construction (MMC/OSC)
 - a. Bathroom pods.
 - b. Volumetric bed and bathroom pods.
 - c. Pre-cast walls and slabs.
 - d. Pre-cast columns.
2. Foundations.
3. Standard form, standard layout and standard materials.
4. Logistics, supply chain management and packaging.

5.0 Cost benefit analysis

The short listed options were analysed looking at the quantity of waste generated and the cost of that waste including both the disposal cost and the cost of the materials. A comparison has been made between the proposed design options and alternative proposed traditional construction methods to identify the savings that will be achieved through adopting the design options. A cost benefit analysis for options 3 and 4 has not been conducted. Assumptions made are contained in Appendix 1.

5.1 Baseline

Waste will arise from the major elements of the scheme, listed below, the major sources of waste are:

- piling arisings,
- over ordered, broken and wasted materials (applies to all materials used),
- packaging from supplied materials, and
- internal fit out.

The major elements of the scheme and materials that will be used are:

- Reinforced concrete (RC) framework; concrete, reinforcing steel and formwork (where manufactured onsite).
- Deep foundations; reinforced concrete piles and soil arisings.
- Cladding; precast (PC) concrete panels (to be confirmed by the architect in Stage C).
- Internal walls; precast walls, blockwork, or quiet walls (to be confirmed by the architect in Stage C).
- Curtain walling; aluminium frame and glass infill.
- Internal fit out; bathroom pods, carpets, furniture and associated packaging.
- Building services; ducts, piping and mechanical and electrical goods.

The quantities of waste that would be generated if the Middlehaven hotel adopted traditional construction techniques are shown below.

Traditional construction	Waste generated	Cost of waste materials	Cost of waste disposal	Embodied carbon of materials
Traditional bathrooms	90m ³ (180 tonnes)	£13,500	£11,500	780 tonnes
Traditional bedroom	490m ³ (980 tonnes)	Unknown	£62,850	Unknown
RC walls and slabs	700 tonnes	£75,500	£45,000	1100 tonnes
RC columns	36 tonnes	£4,600	£2,350	70 tonnes
Foundations	3,850m ³ (2,300 tonnes)	£0	£3,600 - £245,000	Unknown
Totals	4,200 tonnes	£93,600	£366,700	1,950 tonnes

Figure 5 Sources and quantities of waste generated at the Middlehaven hotel development

5.2 Modern Methods of Construction and Offsite Construction (MMC/OSC)

5.2.1 Bathroom Pods

Each of the hotel rooms will have an integral bathroom. The Stage B design proposes to use bathroom pods, rather than traditional bathroom construction throughout the hotel rooms. Detailed dimensions and layout have not yet been designed at this early project stage.

On construction sites, completion of bathrooms represents one of the most demanding activities in terms of resources, time, skills and risks. On site work in bathrooms is carried out in confined areas and involves different trades that are required to work in sequential order and need to return at different stages. This often results in the generation of high levels of waste. The following waste streams typically arise in construction of bathrooms:

- Packaging.
- Adhesives and sealants.
- Damaged goods.
- Unused and off-cuts tiles and decorative trims.
- Unused grouting materials.
- Unused off-cuts – plumbing and electrical materials.

Pods are small volumetric units that are manufactured in factory controlled environment and made ready for connection to services. The interior of the pods are completely finished and furnished with bathroom appliances and furniture. The design and manufacturing process optimise the use of resources and materials by designing out unnecessary material waste and ensuring an effective and efficient procurement chain. The design capacity and manufacturing planning also enable the factory to order the right quantities of finish materials hence reducing waste of materials and packaging.

The ambient environment conditions on site are not always ideal for the use of adhesives, and often finishes on construction site suffer from hurried applications. The end result is often snagging problems that, when rectified, subsequently increase the waste of the materials and resources.

Manufacturing pods in factory conditions will still generate some waste e.g. through broken tiles, however the quantity of waste is reduced through the controlled factory environment and many generated wastes, such as plasterboard, can be reabsorbed into manufacture of further pods.

A comparison has been made between traditional bathroom construction and the use of volumetric pod units. Figure 6 demonstrates that the cost range for traditional and pod construction is similar.

	Minimum cost / unit	Maximum cost / unit
Volumetric pod, fitted, finished, furnished and installed	£3,700	£4,750
Traditional construction, fitted, finished, furnished and installed	£3,500	£5,900

Figure 6 Cost data for traditional versus pod construction, based on a 4.5m plan area bathroom.

Waste

WRAP research indicates that the use of pods can reduce the amount of waste generated on a conventional site by 50%⁹. Waste stream data⁹ and approximate figures for bathroom sizes were used to estimate the quantities of materials used and hence the waste arising from a traditional bathroom fit out compared with a pod system.

Cost and Waste			
Traditional Bathroom Construction			
Material	Quantity used for bathrooms	Assumed % of waste	Quantity of waste generated
Tiles	36.4m ³	32.5%	11.8m ³
Plaster	7.6m ³	13.5%	1m ³
Plasterboard	173.1m ³	20.5%	35.5m ³
Sanitary ware	840 nr	4%	34nr (13.6m ³)
Doors	168 nr	4%	7nr (0.8m ³)
Packaging		30%	26.9m ³
Total			89.6m³
MMC Pod Bathroom Construction			
Total waste generated		50% of traditional	45m³
Embodied Carbon			
Traditional construction	778 tonnes		
MMC pod	755 tonnes		
Embodied CO₂ saving	23 tonnes		

Figure 7 Waste generated for traditional and pod bathroom constructions

Cost of waste materials traditional construction	£0
Cost of waste materials volumetric pods	£13,500
Cost of waste disposal traditional construction	£11,500
Cost of waste disposal volumetric pods	£5,700
<i>Note: This cost will be included in the total cost for the pod, it will not be paid by the contractor on site</i>	
Cost saving through using pods	£25,000

The analysis demonstrates that pod construction is in the same cost range as traditional bathroom construction and 50% waste saving can be achieved through use of pod construction. This equates to saving 45m³ of waste on this project, with a cost saving of £25,000.

