Whole Life Costings Case Studies

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1. Introduction

The London Bridge Station Redevelopment (LBSR), part of the £7bn Thameslink Programme (TLP), involved the complete transformation of the station to meet growing transport needs. The LBSR Sustainable Delivery Statement (N420-COT-STM-EM-000001) set out the way sustainability was to be achieved on the LBSR Project and includes specific objectives from the TLP Sustainability Strategy. This contributed to sustainability being a driving factor throughout the design and construction of the LBSR.

This document relates specifically to **Objective 13** of the LBSR Sustainable Delivery Statement:

- **To understand the whole life cost (WLC) implications of project and purchasing decisions.**
  - Target: *Identify opportunities for ten WLC studies across the TLP covering high impact and/or priority processes and materials.*

To assist with achieving this objective, the LBSR assessed the WLC of the following five key LBSR elements:

1. Geothermal Piles and Heat Pump
2. Escalators
3. Lifts
4. Photovoltaic Cells
5. Platform and Concourse Lighting

The WLC case studies for the above LBSR Project elements are presented in this document. Each WLC study presents a discussion of:

- The options investigated
- The savings (monetary and carbon) and/or other benefits
- Key assumptions used for the WLC assessments (see Section 7)

These WLC case studies also address **Objective 15** of the TLP Sustainable Delivery Statement:

- **Minimise the use of natural resources, water and carbon while increasing the life of materials and avoiding the generation of waste.**
  - Target: *To deliver energy and carbon reductions in line with project targets and to monitor and report progress in line with the TLP carbon policy.*

The carbon reduction measures described in this document (that were implemented), along with other energy efficiency measures that are were incorporated into the station design, resulted in the achievement of the 20% CO₂e emissions reduction (from renewable energy sources) target set by Network Rail for the redeveloped operational station.

The associated Best Practices for the WLC case studies (where generated) are found in Section 8 of this document – all the Sustainability Best Practices generated by the LBSR Project can be found in the following document: N420-COT-REP-MD-000153.
2. Geothermal Piles and Heat Pump

Background:
In May 2012, a design for placing geothermal loops into the structural piles at London Bridge Station was approved. It estimated that the energy piles would deliver heating and cooling via a plate frame heat exchanger interfacing with the main condenser loop running through commercial properties to provide significant energy savings and saving approximately 77 tonnes of CO$_2$ annually. By 2015, geothermal loops were successfully installed within 180no piles. A review and assessment of the original proposal and the effects of recent changes to condenser maximum and minimum temperature on ground loop temperatures was undertaken. This presented a further design opportunity which demonstrated how the installed system, as originally designed, could deliver significant additional cost and CO$_2$ savings with the addition of a heat pump that would enable the piles to provide either heating or cooling to the main condenser loop regardless of the ground loop temperature. Refer to Best Practice document in Section 8 for more information.

WLC Assessment:
Original Design (no heat pump) v’s Addition of the Heat Pump

<table>
<thead>
<tr>
<th>Element</th>
<th>Installation cost</th>
<th>Maintenance cost for 20 years (Silver Plan)</th>
<th>Annual delivered energy (kWh)</th>
<th>Annual emissions savings (tCO2e)</th>
<th>Annual operational cost savings (energy)</th>
<th>Payback period for installation costs using operational cost savings</th>
<th>Payback period for installation and maintenance costs using operational cost savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>£500,000</td>
<td>£102,000</td>
<td>500,924</td>
<td>90.0</td>
<td>£14,000</td>
<td>35.7 years</td>
<td>43 years</td>
</tr>
<tr>
<td>B</td>
<td>Additional £125,695</td>
<td>Additional £18,000</td>
<td>Additional 394,076</td>
<td>Additional 36.24</td>
<td>Additional £5,000 plus £24,000 RHI = £29,000</td>
<td>4.3 years (additional heat pump costs only)</td>
<td>5.0 years (additional heat pump costs only)</td>
</tr>
<tr>
<td>Combined</td>
<td>Geothermal Piles &amp; Heat Pump plus RHI</td>
<td>£625,695</td>
<td>£120,000</td>
<td>895,000</td>
<td>£43,000</td>
<td>12.8 years</td>
<td>15.2 years</td>
</tr>
</tbody>
</table>

Renewable Heat Incentive (RHI):
The installation of the heat pump has provided Network Rail with an opportunity to claim the Renewable Heat Incentive (RHI), worth approx. £24,000 per annum for 20 years (index linked). For more information regarding the RHI, visit [https://www.ofgem.gov.uk/environmental-programmes/non-domestic-rhi](https://www.ofgem.gov.uk/environmental-programmes/non-domestic-rhi).

