Transport for London

Rotherhithe to Canary Wharf River Crossing

Option Assessment Report- Long List

Date: January 2017
Version: Draft

CONTENTS

Executive summary

Context

1. Transport for London (TfL) is investigating the feasibility of providing a new walking and cycling crossing of the River Thames between Rotherhithe and Canary Wharf.
2. This project is one of a number of new river crossings for London which are intended to improve cross-river connectivity. These crossings consist of public transport, highway, pedestrian and cycle links.
3. This proposal seeks to increase travel by sustainable modes, improve the health of Londoners and support economic development. Growth in cycling across London, employment growth in Canary Wharf, and population growth due to new residential and mixed use development particularly at Canada Water are generating an increase in travel demand in the area. With the Jubilee line close to capacity at peak times and the lack of appropriate or sufficient infrastructure to accommodate cyclists and pedestrians wishing to cross the river east of Tower Bridge, there is a strong case to consider a crossing to cater for this demand.
4. The project objectives are:
    - To connect the two Opportunity Areas of Canada Water and the Isle of Dogs
    - To improve connectivity from the Rotherhithe peninsula, particularly the area beyond the walking catchment of Canada Water station
    - To encourage more people to walk and cycle in the area
    - To provide additional capacity and routes for cyclists as an alternative option to existing crossings in the area
    - To produce a well designed and convenient link which achieves value for money and is fundable
    - To provide an alternative link to the Jubilee line between Canada Water and Canary Wharf.
5. This Option Assessment Report- Long List should be read in conjunction with the 'Assessment of Need and Statement of Objectives', which reviews the issues which have been cited in support of a new crossing in this area, and explains the project objectives listed above.

Option shortlisting

6. The purpose of this Option Assessment Report (OAR) – Long List is to outline and assess options, and document any decisions made to identify a Short List of crossing options.
7. Table ES 1 presents the results of the assessment of the Long List options and the decision making behind the selection of the Short List of crossing options.
8. The Short List of options will then be assessed in more detail in a subsequent Option Assessment Report including further modelling, engineering and environmental assessments. The Option Assessment Report- Short List will inform the Strategic Outline Business Case.

Table ES 1 Results of Long List Assessment

Option	Description and rationale for inclusion
Navigable Bridge	This option appears to best meet the project objectives of the options considered, while also meeting the critical design requirements. There are alternative means of building a navigable bridge; the bascule and swing bridges may be the most appropriate options to test navigable bridges in greater depth in the next phase of work, although other structural solutions could also be considered in the design phase.
Immersed Tunnel	A tunnel could also meet the project objectives well, although most likely at a higher cost than a bridge. Of the two tunnel types considered, an immersed one appears to be the most feasible tunnelling technique at this location as it can be delivered at a lower cost than a bored tunnel option. Moreover, an immersed tunnel method can provide a horizontal box cross section which offers more efficient space than a bored tunnel and can be placed closer to the surface.
Enhanced Ferry	An enhanced passenger ferry service could include Pier upgrades, improved access points, roll-on / roll-off cycle friendly vessels and an increased frequency. This option meets the project objectives, be it less strongly than the bridge or tunnel options given the need for cyclists to dismount, the constricted capacity and the non-permanency of the infrastructure. However, this option would be considerably cheaper and faster to implement.

1. Introduction

Context

1.1. Transport for London (TfL) is investigating the feasibility of providing a new walking and cycling crossing of the River Thames between Rotherhithe and Canary Wharf.

1.2. This project is one of a number of new river crossings for London which are intended to improve cross-river connectivity in London. These crossings consist of public transport, highway, pedestrian and cycle links to improve access to jobs, facilitate business activity, support housing development, enhance the resilience of the transport network and encourage more sustainable travel.

1.3. An idea of a river crossing in this area first emerged around a decade ago, under plans to develop Greenways for the 2012 Olympic and Paralympic Games. Work previously led by Sustrans, with funding from TfL and other organisations, resulted in a series of feasibility studies:

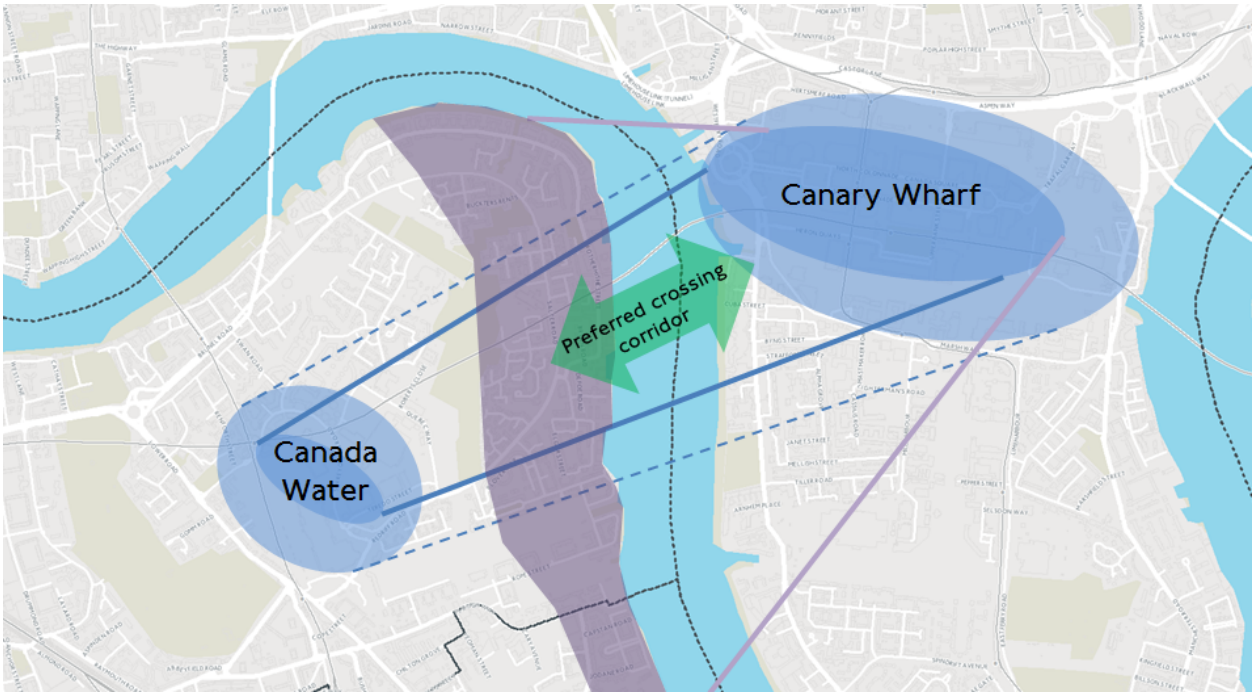
- A Preliminary report – Ramboll Whitby Bird, November 2006
- An Outline Economic Appraisal – Colin Buchanan, March 2007
- A Technical Feasibility Study – Ramboll Whitby Bird, March 2008
- A Demand Forecast report– Colin Buchanan, September 2008
- A Feasibility Study- Sustrans, February 2016.

1.4. Studies undertaken by Sustrans (a sustainable travel charity) concluded that a walking and cycling bridge at Canary Wharf to Rotherhithe would be both economically and technically viable. Relevant outputs from these studies are referenced within this document.

1.5. The work undertaken by Sustrans has informed, but is not part of, the current TfL work; the Mayor, through TfL, has independently reviewed the need and options for a crossing in this area.

1.6. Figure 1-1 below shows the proposed location of the crossing, as identified in the 'Assessment of Need and Statement of Objectives'.

Figure 1-1 Proposed Rotherhithe to Canary Wharf river crossing



1.7. Also outlined in the 'Assessment of Need and Statement of Objectives' are a number of factors, which combined, make it appropriate for the case for this scheme to be considered by TfL:

- Both the Isle of Dogs and Canada Water on the Rotherhithe peninsula are designated as Opportunity Areas where significant housing and employment growth is anticipated in the coming years. The number of employees based at Canary Wharf is planned to increase from 115,000 to around 200,000 over the next 15 years, while over the same period around 4,000 new homes are planned at Canada Water.
- Moreover, significant cycling growth has taken place in central London. Improvements to cycling access and capacity are required if this growth is to be supported, particularly for employees living in south London, for whom the options for crossing the Thames onto the Isle of Dogs (to access Canary Wharf) are limited.
- The section of the Jubilee line between Canada Water and Canary Wharf is increasingly crowded in the peaks, but there are no convenient alternative options for travelling at surface level due to the positon of these growth areas on peninsulas of the Thames. This congestion is forecast to remain even after the opening of the Elizabeth line (Crossrail). Improving the accessibility of the Rotherhithe peninsula for walking and cycling would provide more existing and future residents of the area with an active travel option.

1.8. Because of the issues outlined above, the Mayor has asked TfL to assess a crossing as a priority.

Project objectives

1.9. The project objectives are described in more detail in the 'Assessment of Need and Statement of Objectives' document. They are:

- To connect the two Opportunity Areas of Canada Water and the Isle of Dogs

- To improve connectivity from the Rotherhithe peninsula, particularly the area beyond the walking catchment of Canada Water station
- To encourage more people to walk and cycle in the area
- To provide additional capacity and routes for cyclists as an alternative option to existing crossings in the area
- To produce a well designed and convenient link which achieves value for money and is fundable
- To provide an alternative link to the Jubilee line between Canada Water and Canary Wharf.

Critical design requirements

1.10. While the project objectives set out what the project is seeking to achieve, there are also some critical requirements which the project needs to meet in order to be feasible; in essence, however well in theory an option meets the objectives, can it in reality be constructed given the physical constraints.