5.2.2 Volumetric bed and bathroom pods

Use of volumetric pod construction for whole rooms (bed and bath), rather than just bathrooms would see further waste designed out of the construction process. These pods would arrive at site with fully finished walls, doors,

⁹Source: WRAP, *Current Practices and future Potential in Modern Methods of Construction*, January 2007

carpets etc. in the bedroom with integral bathroom as described above. Units would have to be craned in place as the construction of the hotel progresses. The advantages of this option are:

- Additional waste minimisation benefits over traditional room construction.
- Constructability, very quick construction time.
- Reduced requirement for skilled labour.
- Uniformity and good quality finish; should be zero defects or snagging.

BQL have set a target to minimise construction waste generated to 15m³/100m² floor area. Figure 8 demonstrates the waste saving that could be achieved through using room pods rather than traditional room construction assuming that the target waste generation rate is achieved.

Item	Quantity	Cost of waste disposal
Total assumed construction waste generation	15m ³ /100m ²	
Hotel room floor area (excluding bathroom)	19.5m ²	
Construction waste generated/room	2.9m ³	
Traditional Construction		
Total waste generated for 168 rooms (excluding bathroom)	491m ³	£62,850
Total waste generated (including bathroom pods)	536m³	
Pod construction		
Total waste generated using a whole room pod (excluding bathroom) ¹⁰	161m ³	£20,600
Total waste generated using a whole room bed and bath pod	206m³	

Figure 8 Waste generated for traditional and pod bed and bathroom constructions

This option has been looked at during the Stage B work, where use of fully furnished shipping containers was considered. It has been discounted for a number of reasons outlined below. Use of more traditional volumetric pods was not assessed however the barriers outlined would also apply.

- Sea transportation to site; the Middlehaven site is on a dock, thus lending itself to transportation of pods to site by sea. However there are several issues with this: to avoid double handling the pod manufacturer must be located by a waterway; to be cost effective would require a large number of units delivered in each load; pods would have to be stored on site and risk damage whilst the construction progressed; the supplier would have to be located close enough that the carbon impact of transporting the pods to site does not outweigh the sustainability benefits of adopting the pod solution. This barrier could be overcome with careful logistics management.
- Design freeze; use of whole room pods would require design freeze at a very early stage in the design process, however the operator would like flexibility in the design process to enable last minute changes to be made. This is not compatible with early design freezes.

The waste disposal cost savings that could be achieved through using whole room pods rather than traditional construction has been calculated to be £43,250, saving 330m³ of waste.

5.2.3 Pre-cast walls and slabs (guest floors)

Pre-casting minimises waste through eliminating the following waste streams:

- Formwork.
- Over ordered wet concrete.
- Re-work through damage, early striking etc.
- Over ordered reinforcing steel.
- Mould oil.
- Screed (cement and cement bags).

Precast (PC) walls and slabs were identified as the preferred option for the guest floors, there are two potential solutions: Crosswall and Twin wall.

¹⁰ 70% of traditional. WRAP, *Current Practices and future Potential in Modern Methods of Construction*, January 2007 states that 70 - 90% waste savings of traditional construction for pod construction

Crosswall construction is a generic system that uses vertically cast division walls (cast off site). Floor slabs span to the load-bearing internal walls effectively leaving the external walls as cladding panels. Expanding foam filler is used to seal joints at the intersections. The crosswall system provides two faces of formwork-cast concrete requiring minimal pre-decoration treatment. Twin wall takes the crosswall system a step further. Both internal and external walls are flat cast offsite using high quality steel moulds enabling direct decoration with paint or paper.

Advantages of PC walls and slabs

1. Quicker installation.
2. Shorter supply chain and less sub contractors involved; eliminates the need for skilled labour such as steel fixers and carpenters.
3. Reduced waste; manufacturing units in a controlled environment practically eliminates waste as the correct quantity of concrete can be used and any additional concrete can be re-used in future concrete mixes.
4. Can generate a high quality of finish, minimising pre-decoration treatment.
5. Good acoustic performance minimises need for additional finishes.

Disadvantages of PC walls and slabs

1. PC units will be heavy and will require a crane to manoeuvre the units in to place.
As with RC solutions, PC floor slabs for the first and second floors would need to be thicker than a PT alternative.

Cost

For comparison the use of a traditional reinforced concrete (RC) structure has been analysed to identify waste and cost savings. The cost data only accounts for direct materials costs, installation costs for the walls has not been included. The installation costs for the two options will be significantly different.

Waste

Total waste materials for in-situ reinforced concrete walls and slabs:	700 tonnes
Cost of waste materials for in-situ reinforced concrete walls and slabs:	£75,500
Total waste for precast walls and slabs:	0 tonnes; £0
Total material waste saving:	700 tonnes
Total material cost saving:	£75,500
Cost of waste disposal for in-situ reinforced concrete walls and slabs:	£45,000
Cost of waste disposal for pre-cast concrete walls and slabs:	£0
Total cost saving for waste (materials + disposal):	£120,500

Carbon

Total material embodied CO ₂ for in situ reinforced concrete retaining walls:	318 tonnes CO ₂
Total material embodied CO ₂ for in situ reinforced concrete floor slabs:	788 tonnes CO ₂
Total material embodied CO ₂ for precast concrete twin walls:	262 tonnes CO ₂
Total material embodied CO ₂ for precast hollow core floor slabs:	658 tonnes CO ₂
Total embodied CO ₂ saving:	186 tonnes CO ₂

The figures for embodied CO₂ are based on 'typical' concrete specifications; BQL will be using concrete with high recycled content (both aggregates and cement substitutes) which will reduce the embodied CO₂ of the concrete. There is no published data available on the embodied CO₂ of high recycled content concrete.