Summary:
The WLC demonstrated the heat pump was critical to the sustainability business case for not only the addition of the heat pump, but of the whole system and is reliant on Network Rail successfully applying for the RHI – a first for Network Rail.
Whole Life Costings Case Studies

3. Escalators

Background:
Once fully operational, London Bridge Station will see over 190,000 passengers passing through the main concourse on a daily basis. To assist with passenger movement, 24 new escalators will be installed in the main concourse. Conventional escalators running constantly are costly and carbon intensive. Therefore, to reduce the energy output of the operational station and to minimise its carbon emissions, LBSR procured escalators that are more efficient and provide cost savings year on year – the Kone TransitMaster 140 with ‘Stop & Go and Stand-by-Speed’ technology. This technology detects when the escalator is about to be used, providing on-demand starting. In addition, the escalators automatically switch to a reduced speed once no passenger traffic is detected and completely switch off after a further period of no passenger traffic. Refer to the Best Practice document contained in Section 8 for more information.

WLC Assessment:
Standard Escalators v’s Kone TransitMaster 140 Escalators:
The savings and benefits that resulted were calculated by using the assumption of 24 ‘Stop & Go and Stand-by-Speed’ escalators being used for 20 hours per day, seven days a week for one year. The figures were compared against a standard Kone TransitMaster escalator without the pre-determined ‘Stop & Go and Stand-by-Speed’ options.

<table>
<thead>
<tr>
<th>Escalators Type</th>
<th>Installation cost (x24 escalators)</th>
<th>Annual energy consumption (kWh) (x24 escalators)</th>
<th>Annual operational costs (energy) (x24 escalators)</th>
<th>Annual emissions (tCO2e) (x24 escalators)</th>
<th>Payback period for additional installation cost of Option A using operational cost savings of Option A</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Stop &amp; Go / Standby Speed</td>
<td>£4,597,983</td>
<td>2,664,528</td>
<td>£362,376</td>
<td>1,327.94</td>
<td></td>
</tr>
<tr>
<td>B Standard TransitMaster 140</td>
<td>£4,561,983</td>
<td>2,736,720</td>
<td>£372,192</td>
<td>1,364.40</td>
<td></td>
</tr>
<tr>
<td>Difference = A - B</td>
<td>£36,000</td>
<td>-72,192</td>
<td>-£9,816</td>
<td>-36.46</td>
<td>3.7 years</td>
</tr>
</tbody>
</table>

Summary:
Although the 24 ‘Stop & Go and Stand-by-Speed’ escalators being installed at LBSR will cost approximately £36,000 extra to install, they will achieve a year on year annual operational saving of over 36 tonnes of CO₂e and savings of close to £10,000 in operational costs. Based on this, the 24 ‘Stop & Go and Stand-by-Speed’ escalators will have a payback period of less than four years.
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4. Lifts

Background:
The redeveloped London Bridge Station has achieved complete step-free access between the concourse and platforms by installing ten lifts across the station (eight passenger and two goods lifts). LBSR investigated the benefits and costs of two types of lifts: machine-less room lifts (MRL’s) and hydraulic lifts.

A true energy and carbon analysis is dependent on lift usage – this data was not available at time of this WLC assessment. However, reported data indicates MRL’s are more energy efficient on half and full loads and in standby mode – energy savings of up to 40% have been reported through use of MRL’s compared to hydraulic lifts. However, hydraulic lifts are reported to be more energy efficient with small loads.

Other comparisons: Hydraulic lifts occupy more space as they require a machine room with ventilation and the lift load going through the pit floor. MRL’s require less space as they do not require a machine room and the lift load is through the shaft structure.