1.11. The list of requirements will grow as the project progresses into more detailed stages. Many of these could impact on the deliverability of the project, but the ability of an option to meet some of these requirements is difficult to ascertain at this stage in some cases without a design or mitigation strategy in place (for example, mitigation of any impacts on public open space will be critical, but cannot easily be assessed until there is a design and the impacts and mitigations are known). Hence a more detailed set of requirements will be developed as the project progresses to ensure that at the design stage all the requirements are met.

1.12. However some requirements are fundamental, and can be assessed, at least at a high level, at an early stage. If an option cannot meet these critical requirements, it will not be feasible and cannot be pursued.

1.13. The critical design requirements are presently:

- to meet the river navigational requirements, because without doing so it will not be possible to gain consent for the project; and
- the alignment is technically feasible taking into account the land and property constraints.

Stakeholder engagement

1.14. TfL has so far involved a number of key stakeholder organisations in the development of proposals for a new river crossing. This includes the affected local authorities, Port of London Authority (PLA), Canary Wharf Group (CWG), British Land, JP Morgan, and the Canal and River Trust.

1.15. Some public engagement has been undertaken (such as the presentation of the concept to community groups) but this has as yet been on a limited scale, given the early stage of the appraisal process. More stakeholder and community engagement will be needed to progress the project further, particularly with local residents living in the areas affected.

1.16. A Stakeholder Engagement Plan will be produced to outline the identified stakeholders and recommended engagement approach.

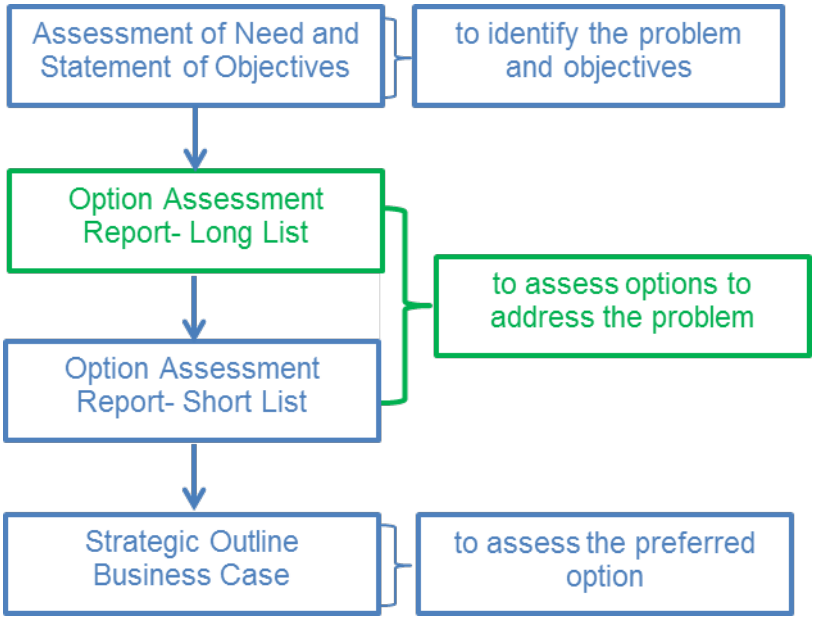
Scope of this report

1.17. This Option Assessment Report- Long List should be read in conjunction with the 'Assessment of Need and Statement of Objectives', which outlines in more detail the need and case for a crossing at this location.

1.18. The purpose of this Option Assessment Report (OAR) – Long List is to outline and assess options, and document any decisions made to identify a Short List of crossing options.

1.19. The Short List of options will then be considered in more detail in a subsequent Option Assessment Report including further modelling, engineering and environmental assessments. The Option Assessment Report- Short List will then inform the Strategic Outline Business Case.

Figure 1-2 Suite of documents



Structure

1.20. The remainder of this report will be structured as follows:

- Chapter 2 of this report describes potential crossing locations and alignment constraints (including previous feasibility work);
- Chapter 3 assesses the Long List of crossing options; and
- Chapter 4 of this report presents the conclusion, outlining the rationale for the selection of Short List of crossing options.