Transport¹¹

Total transport distances for in situ reinforced concrete retaining walls:	2,425 miles
Total transport distances for in situ reinforced concrete floor slabs:	4,274 miles

¹¹ Transport analysis for distance that materials travel between site and supplier or disposal option, not including distance that raw materials travel to supplier. Data from research of local suppliers and disposal options, and average distances from BRE (as published in BioRegionals Carbon Neutral Toolkit).

Total transport distances for precast concrete twin walls:	23,782 miles
Total transport distances for precast hollow core floor slabs:	53,423 miles
Total transport distance premium for precast solution:	70,500 miles
Total transport CO ₂ for precast solution:	-36 tonnes CO ₂

Going forward

The use of pre-cast wall and floor slabs throughout the guest floors will be progressed into Stage C, offering the project a potential waste saving of 254 tonnes of waste, saving £70,800.

5.2.4 Pre-cast columns

The Stage B report incorporated load-bearing cylindrical columns into the designs for the ground, first and second floors. The report identifies these columns to be cast in-situ from reinforced concrete. The potential for a precast solution was raised at the waste minimisation workshop, pre-cast columns, reclaimed steel columns and traditional RC columns will be looked at further Stage C. Advantages and disadvantages of incorporating PC columns are as those outlined in section Pre-cast walls and slabs 5.2.3 above. Additionally:

- Disadvantage – suppliers suggested that factory headroom was a limiting factor for vertical casting cylindrical columns. Rectangular columns may be more readily cast horizontally, using a trowel finish for one face.

The Stage B report identified a mixture of three diameters of cylindrical columns across the three floors – 250mm, 550mm, and 850mm. The location and dimension of each column is dependent on the loadings that the engineers are designing for. Different structural frameworks produce different loadings and require columns of different capacity. The capacity of concrete columns can be increased either by increasing their diameter or by increasing their reinforcement content. The use of post tensioned concrete instead of reinforced concrete or pre-cast concrete slabs could require lower capacity columns, thereby minimising material use and wastage. This exemplifies the effects of design decisions on broader material use and wastage, and shows how this project team are designing the most materially efficient system.

Cost

The cost data only accounts for direct materials costs, installation costs for the walls has not been included. The installation costs for the two options will be significantly different.

Waste

Total materials waste for in-situ reinforced concrete columns:	36 tonnes
Cost of waste materials for in-situ reinforced concrete columns:	£4,600
Total waste for pre-cast concrete columns:	0 tonnes; £0
Total materials waste saving:	36 tonnes
Total materials cost saving:	£4,600
Cost of waste disposal for in-situ reinforced concrete columns:	£2,350
Cost of waste disposal for in-situ reinforced concrete columns:	£0
Total cost saving for waste (materials + disposal):	£6,950

Carbon

Total material embodied CO ₂ for in situ reinforced concrete columns:	70 tonnes CO ₂
Total material embodied CO ₂ for pre-cast concrete columns:	57 tonnes CO ₂
Embodied CO ₂ saving:	13 tonnes CO ₂

Transport

Total transport distances for in situ reinforced concrete columns:	583 miles
Total transport distances for precast concrete columns:	4,136 miles
Total transport distance premium for precast solution:	3,600 miles
Total transport CO ₂ premium for precast solution:	2 tonnes CO ₂

Going Forward

The design team will consider the potential for using precast columns in later development stages as framework solutions and therefore column capacity are determined.

5.3 Foundations

Deep foundations commonly generate significant wastes resulting from ground being removed and replaced with piling. The increasing cost of disposal of contaminated arisings is driving the development of techniques that minimise arisings. Low-level heavy metal contamination exists across the western part of the site and is likely to be a feature of the made ground (2-5m below ground level) upon which the proposed hotel will be built. As a result the design team are actively investigating piling solutions that minimise arisings and the cost of disposal.

Analysis of the remediation works carried out by Harbour and General in 2001 suggests that tie rods and poor quality fill beneath the building footprint prevent the use of a raft foundation. As a result a rotary pile foundation has been identified as the preferred solution. Common rotary piles such as Continuous Flight Auger (CFA) piles result in 100% spoil arisings. Arisings may be reduced to less than 50% per pile through the use of rotary displacement piles. This technique uses a powerful, high torque piling rig to screw a displacement tool into the ground and displace it laterally and downwards. Both methods provide a reinforced concrete solution, which will produce comparable wastes and volumes of over ordered materials for equivalent capacities.

The advantages of using a rotary displacement pile when compared with CFA are:

Advantages

1. Minimising spoil arisings; reduces waste and associated management costs, particularly where contamination persists as in this instance.
2. Effective in soils that are susceptible to 'flighting'¹².
3. Ground displacement results in very high end bearing and shaft friction values from much shorter piles than a CFA design in the same ground conditions.
4. Displacement piles are comparable in terms of time and cost.

Disadvantages

1. Displacement piles currently available are of limited capacity (300 – 600mm) and depth (16 – 18m). Further research and development by UK's principle piling contractors is seeking to address this.
2. Several smaller diameter displacement piles may be required to compete with the higher capacity piles offered by CFA. This is possible when not limited by below ground obstructions and cost competitive, as larger diameter deep piles are disproportionately more expensive. Direct substitution may require additional design changes and should be considered at the earliest stages by design teams.
3. Displacement piles can not be used in combination with CFA piles as differential settlements can lead to different movements. They should only be used on independent structures.
4. Displacement piles are only suited to granular soils and soft clays and silts. They are inappropriate for heavy soils and where thick bands of different soils exist. The bands of granular and clay soils at Middlehaven may preclude the use of certain rotary displacement piles.