WLC Assessment:
MRL’s v’s Hydraulic Lifts

As no data was available for a true energy analysis, the energy calculator available on the following website was used to generate energy and carbon comparisons between 10x MRL’s and 10x hydraulic lifts: https://www.thyssenkruppelevator.com/Tools/energy-calculator

Cost data is taken from the commercial assessment undertaken by LBSR.

<table>
<thead>
<tr>
<th>Lift Type</th>
<th>Installation costs</th>
<th>Annual maintenance costs</th>
<th>Annual energy consumption (kWh)</th>
<th>Annual operational costs (energy consumption)</th>
<th>Annual emissions (tCO2e)</th>
<th>Payback period for additional installation costs of MRLs using operational cost savings of MRLs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A MRL</td>
<td>£1,742,637</td>
<td>£460,800</td>
<td>214,130</td>
<td>£17,000</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td>B Hydraulic</td>
<td>£1,675,637</td>
<td>£460,800</td>
<td>412,000</td>
<td>£25,540</td>
<td>11.7</td>
<td></td>
</tr>
<tr>
<td>Difference = A - B</td>
<td>£67,230</td>
<td>£0</td>
<td>-197,870</td>
<td>-£8,540</td>
<td>-3.9</td>
<td>7.9 years</td>
</tr>
</tbody>
</table>

Summary:
Overall, MRL’s have higher installation costs but have the potential to achieve energy and carbon savings. Based on this, the MRL’s have a potential payback period of just under eight years. However, LBSR made the decision to install hydraulic lifts based on recommendations from supplying companies, lift engineer specialists and Network Rail (i.e. local Network Rail maintenance contract was set up to service hydraulic lifts only and it was not commercially viable to set up a separate contract for a maintenance regime at London Bridge only).
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5. Photovoltaic Cells

Background:
All of the platform canopies of the redeveloped London Bridge Station extend to the end of the platforms, meaning that there is a high surface area of canopy roof. Therefore, LBSR investigated the potential to install photovoltaic (PV) cells (solar panels) on the canopy roofs in order to generate electricity for the operational station.

Due to the Shard creating a shadow over the western platform canopies, the installation of PV cells was not considered beyond the 45° angle from north to south. Therefore, the area of viable canopy capable of accommodating PV cells, taking into account space for access and other equipment, was 2,590m², equating to a rating of 133 kW peak.

WLC Assessment:

<table>
<thead>
<tr>
<th>PV cell area</th>
<th>Installation costs</th>
<th>Annual operating costs</th>
<th>Annual energy savings (kWh)</th>
<th>Annual operating savings (energy savings)</th>
<th>Annual emissions savings (tCO2e)</th>
<th>Payback period for installation costs using operational cost savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,590m²</td>
<td>£1,205,826</td>
<td>£2,800</td>
<td>107,000</td>
<td>£28,000</td>
<td>44.1</td>
<td>43.1 years</td>
</tr>
</tbody>
</table>

Summary:
The carbon savings that would be achieved through use of the PV cells renewable energy source equates to an overall CO2e emissions reduction of approximately 2% (from the redeveloped operational station). This 2% reduction falls short of the 6% reduction target required to be achieved by the PV cells in order to meet the overall 20% CO2e emissions reduction (from renewable energy sources) target set by Network Rail for the redeveloped operational station.

To achieve the 6% CO2e reduction, PV cells would need to cover around 12,090 m² of the roof canopy (noting, energy generated per m² is reduced because the additional panels would not be located in the optimum orientation).

Therefore, it was decided that PV cells would not be installed due to financial constraints (no economic payback) and technical constraints, including space issues and lightning protection issues. In addition, inclusion of PV cells and lightning protection equipment in the design would require an addendum to the planning consent as both were not included in the approved planning consent.
6. Platform and Concourse Lighting

Background:
Lighting is crucial for the functioning of the redeveloped London Bridge Station, both up on the platforms and on the street level concourse. Therefore, LBSR carried out analysis of different lighting options to assess which would be the most effective at delivering the required lighting requirements plus provide cost and energy efficiencies. Options for using energy efficient light emitting diode (LED) lighting were explored for both the platforms and the street level concourse – these options were compared against traditional lighting options (e.g. fluorescent and metal halide lighting).