2. Location, constraints and user requirements

Preferred corridor

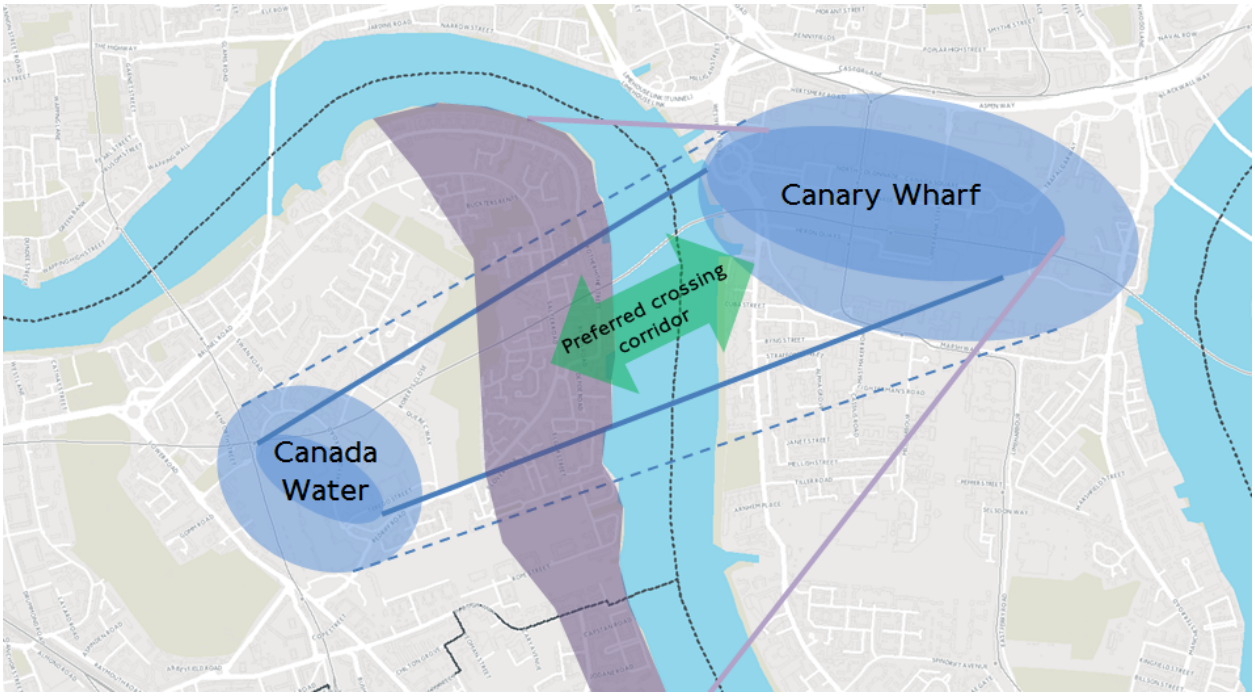
2.1. The 'Assessment of Need and Statement of Objectives' has helped to define a preferred corridor along which any new link should ideally be provided.

2.2. Firstly, it is important to provide a crossing which lies on, or very close to, the central axis of demand between the two centres of Canada Water and Canary Wharf, if it is to successfully attract new journeys between them (which may otherwise have been undertaken by Underground; journeys on foot in particular, and also by bicycle, are very sensitive to distance).

2.3. In addition, to address the poor public transport accessibility on the eastern side of the Rotherhithe peninsula, a crossing should link the area of low connectivity on the southern bank to the core urban area and transport nodes, on the northern bank.

2.4. Figure 2-1 below illustrates the core urban centres of Canada Water and Canary Wharf (in blue), and the area of poor accessibility (in purple), and indicates the corridor between them which would minimise the walking distance between the core urban areas on each bank while serving the area of poor connectivity.

Figure 2-1 Preferred crossing corridor



2.5. Corridors outside this broad alignment are unlikely to successfully meet the project's key aims of connecting these two centres.

2.6. Identification of the prefered corridor is described in more detail in the 'Assessment of Need and Statement of Objectives'.

Alignment constraints

2.7. The precise alignment options will vary by option, as the technical constraints vary between, for example, bridge and tunnel options.

2.8. Several local factors and impacts that need to be taken into account include property, environment, access to the walking and cycling network, infrastructure (e.g. Jubilee line tunnels below), and open space. As such, large parts of the riverside in the study area have constraints on one side, or the other, or both.

2.9. Some of the most important constraints which affect all or most options are summarised below; constraints specific to particular options are described under that option in the following section.

River navigation

2.10. A critical constraint for a new crossing is the safeguarding of the navigational channel for shipping.

2.11. There is a right of navigation on the Thames, and it is the duty of the Port of London Authority (PLA) to safeguard this right. Downstream of London Bridge this includes safeguarding passage for large ships, including cruise ships, naval ships, tall ships and large yachts, which currently travel as far upstream as the Upper Pool of London, alongside HMS Belfast.

2.12. The largest vessels passing through this part of the river tend to be cruise ships, which berth in the Pool of London. While the very largest cruise ships cannot be accommodated in central London, the ships are still of a considerable size. The Silver Cloud, for example, is 155.8 metres in length (see Figure 2-2).

Figure 2-2 Silver Cloud alongside HMS Belfast

2.13. The size of these ships determines the construction of any permanent structure in the river, for example the possible spans between bridge piers, as they would need to allow for the safe passage of large ships, taking into account the tides, currents, weather conditions, and allowing for potential human or technical errors in navigating around the Thames.

2.14. In terms of the necessary height clearance, while cruise ships are large, for example the Silver Cloud has an air draft (height above the water line) of 36 metres, this part of the Thames is also still visited by sailing ships, or "tall ships".

2.15. In its open position, Tower Bridge as a clearance of 42 metres above Mean High Water Springs (MHWS). Meanwhile the Queen Elizabeth II Bridge at Dartford has a clearance of 54 metres (also at MHWS).