Several disposal options exist for contaminated arisings with distinct implications for cost and programme. Where contamination is of limited severity, arisings may be used as fill under hard landscaping or buildings where the contaminants are effectively capped and contained, subject to agreement with the local regulatory authority. Whilst this option doesn't incur any offsite transport, taxes or gate fees, it relies on spare capacity in the cut-fill balance sheet. Alternatively heavy metal contamination can be removed via soil washing and the soil reused in soft landscaping or disposed of as inert waste. This option incurs taxes and gate fees unless the volumes of spoil are sufficient to enable onsite processing, but the end product has wider landscaping applications. Finally, contaminated spoil can be disposed of in a designated hazardous landfill site, incurring significant costs from offsite transport, taxes and gate fees.

Disposal costs are outlined for all three disposal options because wastes can only be accepted at a landfill if they meet the relevant Waste Acceptance Criteria (WAC¹³) for that type of landfill. The cheapest solution will commonly be used.

¹² *The lack of penetration under continuous rotation due to a hard layer or an obstruction can lead to soil flighting up the auger, causing ground loss and settlement.*

¹³ *As set out in Part 3 of the Landfill (England and Wales) (Amendment) Regulations 2004 ([Statutory Instrument No. 1375](#)) as amended by the Landfill (England and Wales) (Amendment) Regulations 2005 ([Statutory Instrument No.1640](#)).*

Cost

A comparison has been made between the cost of displacement and CFA piling systems for the required diameters as specified in the Stage B report. The overall cost for the two schemes is outlined in Figure 9 below. Piling costs include plant, labour and materials; waste disposal costs include all taxes and gate fees. Transport costs are not considered.

	Continuous Flight Auger	Rotary displacement pile
Piling:		
Cost for complete piling solution	£347,250	£283,500
Spoil arisings	3,850 m ³	0 m ³
Disposal option costs:		
1. Hazardous landfill;	£245,227	n/a
2. Soil washing; or	£210,742	n/a
3. Fill under hard landscaping	£3,640	n/a
Total cost (for disposal to hazardous landfill)	£592,500	£283,500

Figure 9 Cost data for continuous flight auger versus rotary displacement piles

The most likely option to be taken by the Middlehaven team is for the arisings to be used as fill under the hard landscaping, this is the lowest cost option. The highest cost option has been used for the comparison in Figure 9.

Carbon

The CFA and rotary displacement solutions addressed in this comparison both result in reinforced concrete piles. Industry communication suggests that to achieve equivalent capacities, the two solutions require equal quantities of concrete and reinforcement, with comparable material embodied CO₂ values. The spoil arisings of CFA piles result in additional carbon emissions relating to their disposal which are addressed in the following transport section.

Transport

Total transport distance for disposal of CFA arisings: 6,390 miles

Total transport CO₂ for disposal of CFA arisings: 3 tonnes CO₂

Going forward

The Stage B design considers the use of CFA piles, however the team is investigating whether it is possible to use displacement piles on this development. Displacement piles were investigated for use in the first two buildings of the development and were not viable due to the soil type below the site.

5.4 Standard form, standard layout and standard materials

Hotels have multiple areas providing identical functions e.g. bedrooms and bathrooms. This presents significant opportunities for the standardisation of form, layout and materials. Such a standardised approach reduces the waste generated by reducing the variety of materials and refining the processes through repetition.

The Middlehaven hotel design has a number of guest floors all based on a typical floor layout. The standardised structural layout favoured an off-site construction solution where repeatability and volume of units made for competitive pricing.

The ground and first floor designs incorporate the greatest variety of materials including in-situ concrete floor and columns, concrete blockwork, plasterboard partitions and curtain walling. Plasterboard commonly forms a significant percentage of construction waste streams through damage and offcuts – around 35% of total waste arisings on high-rise apartment schemes¹⁴. Whilst the floor to ceiling height will not be designed to the standard

¹⁴ WRAP's Current Practices and Future Potential in Modern Methods of Construction

plasterboard sheet dimensions, as the room heights are dictated by the requirements of the hotel operator, off-cuts may be reduced by fixing the sheets horizontally not vertically, the floor heights and specifications will be developed in Stage C.

5.5 Logistics, supply chain management and packaging

The detailed analysis of the previous sections looks at design decisions that influence waste minimisation; designs dictate the choice of construction method which influences the quantity of waste generated. However there is a limit to the amount of waste minimisation that can be achieved through design decisions alone. Site practices also generate waste e.g. through rework, packaging generated from materials delivered to site, materials damaged on site etc.

Whilst site practices cannot be controlled by the design team, documents put together by the design team can still influence site practice e.g. through production of tender documents. At this stage BCL are not aware of exactly how the contract will be tendered, i.e. design and build or traditional build, also whether or not early contractor involvement will be used is at this stage unknown. Regardless of the method of tendering or timing within the project there will still be a requirement to develop tender documents by the design teams, it would be recommended to include the following in the tender documents for the hotel construction:

- Invitation to tender to include a requirement to demonstrate how the contractor will ensure that materials delivered to site have minimum packaging (e.g. through local sourcing, working with supply chain).
- Specification to include a requirement to introduce take back schemes for certain materials e.g. plasterboard (particular materials can be defined following the outline design and quantification of materials used on the project).
- Invitation to tender to include a requirement to demonstrate how the contractor will ensure just in time delivery, secure and safe storage of materials on site, any innovative ways to reduce damage/wastage.
- Designers should be required to provide accurate quantities, provide data/drawings in electronically compatible formats and clear statements of the waste minimisation decisions made and why for contractors to use.

BCL anticipate that the above will be included in the tender documents for the Middlehaven development as part of the sustainability requirements for the development. It is included in this discussion as it could be relevant for future hotel developments of the operators or a similar chain.