WLC Assessment:
Platform Lighting: LED v Fluorescent

<table>
<thead>
<tr>
<th>Platform Lighting</th>
<th>Installation costs</th>
<th>Annual maintenance costs</th>
<th>Annual energy consumption (kWh)</th>
<th>Annual energy costs</th>
<th>Annual emissions (tCO2e)</th>
<th>Payback period for additional LED installation costs using LED energy cost savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>A LED</td>
<td>£703,625</td>
<td>£86,700</td>
<td>672,790</td>
<td>£47,396</td>
<td>366.71</td>
<td></td>
</tr>
<tr>
<td>B Fluorescent</td>
<td>£424,001</td>
<td>£52,968</td>
<td>995,108</td>
<td>£89,253</td>
<td>552.08</td>
<td></td>
</tr>
<tr>
<td>Difference = A - B</td>
<td>£279,624</td>
<td>£33,732</td>
<td>-322,318</td>
<td>£41,857</td>
<td>185.37</td>
<td></td>
</tr>
</tbody>
</table>

Street Level Concourse Lighting: LED v Metal Halide

<table>
<thead>
<tr>
<th>Street Level Concourse Lighting</th>
<th>Installation costs</th>
<th>Annual maintenance costs</th>
<th>Annual energy consumption (kWh)</th>
<th>Annual energy costs</th>
<th>Annual emissions (tCO2e)</th>
<th>Payback period</th>
</tr>
</thead>
<tbody>
<tr>
<td>A LED</td>
<td>£196,175</td>
<td>£30,780</td>
<td>796,845</td>
<td>£28,836</td>
<td>377.08</td>
<td>N/A, LED option is the more cost and energy effective option</td>
</tr>
<tr>
<td>B Metal Halide</td>
<td>£202,475</td>
<td>£74,720</td>
<td>892,652</td>
<td>£49,608</td>
<td>424.99</td>
<td></td>
</tr>
<tr>
<td>Difference = A - B</td>
<td>-6,300</td>
<td>-43,940</td>
<td>-95,806</td>
<td>-£20,772</td>
<td>-47.90</td>
<td></td>
</tr>
</tbody>
</table>

Summary:
For the platform lighting, LEDs were assessed as being more expensive than fluorescent lighting to install and maintain, but LEDs were assessed as being more energy efficient – and hence, lower operating costs (associated with energy consumption) and carbon emissions. Based on this, the payback period for LED lighting is just under seven years. For the street level concourse, LED lighting was assessed as being the more cost effective (including installation, maintenance and energy usage costs) and carbon efficient option compared to metal halide lighting.

As a result, LED lighting was installed in the vast majority of the station concourse, platforms and some of the back of house areas.
7. WLC Assessments Key Assumptions

Note: The underlying calculations used for the WLC assessments are contained within the Sustainable Delivery Statement Target Tracker (N420-COT-REG-EN-000004). Key assumptions are provided below for reference.

Geothermal Piles and Heat Pump:
Geothermal piles and heat pump installation and maintenance cost data provided by suppliers (GI Energy) and/or project Commercial Team.

Other key assumptions:
- RHI available for 20 years and indexed at 2%
- Service life of system of 20 years
- Maintenance costs based on Silver Package as quoted by GI Energy in 2016
- Annual emissions and cost savings based on electricity not required to be purchased/used

Escalators:
Escalator installation and maintenance cost data provided by suppliers (KONE) and/or project Commercial Team.