2.16. The Polish sailing ship Dar M•odzie•y has visited the Thames and has an air draft of 49.5 metres (see Figure 2-3).

Figure 2-3 Tall Ship passing under Tower Bridge

2.17. The centre of the River Thames has a designated navigational channel which is kept clear of obstructions for the passage of ships. A 15m exclusion zone either side of this navigable channel should be maintained for safety reasons. Any structures (including ship impact protection) should be outside of these sections of the river.

Jubilee line tunnels

2.18. The Jubilee line passes under the river in close proximity to the proposed location. Restrictions exist for construction of a number of these crossing options (namely bridges and tunnels) close to the existing tunnel alignment; TfL has advised that there is a strong preference for all structures within the river to be outside a 30m clearance of the Jubilee line tunnels. The closer to the tunnels, the greater the challenges and risks, and the higher the cost of construction.

Environment

2.19. The River Thames is a sensitive environmental site, particularly in terms of its aquatic ecology and historic environment (with a number of listed structures in the study area). Additionally, the close proximity of a large number of residents is a factor for consideration, given the potential visual and noise impacts. The environmental impacts will be discussed in further detail in the subsequent Option Assessment Report- Short List.

User requirements

2.20. The following factors should be considered to ensure any crossing option selected encourages walking and cycling. TfL outline the '5Cs' of good walking networks, although these factors are also largely applicable to cycling networks.

The '5Cs' of Good Walking Networks[1]

- Connected: Walking routes should connect each area with other areas and with key 'attractors' such as public transport stops, schools, work, and leisure destinations. Routes should connect at the local and district level, forming a comprehensive network.
- Convivial: Walking routes and public spaces should be pleasant to use, allowing social interaction between people, including other road users. They should be safe and inviting, with diversity of activity and continuous interest at ground floor level.
- Conspicuous: Routes should be clear and legible, if necessary with the help of signposting and waymarking. Street names and property numbers should be comprehensively provided.
- Comfortable: Walking should be enjoyed through high quality pavement surfaces, attractive landscape design and architecture, and as much freedom as possible from the noise and fumes and harassment arising from proximity to motor traffic. Opportunities for rest and shelter should be provided.
- Convenient: Routes should be direct, and designed for the convenience of those on foot, not those in vehicles. This should apply to all users, including those whose mobility is impaired. Road crossing opportunities should be provided as of right, located in relation to desire lines.

Other factors

2.21. The following factors are also identified within government guidance :

- A crossing free of charge is preferable to users. Individuals' 'willingness to pay' for travel time savings will vary considerably, depending on factors like income, journey purpose and urgency, and the comfort and attractiveness of the journey[2];
- A crossing where dismount if not required is preferable to cyclists i.e. unrestricted travel via a ramp is preferable to having to dismount and wait for a lift. There is consistent evidence that people will pay more to save walking and waiting time than they will for an equivalent saving in in-vehicle/transit time. Typically, a factor of 2.5 for time spent waiting for public transport and by 2 for

[1] http://content.tfl.gov.uk/tfl-improving-walkability.pdf

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/313222/webtag-tag-unit-a1-3-user-and-provider-impacts.pdf

time spent accessing or interchanging between modes of transport by walking or cycling can be applied to represent the inconvenience experienced[2]; and

- A crossing option which is unrestricted is preferable to users. Travellers are sensitive to the consequences of travel time variability, such as prolonged waiting times, missed connections and arrival at the destination either before or after the desired or expected arrival time[2].

3. Long List of crossing options

3.1. This section looks at the potential crossing options, summarising the feasibility of each option and assessing how well each option performs against the scheme objectives and critical design requirements.

Assessment criteria

3.2. The long list of options has been assessed against a range of criteria:

- project objectives
- critical design requirements
- other considerations

Fit with project objectives

3.3. Each of the Long List of crossing options against the project objectives. A three level rating has been applied:

- ü ü Achieves the project objective
- ü Partially achieves the project objective
- û Does not achieve the project objective.

Fit with critical design requirements

3.4. While the project objectives set out what the project is seeking to achieve, there are also some critical design requirements which the project needs to meet in order to be successful; in essence, however well in theory an option meets the objectives, can it in reality be constructed given the physical constraints. If an option cannot meet these critical design requirements, it is not feasible and cannot be pursued, and therefore an option is deemed to pass or fail.

3.5. These are:

- to meet the river navigational requirements, because without doing so it will not be possible to gain consent for the project; and
- the alignment is technically feasible taking into account the land and property constraints.

Other considerations

3.6. In addition to the project objectives and requirements, there are other factors which need to be taken into account at an early stage. These could potentially be factors which make an option unfeasible, for example an option may achieve the functionality desired in the objectives, and be physically feasible to build, but have unacceptable environmental impacts.

3.7. Commentary is given on these other considerations:

- Environmental impacts;
- Constructability;
- Land and property.

Long list options

3.8. The crossing options considered are:

- New non-navigable bridge (low-level fixed bridge)
- New navigable bridge (moveable or high level)
- New bored or mined tunnel
- New immersed tunnel
- New cable car
- Enhanced ferry.