BQL are in the fortunate position to have acquired the use of a temporary storage facility in the form of a large (25,000ft²) warehouse, which is due for demolition in later stages of the Middlesbrough redevelopment project (around 2015). This warehouse will be used to store construction materials, in particular reclaimed materials. Successful use of reclaimed materials requires long lead times, this storage facility will ensure that reclaimed materials can be bought when they become available and stored until the appropriate time for use on the project. This may be particularly advantageous for large orders of reclaimed e.g. 100 tonnes of reclaimed timber sleepers, with 50 tonnes required for the first 2 buildings and the rest required for 6th building for example. Reclaimed materials reduce the requirements for new materials and their associated wastes. This warehouse could also be used to store other non-reclaimed materials, using the model of a consolidation/logistics centre developed at Heathrow Terminal 5, although the Middlehaven development is a fraction of the size of an airport terminal. This reduces waste through being able to store generic materials between phases of work e.g. half boxes of light bulbs or plugs. The project team will develop a logistics plan for management and use of the warehouse, during the design process.

A number of elements of the internal fit out of the hotel are stipulated by the operator to fit with their brand. The packaging delivered with these materials cannot be controlled by the design team, however there could be an opportunity for the operator to engage with its suppliers throughout the supply chain for all of their hotels to reduce packaging.

6.0 Action and communications plan

6.1 Project Communications

As outlined in the introduction, BQL require all of their consultants and contractors to sign up to the objectives of One Planet Living, which requires consideration of BQL's 'Zero Waste' plan. This sets out requirements to reduce waste on the construction site through a combination of waste minimisation during design and waste minimisation and management on site. Therefore the project team are set up to deliver a sustainable design that incorporates the principles of waste minimisation tested through this design review.

The design team have agreed that during Stage C they will be investigating the following:

- Ground and first floor slabs - to identify whether or not pre-casting is a viable option.
- Columns – to investigate which is the most viable RC, PC, reclaimed steel.
- Piling – to assess the viability of using displacement piles.
- Design freezes - particularly for the use of bathroom pods.

The project team is committed to continuing to develop their designs through Stage C using the outline proposals that they have developed for Stage B. These commitments demonstrate adopting best practice waste minimisation solutions. There is no additional cost to the design team in terms of personnel, as a result of this design review as the designs are already considering waste minimisation.

6.2 Middlehaven Development Communications

BCL have developed a roll out document to disseminate the lessons learnt through this design review process to the wider Middlehaven development project teams. This document is provided in Appendix 2 and should be distributed as a communications package with the exemplar case study.

The design proposals for Middlehaven are based on solutions that minimise waste. If more traditional solutions had been adopted 3,140 tonnes of waste could have been generated costing £397,500 to buy and dispose of.

The Middlehaven hotel accounts for approximately 10% of the total works of the development to be carried out by BQL. The other elements of the scheme include residential and mixed use buildings and large areas of public realm. Waste minimisation will be optimised on all of the other scheme elements in the same way that has been seen for the hotel development, due to the approach to sustainability being taken by the developer and design teams. It is not possible to quantify the potential savings across the development as the hotel does not provide a template for the rest of the scheme due to the mixed development types.

7.0 Constraints to adoption

The main barrier to adopting waste minimisation solutions was that design decisions were made for reasons other than to minimise waste. It was noted that a number of low waste solutions have been identified at this early stage of the project and it is anticipated that they will be developed into detailed designs as the project progresses. The following table identifies additional options proposed which need further consideration or have been discounted and the reasons.

Option proposed	Constraint to option
Volumetric room pods	Logistics of transporting wide loads on roads. The operator requires flexibility in the designs until late in the programme preventing the necessary design freeze.
Kitchen pods	Logistics of installing large industrial kitchen elements into the building. Project timing requiring protection of expensive kitchen units throughout the build. Large unit would require delivery in sections which introduces a hygiene issue.
Design freeze	The operator requires flexibility in their design process, educating them regarding the benefits of design freezes may help to overcome this issue
Use of post tensioned slabs	Overall saving on materials as post tensioned slabs are thinner.

Figure 10 Constraints to options assessed and reasons they cannot be taken forward

This project has demonstrated that hotels provide the opportunity to incorporate many of modern methods of construction techniques as the structure contains small repeatable units. Where possible these low waste solutions have been adopted.

8.0 Conclusions

8.1 Key opportunities and benefits

A long list of waste minimisation opportunities was developed specific to the Middlehaven scheme based on WRAP guidance document WAS004-005 'Achieving effective waste minimisation through design'. These options were analysed for their applicability to this project. From the long list, four options were identified for short listing for further discussion and analysis:

1. Modern methods of construction/off site construction (MMC/OSC)
 - a. Bathroom pods.
 - b. Volumetric bed and bathroom pods.
 - c. Pre-cast lifts and stairs.
 - d. Pre-cast walls and slabs.
 - e. Pre-cast columns.
2. Foundations.
3. Standard form, standard layout and standard materials.
4. Logistics, supply chain management and packaging.

The summary results for options 1 and 2 are presented in Figure 11 below. Waste minimisation solutions for each of the options had already been considered in the Stage B design, the analysis outlines the potential waste saving that will be achieved through adopting these solutions compared to a traditional construction method. Options 3 and 4 are not quantifiable and have been discussed qualitatively within this document.