Energy and carbon data provided in ‘Escalator Energy Calculation Report: London Bridge Station Redevelopment’ (KONE, 2nd July 2015 – Stephen Normington, Escalator Product Manager, KONE Plc.). Key assumptions:
- Average person weight: 75 kg
- Operational hours: 20 hours
- Operational days: 7 days/week

Other key assumptions:
- £0.136 per kWh
- Stop & Go escalator payback period calculated by following calculation: Additional installation cost associated with Stop & Go escalators (compared to standard escalators) / Annual operational savings associated with Stop & Go escalators (compared to standard escalator)
### Key Assumptions Continued

#### Lifts:
Lift installation and maintenance cost data provided by suppliers (Stannah) and/or project Commercial Team.

Energy and carbon data not available so this data was derived using the following online calculator using the assumptions below: [https://www.thyssenkruppenlevator.com/Tools/energy-calculator](https://www.thyssenkruppenlevator.com/Tools/energy-calculator)

- Compared hydraulic lift (dry) with a traction MRL (non-regenerating)
- 10 lifts of 3,500 lb capacity travelling at 50 feet/minute and servicing one floor of an office building
- £0.062 per kWh
- 67 movements per hour or 800 movements per day

Other key assumptions:
- Annual maintenance costs include required inspections and proactive maintenance programme
- MRL payback period calculated by following calculation: Additional installation costs associated with MRL's (compared to hydraulic lifts) / Annual operational cost savings associated with MRL's (compared to hydraulic lifts)

#### Photovoltaic Cells:
Most data provided by Meike Borchers of WSP, including system installation and maintenance costs (email to Hannah Rich dated 30\(^{th}\) January 2013). Key assumptions:

- Annual operating costs associated with cleaning the PV cells and other minor maintenance activities
- Annual energy savings based on saved energy not imported from the grid (£0.13 per kWh) and payment made by UK Government Feed in Tariff (FiT) scheme (£0.129 per kWh generated up to 250 kW peak and £0.085 above 250 kW peak)

Other key assumptions:
- Annual emissions saving calculated using a carbon factor of 0.41205 kgCO₂e/kWh
- Payback period calculated by following calculation: Installation cost / Annual operating savings

#### Platform and Concourse Lighting:
Lighting installation and maintenance cost data provided by suppliers and/or project Commercial Team.


Other key assumptions:
- See Appendix 1 of above mentioned GRIP 5 Energy Statement for detailed assumptions, including number of lights and required lighting power densities for each station area.
Whole Life Costings Case Studies

8. Best Practices

1. Geothermal Piling
2. Designing in Sustainability — Kone Escalators
LONDON BRIDGE BEST PRACTICE

Geothermal Piling

Overview

The London Bridge Redevelopment Project has an aspiration to provide CO₂ savings of 77 tonnes per year. Heating and cooling the newly designed station would be highly carbon intensive if regular temperature control methods were used. Such methods would create a barrier to the reduction target specified. Therefore, London Bridge collaborated with GI Energy to implement an innovative technology into the project. Working together, the companies identified installing geothermal loops into 145 of the planned piles, with routing arrangements to the proposed plant room in order to achieve the specified CO₂ saving.

require pile foundations. These offer the lowest total cost and the highest renewable contribution combined with low spatial requirements.

The geothermal pile system at London Bridge is designed to provide a peak heat rejection load of 200kWt and heat extraction of 100kWt using 145 geothermal piles. This will produce a maximum temperature of 44°C from piles with a depth of 25 metres. The current calculations for the geothermal pile system suggest that the aspiration of a CO₂ saving of 77 tonnes per year will be exceeded.

<table>
<thead>
<tr>
<th></th>
<th>Delivered kWh</th>
<th>Consumed kWh (pumps)</th>
<th>CO₂ savings (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>100,000</td>
<td>11,122</td>
<td>18</td>
</tr>
<tr>
<td>Cooling</td>
<td>440,000</td>
<td>27,878</td>
<td>61</td>
</tr>
<tr>
<td>Total</td>
<td>540,000</td>
<td>39,000</td>
<td>79</td>
</tr>
</tbody>
</table>

Geothermal piles provide long term benefits despite higher initial investment costs. The project have carried out whole life cost exercises on the piles which indicate that this form of heating and cooling has lower running and life cycle costs and over time will reap cost saving advantages. It has been estimated that the lifecycle financial operating benefit will be around £41,000.