Do Nothing

3.9. The crossing options are considered relative to a 'Do Nothing' scenario comprising the likely future transport networks in the study area, and predicted population and employment growth in the future without any new or improved crossing.

3.10. The assessment in the Option Assessment Report- Short List will quantify the differences between a 'Do Nothing' scenario and the Short List of options.

New non-navigable bridge (low-level fixed bridge)

3.11. A new low-level fixed bridge would be the first type of crossing considered over most waterways, providing a convenient crossing structure available to users at all times of the day.

Figure 3-1 A low-level non-navigable bridge concept

3.12. At this location on a navigable river, a fixed low-level bridge would require the closure of the Pool of London to ships, and many smaller vessels with masts; this would impact upon cruise ships, war ships, tall ships, Thames barges, and many smaller yachts and boats, where their use of the Thames is protected in law. Additionally, HMS Belfast would need to be removed from the Pool of London, and tall ships events would no longer be able to visit central London.

3.13. Closure of the Pool of London to shipping would be strongly opposed by those directly affected, such as cruise operators, St Katherine Docks, owners and operators of vessels which moor or visit the Thames, and those industries such as tourism which depend on those visits or events.

3.14. Moreover, such a major departure would need to be approved by the PLA, which is responsible for safeguarding the legal right of navigation on the Thames. Given the impacts of closing this section of the Thames to shipping, the PLA could not support a measure which impinged so greatly on the right of navigation.

ASSESSMENT: Non-navigable bridge		
FIT WITH THE PROJECT OBJECTIVES		
To connect the two Opportunity Areas of Canada Water and the Isle of Dogs	ü ü **Achieved**	Would provide a high quality connection between the two opportunity areas
To improve connectivity from the Rotherhithe peninsula, particularly the area beyond the walking catchment of Canada Water station	ü ü **Achieved**	Would bring the eastern side of the peninsula within walking distance of Canary Wharf
To encourage more people to walk and cycle in the area	ü ü **Achieved**	Much greater accessibility for pedestrian and cycle trips likely to encourage more local trips on foot or cycle
To provide additional capacity and routes for cyclists as an alternative option to existing crossings in the area	ü ü **Achieved**	Compared with existing routes a fixed low level bridge would provide significant new capacity to cross between Canary Wharf and south London by cycle
To produce a well designed and convenient link which achieves value for money and is fundable	ü ü **Achieved**	A fixed bridge would provide a direct, safe and pleasant form of crossing to users. It would be a low cost option compared with a tunnelled option (although more expensive then an enhanced ferry service)
To provide an alternative link to the Jubilee line between Canada Water and Canary Wharf	ü ü **Achieved**	A new bridge would provide an alternative means of travelling between the Canada Water and Canary Wharf areas
FIT WITH THE CRITICAL DESIGN REQUIREMENTS		
Meets the river navigational requirements	û **FAIL**	A bridge which does not allow shipping past this point would not meet the navigational requirements and would not achieve a River Works Licence from the PLA
A technically feasible alignment has been identified	ü **PASS**	
OTHER CONSIDERATIONS		
Environmental issues	A low-level fixed bridge is likely to impact on the river bed and foreshore, and aquatic ecology but consideration will need to be taken with regard to appropriate planning and mitigation. Impacts on the land will depend on the height of the bridge deck and the extent and design of any ramps; there could be some impacts on Durand's Wharf park (or the foreshore) depending on the extent and design of the approach ramps. It is possible that compensatory habitat may be required. Consideration of hydrological impacts of structures within the river channel would need to be examined further.	
Constructability issues	A low-level fixed bridge would be a standard construction task and no significant constructability issues have been identified.	
Land and property impacts	The land and property impacts will depend on the height of the bridge deck and the extent and design of any ramps; the longer the approach ramps, the greater the potential to impact on land interests.	

Navigable bridge (moveable or high-level)

3.15. A navigable bridge would maintain a navigational channel of around 50m height and around 180m width (the precise dimensions will be dependent on the location, alignment, orientation and type of structure) either permanently, or when large and/or tall vessels need to pass.

High level bridge

3.16. A high level bridge could be built around the navigational channel; it would need a main span at a considerable height, in the order of 50 metres above MHWS, slightly higher than the walkways of Tower Bridge, and a span of over 180m, which would be considerably longer than Tower Bridge's main span of 61m.

Figure 3-2 Tower Bridge with its high-level walkways

3.17. It is not likely to be feasible or desirable to provide ramps to such a height, and therefore it is assumed that such a bridge would be accessed from lift towers on either side; something akin to Tower Bridge (without the opening bascules) but on a larger scale (in this location on the river it would require a higher walkway and a longer span between piers).

3.18. The area around the proposed crossing is heavily built up; the scale of the bridge could be imposing, with substantial towers on each side of the main span to support the long deck, to house lifts of sufficient capacity, and to include ship impact protection, and as such this could create noise and/or visual impacts to those residents who would be close to the new tower.