	Waste generated	Cost of waste materials	Cost of waste disposal	Embodied carbon of materials and waste	
Traditional construction	4,200 tonnes	£93,600	£366,700	1,950 tonnes	
Waste minimising option	Waste saving	Cost of waste materials saving	Waste disposal cost saving	Embodied carbon saving	Adopted by the project team
1(a) Bathroom pods	45m ³ (90 tonnes)	£13,500	£11,500	23 tonnes	Yes (existing opportunity)
1 (b) Volumetric pods (bed and bathroom)	330m ³ (660 tonnes)	Unknown	£43,250	Unknown	No
1(d) Pre-cast walls and slabs	700 tonnes	£75,500	£45,000	186 tonnes	Yes (existing opportunity)
1 (e) Pre-cast columns	36 tonnes	£4,600	£2,350	13 tonnes	To be investigated at Stage C
2. Foundations	3,850m ³ (2,310 tonnes)	£0	£245,000	3 tonnes	To be investigated at Stage C
Total potential savings¹⁵	3,140 tonnes	£93,600	£303,900	230 tonnes	
		£397,000			

Figure 11 Summary of the options analysis for the Middlehaven development

Engineering design decisions are made for a number of reasons, waste is intuitive in this decision making process as well as driven by the tools provided by BQL through the One Planet Living¹⁶ sustainability requirements for the

¹⁵ option 1(a) + option 1(d) + option 1(e) + option 2

¹⁶ One Planet Living is a global initiative based on ten principles of sustainability developed by BioRegional and WWF International www.oneplanetliving.org

site. Hotels have multiple areas providing identical functions e.g. bedrooms and bathrooms, which lend themselves to a standard form and layout, reduced complexity and the use of modern methods of construction and off site construction. This has driven the design solutions adopted by the team. Sustainability drivers which influence the design and materials specification for buildings include acoustic, thermal, air-tightness, certified, locally sourced, Green guide rated etc. The design decisions made at Middlehaven have shown that waste minimisation is optimised within the context of these many multiple drivers.

Overall the study identified potential for waste savings (through a combination of existing opportunities and opportunities identified during the waste minimisation workshops) of 3,140 tonnes, cost savings of £397,000 and embodied carbon savings of 230 tonnes.

8.2 Communications and potential savings across the Middlehaven development

A communications plan and waste minimisation strategy has been developed as a guide for designers in subsequent phases of the Middlehaven development project (residential and commercial units) to adopt waste minimisation solutions in their designs. This document identifies key opportunities and lessons learnt on this project.

The Middlehaven hotel accounts for approximately 10% of the total works of the development to be carried out by BQL. The other elements of the scheme include residential and mixed use buildings and large areas of public realm. Waste minimisation will be optimised on all of the other scheme elements in the same way that has been seen for the hotel development, due to the approach to sustainability being taken by the developer and design teams. It is not possible to quantify the potential savings as the other elements of the scheme are for very different types of work. However it is likely that similar savings could be achieved on each of the future elements using the methodology demonstrated in this study.

8.3 Lessons learnt

The key lessons learnt on this project are:

1. To be effective, waste minimisation must be an important issue early in options appraisal and the design process of construction projects. Design decisions made at an early stage in the process affect waste production on site.
2. Other factors limiting waste minimisation can be equally if not more important e.g. other sustainability drivers, health & safety, cost, legislative/planning requirements, CO₂ footprint, ongoing maintenance requirements etc.
3. Sustainability, which incorporates resource efficiency, should be a key driver in decision making to ensure waste minimisation is optimised; the carbon impact of transporting pre-cast units long distances, may in some cases outweigh the embodied carbon savings achieved through the use of pre-cast units.
4. Waste of time and resources is a bigger cost and risk than waste of construction materials.
5. Waste minimisation of different design options is not easily quantifiable without spending considerable resources on detailed planning of multiple design solutions.
6. Design decisions made at an early stage in the process affect waste production on site.
7. Good planning and logistics minimise over ordering but some is inevitable to prevent unacceptable levels of risk to programme. Strategies should be in place to ensure the highest use for over ordered materials.
8. Modern methods of construction and offsite construction (MMC/OSC) provide a huge opportunity to save both waste and time on construction projects.
9. WRAP guidance on waste minimisation provides a useful document to support designers consider waste minimisation options. A summary checklist of the generic 'long list' of opportunities would be an important tool to ensure effective design team actions.

9.0 Bibliography

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- Designing to encourage waste minimisation in the construction industry, A Keys, A Bladwin and S Austin, CIBSE
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- Setting a requirement for waste minimisation, WRAP
- The Small Environmental Guide for Construction Workers, SEPA and CIRIA
- Spon's civil engineering and highway works price book, 2007
- A guide to modern methods of construction, NHBC Foundation
- Modern methods of house construction, A surveyors guide, BRE Trust
- Demonstrating waste minimisation benefits in construction, CIRIA, 2001

Appendix 1 Assumptions

The main assumptions used to obtain the results shown in Figure 4 were:

- Timber formwork to in-situ concrete walls; 12mm thick plywood re-used 4 times before being landfilled¹⁷.
- Wastage; minimum 2.5%, maximum 5%¹⁸ for concrete and reinforcement.
- Over ordering of 10% on all materials¹⁹.
- Waste reduction and disposal looks at industry standard practice.

Sources of waste excluded from the calculations

Waste generated has been calculated only for the concrete framework, piling, bedroom pods and bathroom pods, the remainder of the hotel construction has not been assessed in this study for the following reasons:

- Identified options were considered to demonstrate best practice waste minimisation for design.
- Insufficient data available to quantify packaging waste or waste arising from fit out.
- The design was sufficiently advanced in the areas considered to make a reasonable assessment of waste savings. The designs in other areas such as external cladding, internal fit out, building services etc have not been sufficiently advanced during Stage B to make an assessment about the waste arisings.

Cost Analyses Assumptions

Cost has been based on the proposed structural drawings of the Stage B report received on 23 January 2008 and the architects drawings received on 5 November 2007. These are scale drawings with dimensional details provided.

Cost data has been obtained from SPONS²⁰ where materials prices 'include the cost of any ancillary materials, nails screws, waste etc., which may be needed in association with the main material products'.

Where SPONS data is not available, cost data has been obtained from suppliers. Quotes given provide materials cost data enabling a comparison of materials. Labour and plant costs are unknown and therefore no cost comparison has been made for these. It should be noted that offsite construction often reduces onsite labour and plant costs and incorporation of these costs are likely to affect a total cost comparison.

Landfill tax costs are based on the 2007 Budget figures for the year commencing April 2008 when the standard rate will increase by £8 to £34 per tonne and the rate for inert waste will increase by 50p to £2.50.