Benefits:

- Provides a continuous, reliable, sustainable and clean energy source
- Reduces dependence on fossil fuels
- Reduced whole life cost due to low operating and maintenance charges
- The cost of geothermal energy is not prone to the fluctuations often experienced when reliant on gas or electricity
- Allows the London Bridge development scheme to meet the aspiration of a CO₂ saving of 77 tonnes

Objectives and Targets:

- London Bridge Sustainability Delivery Statement – minimise the levels of carbon generated over the whole life of TLP; understand the whole life cost implications of project and purchasing decisions; identify opportunities to proof the rail network against climate change; reduce the cost of delivery of TLP
- CEEQUAL – energy and carbon

The Solution: Geothermal Piles

The geothermal piles installed consist of pile foundations combined with 2 closed-loop ground source heat pump systems which span the length of the pile. Their purpose is to deliver support to the building at the same time as acting as a heat source in winter and a heat sink in the summer. They are able to do this by using the earth’s natural heat which is collected through the loops which is carried by a heat transfer fluid to a unit in the station building.

When constructing the piles, the soil is bored out of the ground and a rigid, welded reinforcement cage is inserted into the hole. Two close-ended loops made of high density polyethylene plastic with an external diameter of 32mm are then fixed evenly around the inside of the reinforcement cage, spanning the full depth of the pile.

Geothermal energy can be considered a clean and environmentally friendly energy source. It produces minimal greenhouse gas emissions because the conversion and utilisation processes do not involve any chemical reactions, such as combustion. It is also classified as both renewable and sustainable. Geothermal piles are becoming increasingly attractive to city developers as larger developments already tend to

For more information contact trevor.sharp@lbstation.co.uk or verity.avery@lbstation.co.uk October 2014
London Bridge Best Practice

Case Study Title: Designing in Sustainability - Kone Escalators

Month/Year: April 2016

Key Benefits

- Energy and Carbon savings throughout the operational phase of London Bridge Station;
  - Annual operational cost saving of over £9,000
  - Annual reduction in maintenance costs
- Payback period of just 4 years

Objectives and Targets

- Objective 15 – minimising levels of carbon generated over the whole life of TLP
- CEEQUAL – Design for Resource Efficiency, Whole Life Approach

Overview

Once fully operational London Bridge Station will see over 190,000* passengers passing through the new street level main concourse during AM and PM peaks, Monday to Friday. To accommodate such a high capacity ped flow 24 escalators were required to connect the concourse to the high level platforms. Having 24 standard escalators running constantly would have proven costly and would use vast amounts of energy. However, in line with the TLP’s Sustainability Strategy target to reduce energy output of the operational station and to minimise its carbon emissions, the London Bridge Station Redevelopment team sought out and procured escalators that are designed to be more energy efficient and provide cost savings year on year.

Sustainable Solution – ‘Stop & Go’ technology

The KONE TransitMaster escalators procured by the project are designed with a ‘Stop & Go and Stand-by Speed’ mechanism. This mechanism detects when the escalator is about to be used and provides on-demand starting. This system can sense passenger movement within 1.3m distance from the end of the escalator to which it will start to run in its pre-set direction.

After 10 seconds of ‘no passenger traffic’ the escalator automatically switches to stand-by mode which operates at a reduced speed and thus a reduced energy demand. After another 10 seconds with ‘no passenger traffic’, the escalator will completely stop. This cycle will continue to repeat depending on passenger flow.

This Stop & Go mechanism saves energy and cost both through reducing energy demand and the avoidance of additional maintenance costs that you would need from the additional wear and tear you see from a non-stop escalator.

Saving Energy and Carbon

An energy performance study of the Stop & Go escalators was carried out. This study took the assumption of one Stop & Go escalator being used for 20 hours per day, 7 days a week for 1 year. This was compared against a standard TransitMaster KONE escalator without the pre-determined Stop & Go options.

The study concluded that overall, one Stop & Go escalator uses up to 111 022 kWh/year of energy. When compared against the standard TransitMaster, this produced a saving of 3008 kWh, equating to a carbon saving of 1519 kgCO_{2}e.

In total, the 24 escalator being installed at London Bridge will achieve an annual operational saving of 36.46 tonnes of CO_{2}e and over £9,000 in operational costs year on year generating a payback period of only 4 years.

*Please note this figure is based on current pedflow predictions for modelling purposes