3.19. Such a bridge would have disadvantages for users compared with a lower level bridge: there would be delays waiting for lifts, and possibly capacity issues at peak times should demand be higher than forecast, given the highly peaked nature of anticipated cycle demand and uncertain future demand and long term cycling trends (a design will need to work for decades). This need to dismount and wait for a lift could discourage some cyclists, as could the height of the main bridge deck in poor weather.

3.20. However, a fixed crossing of this type would be available to users at all times, and would not need to close for shipping. As a fixed structure, it would also be easier to maintain than a long-span moveable bridge, and would not require the operational staffing associated with managing a moveable structure, and so its ongoing maintenance and operating cost would be lower than a moveable bridge.

Moveable bridge

3.21. An alternative option is to build a lower-level bridge but with a movable central span to allow the bridge deck to be opened for passing vessels.

3.22. The attraction of a moveable bridge is that the low-level position of the span could be maintained at around 20 metres above MHWS so that it could be accessed by ramps, but would not be opening very frequently for shipping.

3.23. More detailed work would be needed to set the precise height of any structure over the navigable channel in order to maintain the right of navigation. Setting the height of the bridge is a balance of conflicting criteria. A lower bridge height will reduce the impact of the ramped approaches but will require the bridge to open and therefore be out of use more often. A higher bridge will open less frequently but will have a greater impact on the approaches to the bridge on either bank.

3.24. The duration of an opening would need to be agreed with the PLA because it is dependent on the detailed operational procedures, but this would include an allowance of time for shipping movements to be aborted in the event that the bridge cannot be opened for shipping. For large ships this time could be well in excess of 40 minutes. Small crafts with masts higher than the bridge height will generally not have such onerous requirements as large ships, because in an emergency they could abort and drop anchor close to the crossing. For these craft, a shorter opening time could potentially be achieved, subject to PLA agreement.

3.25. All such openings for shipping would impact on the utility of the crossing for users, as during these periods the crossing would not be available to either pedestrians or cyclists. While brief openings for small craft would result in only a minor delay, akin to those encountered and accepted at Tower Bridge, the longer closures would have a much greater impact on users, particularly given the distance to alternative routes. Very good advance warning of such closures would be needed to ensure that users could plan around such events.

3.26. A new moveable bridge would provide a direct, safe and pleasant form of crossing to users, albeit one subject to closures for shipping movements. The different moveable bridge options are discussed below.

Moveable bridge types

3.27. The differing types of moveable bridges each best serve the differing needs of a given location and use. These can be broken down into the following principle categories:

- Horizontal Swing
- Bascule
- Vertical Lift
- Other / Hinge

3.28. To understand the merits and assess the viability of each type of bridge design for this location, a brief description of each type has been detailed.

Horizontal Swing

3.29. Swing bridges allow the horizontal movement of the bridge deck around a vertical axis. The opening span of a swing bridge may rotate around a pivot point in the centre of the span (symmetrical), or else the entire span may rotate about one pier only (asymmetric). In an asymmetric arrangement, the pier ends of the opening spans are often counterweighted in order to achieve equilibrium.

3.30. Swing bridges of considerable scale have been built before; the Puente de la Mujer swing bridge in Buenos Aires has a main span of around 100m.

Figure 3-3 Puente de la Mujer swing bridge in Buenos Aires

Bascule

3.31. Bascule is the term used to describe bridges whose motion is based on the vertical tilt of the deck. Bascule bridges can take two forms, the first being a simple trunnion bascule in which there is a specific pivot point of the opening span – a hinge where rotation occurs without longitudinal movement. The second is a rolling bascule bridge which has no specific centre of rotation but instead a section rolls along a track allowing simultaneous longitudinal moment and vertical rotation.

3.32. Tower Bridge is possibly the most famous bascule bridge, which combines an opening roadway with fixed high level walkways. A bascule bridge concept has been considered by Sustrans for this location, designed by reForm architects.

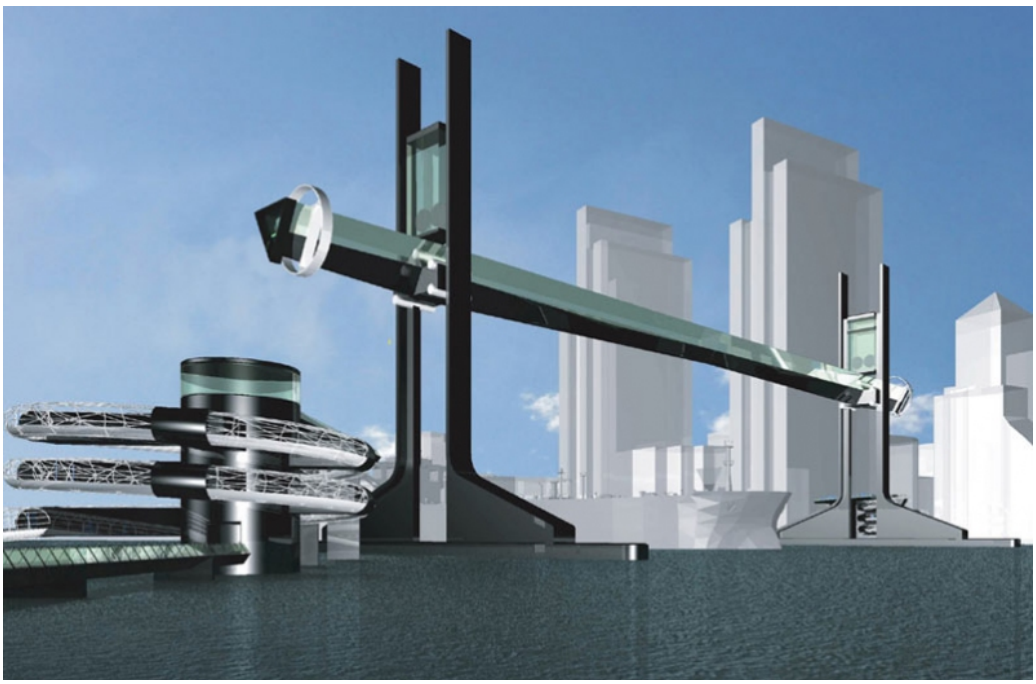
Figure 3-4 Bascule bridge concept[3]