Waste Analyses Assumptions

Quantities of waste generated on site have been calculated for the following:

- Wastage; considered minimum 2.5% – maximum 5% (Concrete, bricks, formwork)²¹
- Over ordering; minimum 5% to maximum 10% (concrete, steel, formwork)²²
- Formwork; all formwork used on site is waste, assumed to be timber, each formwork is used 4 times²³

Industry standard waste management practices on site have been used to calculate the baseline waste disposal costs, with proposed Middlehaven waste management practices have been included for comparison. The proposed Middlehaven approach will include segregated skips for recycling materials and the re-use of materials on site where possible. The cost of waste materials accounts for both the over ordered and wasted material.

Carbon Analyses Assumptions

¹⁷ *Spens Architects and Builders Price Book, 2007, Davis Langdon*

¹⁸ *Spens Civil Engineers and Highway Works Price Book 2007, Davis Langdon*

¹⁹ *Typical practice for over ordering on construction project is 10%*

²⁰ *SPONS' Architects' and Builders' Price Book 2007 and SPONS' Civil Engineering and Highway Works Price Book 2007*

²¹ *Wastage rates assumed in SPONS' Civil Engineering and Highway Works Price Book, 2007, Davis Langdon*

²² *Birse contractors, who worked on the parallel Environment Agency project, stated that 10% over ordering is typical practice and that they are striving to reduce this to 5%*

²³ *Based on assumptions used in SPONS' Architects' and Builders' Price Book 2007*

Embodied carbon has been calculated for the construction materials and waste disposal based on data from the University of Bath²⁴. Plant, personnel and portakabins have not been included in the calculations as the carbon impacts are based on the time that the project is on site, which at this stage is unknown.

The embodied CO₂ of concrete can be reduced through the inclusion of recycled aggregates and cement substitution. BQL's concrete specification will include high percentages of both thereby reducing their embodied CO₂ and any associated savings below baseline concrete figures. Base line figures are still used in the calculations because exact percentages are not known and to provide a better comparison to industry standard operation.

Transport Analyses Assumptions

Transport of materials from the supplier to the site has been assessed. No assessment of transport of raw materials to suppliers has been made as there was insufficient data available. It has been assumed that all deliveries are made by road and the total distance travelled by the lorry is for a return journey to the supplier. A carbon emissions factor of 0.0003174tCO₂/km has been assumed for the total distances.

²⁴ *Inventory of Carbon and Energy version 1.5 Beta, University of Bath, 2006*

Appendix 2 Middlehaven communications roll out strategy

Waste Minimisation Strategy for the Middlehaven Development

This document has been developed following the design review for waste minimisation case study conducted by BioRegional Consulting Ltd on behalf of WRAP for the hotel as part of the Middlehaven development.

This document is provided for use by the design teams working on subsequent phases of the Middlehaven development.

Key Objectives

- Provide a **waste minimisation framework** for the project development process.
- Provide design teams with a list of **key waste minimisation opportunities** specifically for the remaining buildings of the Middlehaven development.
- Outline the **lessons learnt** through the BCL study that are relevant to the later stages of Middlehaven development.
- Provide design teams with a **checklist** for waste minimisation opportunities.

The design review of the Middlehaven hotel demonstrated that the potential to save 3,140 tonnes of waste saving £400,000 to the project and also saving 230 tonnes of embodied CO₂ compared to a traditional construction has been adopted by the design team through their design. The hotel lends itself well to adopting certain waste minimisation techniques such as reduced design complexity, repeatability and modern methods of construction. However the design review process has identified key lessons learnt that are applicable to the residential and commercial elements of the remainder of the Middlehaven scheme. However it is likely that similar savings could be achieved on each of the future elements using the methodology demonstrated in this study.

Waste minimisation framework

The following are suggestions for introducing a rigorous approach to addressing waste minimisation throughout project development. These recommendations are made in addition to the existing project requirements to deliver Zero Waste defined in the One Planet Living Sustainability Action Plan.

1. Waste minimisation workshops

Suggested times to have a workshop specifically regarding waste minimisation opportunities in design would be at the beginning of Stage B and the middle of Stage C. Early identification of waste minimisation opportunities offers the greatest potential for waste savings. It also ensures that designs do not become fixed into a higher waste option (e.g. choice of piling technique is required early in the project as it dictates superstructure design)

2. Waste minimisation checklist

Using the quick wins identified below and the waste minimisation checklist at the end of this document design teams can identify low waste options during their design development process.

3. Waste minimisation in tender documents

Whilst site practices cannot be controlled by the design team, documents put together by the design team can still influence site practice e.g. through production of tender documents. At this stage BCL are not aware of exactly how the contracts will be tendered, i.e. design and build, traditional build etc. Regardless of the method of tendering or timing within the project there will still be a requirement to develop tender documents by the design teams, it would be recommended to include the following in the tender documents:

- Invitation to tender to include a requirement to demonstrate how the contractor will ensure that materials delivered to site have minimum packaging (e.g. through local sourcing, working with supply chain)
- Specification to include a requirement to introduce take back schemes for certain materials (particular materials can be defined following the outline design and quantification of materials used on the project).
- Invitation to tender to include a requirement to demonstrate how the contractor will ensure just in time delivery, secure and safe storage of materials on site, any innovative ways to reduce damage/wastage.

BCL anticipate that the above will be included in the tender documents for the Middlehaven development as part of the sustainability requirements for the development. It is included in this discussion as it could be relevant for other similar developments.

Key waste minimisation opportunities

The following provide a key opportunity to save waste for the remaining buildings on the Middlehaven development.

1. Bathroom pods

Pods are small volumetric units that are manufactured in factory controlled environment and made ready for connection to services. The interior of the pods are completely finished and furnished with bathroom appliances and furniture. The design and manufacturing process optimise the use of resources and materials by designing out unnecessary material waste and ensuring an effective and efficient procurement chain. The design capacity and manufacturing planning also enable the factory to order the right quantities of finish materials hence reducing waste of materials and packaging.

Potential waste saving²⁵: 500kg / pod

Potential carbon saving: 150 kg / pod

2. Kitchen pods and volumetric pods

Similar to bathroom pods, small kitchen pods for apartment units would be manufactured similarly to bathroom pods. The potential waste savings are likely to be higher, as the sources and quantities of waste arising in kitchens are higher than bathrooms.

3. Displacement piles

Deep foundations commonly generate significant wastes resulting from ground being removed and replaced with piling. The increasing cost of disposal of contaminated arisings is driving the development of techniques that minimise arisings.

Common rotary piles such as Continuous Flight Auger (CFA) piles result in 100% spoil arisings. Arisings may be reduced to less than 50% per pile through the use of rotary displacement piles. This technique uses a powerful, high torque piling rig to screw a displacement tool into the ground and displace it laterally and downwards.

Displacement piles currently available are of limited capacity (300 – 600mm) and depth. Several smaller diameter displacement piles may be required to compete with the higher capacity piles offered by CFA. This requires consideration of the piling technique at the earliest stage in the project, as the capacity and location of piles determines the design of the superstructure.

Potential waste saving through using displacement piles rather than CFA:	100%
Potential carbon saving through using displacement piles rather than CFA:	1 tonne / 1,000m ³ from eliminating the need to dispose of waste

4. Pre-cast elements

Where concrete elements are considered in the design, designers should investigate the possibility of using pre-cast rather than cast in situ. Pre-casting has the following advantages:

- Quicker installation
- Shorter supply chain less sub contractors involved, eliminates the need for steel fixers and carpenters
- Reduced waste; manufacturing units in a controlled environment practically eliminates waste as the correct quantity of concrete can be used and any additional concrete can be re-used in future concrete mixes

Some examples of pre-cast elements that may be relevant throughout the Middlehaven development include slabs, walls, stairs, lift wells etc.

5. Facades

Numerous pre-cast cladding and façade solutions are available on the market, use of pre-cast elements saves time and minimises waste. It is possible to develop an interesting façade with pre-cast units.

²⁵ Savings based on 4.5m² plan area pod

Lessons Learnt

1. To be effective, waste minimisation must be an important issue early in options appraisal and the design process of construction projects. Design decisions made at an early stage in the process affect waste production on site.
2. Other factors limiting waste minimisation can be equally if not more important e.g. other sustainability drivers, health & safety, cost, legislative/planning requirements, CO₂ footprint, ongoing maintenance requirements etc.
3. Sustainability, which incorporates resource efficiency, should be a key driver in decision making to ensure waste minimisation is optimised; the carbon impact of transporting pre-cast units long distances, may in some cases outweigh the carbon savings achieved through use of pre-cast units.
4. Waste of time and resources is a bigger cost and risk than waste of construction materials.
5. Waste minimisation of different design options is not easily quantifiable without spending considerable resources on detailed planning of multiple solutions.
6. Design decisions made at an early stage in the process affect waste production on site.
7. Good planning and logistics minimise over ordering but some is inevitable to prevent unacceptable levels of risk to programme. Strategies should be in place to ensure the highest use for over ordered materials.
8. Modern methods of construction and offsite construction (MMC/OSC) provide a huge opportunity to save both waste and time on construction projects.
9. WRAP guidance on waste minimisation provides a useful document to support designers consider waste minimisation options. A summary checklist of the generic 'long list' of opportunities would be an important tool to ensure effective design team actions.

Design team check list adapted from WRAP's 'Achieving effective waste minimisation through design'

Design team issue	Action required	Date completed
Brief		
Is the design team clear about the priority of waste in the project?	<i>Communicate the output from the Client team checklist to the design team</i>	
Is the concept of designing out waste clearly understood?	<i>Appoint design waste champion to raise profile and understanding</i>	
Design and review		
How can the outline design and construction process be made more efficient?	<i>Carry out design team review and workshop</i>	
What are the consequences of these actions?	<i>Review all implications (time, cost etc) and other impacts before adopting</i>	
What type and volume of waste materials will be produced in the project?	<i>Create materials list and matrix to identify expected levels of waste</i>	
What are the reasons for each waste stream?	<i>Record in materials matrix; consider ways of reducing waste</i>	
Is there a better method or material for each job?	<i>Review design and hold workshop</i>	
How can the requirement for onsite cutting be reduced?	<i>Consider alternatives to site cutting. Review Section 6 of WRAP Quick Win Design Solutions</i>	
How can the design be simplified, or repeatability and standardisation emphasised (e.g. for dimensions, elements, details and material types and grades)?	<i>Carry out design review. Review Sections 7 and 8 of WRAP Quick Win Design Solutions</i>	
Can the following specific design solutions be incorporated; offsite construction (e.g. pre-cast elements, room pods etc.), onsite reuse of materials?	<i>Carry out design review</i>	
Coordination and communication		
Has the design been reviewed by other stakeholders to detect potential clashes, problems and issues?	<i>Identify time and resources for review and workshop activities</i>	
Can alternatives be provided by contractors, subcontractors, suppliers or manufacturers?	<i>Consult construction industry</i>	
How can the construction materials or sequence be changed to minimise the risk of damage, abortive work and reworking?	<i>Carry out design review. Review Section 6 and 7 of WRAP Quick Win Design Solutions</i>	

Written by: Jonny Miller and Liz Darley, BioRegional Consulting Ltd

BioRegional

BioRegional Consulting

**Waste & Resources
Action Programme**

The Old Academy
21 Horse Fair
Banbury, Oxon
OX16 0AH

Tel: 01295 819 900
Fax: 01295 819 911
E-mail: info@wrap.org.uk

Helpline freephone
0808 100 2040

www.wrap.org.uk/construction