Vertical Lift

3.33. A vertical lift bridge is one in which the whole span of the bridge between piers is raised in order to allow the passage of vehicles or vessels. Whilst both bascule and swing bridges can have unlimited headroom when open, the headroom beneath a vertical lift bridge is restricted to the lifted height. This usually entails the construction of large towers over each pier to support the bridge deck in lowered or lifted position.

[3] Source: http://www.reform-architects.london/projects/rotherhithe-bridge-2/

Figure 3-5 Lifting bridge concept[4]



3.34. A vertical lifting bridge concept was considered for this location in 2008, in a concept by Ramboll.

Other / Hinge

3.35. There are other forms of moveable bridge; although not as prevalent, these forms are:

- **Retractable bridges:** In which the bridge deck can be longitudinally displaced leaving a navigable channel.
- **Folding bridges:** These are when the deck is not moved in a single section, but instead folded to form a concertina. The advantage of which is that it lowers the height of any supporting structure.
- **Rolling bridges:** Similar to the folding bridge form, the deck on the rolling bridge is segmented when open and the deck of the opening span curls into a spiral.
- **Transporter bridges:** The supporting structure does not move and a fixed overhead structure that supports a carriage moves longitudinally across the river.
- **Other Tilting bridges:** These involve tilting the bridge structure in a different way to a conventional bascule bridge.
- **Floating bridges:** These use floats to support a continuous deck. The buoyancy of the support limits the maximum load they can carry and this option is likely to be impacted by the tidal flow on the Thames.

[4] Source: http://www.ramboll.co.uk/projects/ruk/sustrans%20thames%20pedestrian%20cycle%20bridge%20proposal

ASSESSMENT: Navigable bridge		
FIT WITH THE PROJECT OBJECTIVES		
To connect the two Opportunity Areas of Canada Water and the Isle of Dogs	ü ü **Achieved**	Would provide a high quality connection between the two opportunity areas
To improve connectivity from the Rotherhithe peninsula, particularly the area beyond the walking catchment of Canada Water station	ü ü **Achieved**	Would bring the eastern side of the peninsula within walking distance of Canary Wharf
To encourage more people to walk and cycle in the area	ü ü **Achieved**	Much greater accessibility for pedestrian and cycle trips likely to encourage more local tips on foot or cycle
To provide additional capacity and routes for cyclists as an alternative option to existing crossings in the area	ü **Partially achieved**	Compared with existing routes a bridge would provide significant new capacity to cross between Canary Wharf and south London by cycle when available to users, especially if the deck is at a low level, but there would be times when it would be closed to users
To produce a well designed and convenient link which achieves value for money and is fundable	ü **Partially achieved**	A fixed bridge would provide a direct, safe and pleasant form of crossing to users, albeit one subject to closures for shipping movements (there is strong potential to mitigate the impacts of these closures). A bridge would be a low cost option compared with a tunnelled option (although more expensive then a new ferry service)
To provide an alternative link to the Jubilee line between Canada Water and Canary Wharf	ü **Partially achieved**	A new bridge would provide an alternative means of travelling between the Canada Water and Canary Wharf areas, but a moveable design would be unavailable during shipping movements
FIT WITH THE CRITICAL DESIGN REQUIREMENTS		
Meets the river navigational requirements	ü **PASS**	A navigable bridge would be designed to meet the shipping constraint
A technically feasible alignment has been identified	ü **PASS**	Concept design work suggests there are feasible bridge alignments in this area
OTHER CONSIDERATIONS		
Environmental issues	A navigable bridge is likely to impact on the river bed and foreshore, and aquatic ecology but consideration will need to be taken with regard to appropriate planning and mitigation. Impacts on the land will depend on the height of the bridge deck and the extent and design of any ramps; there could be some impacts on Durand's Wharf park (or the foreshore) depending on the extent and design of the approach ramps. It is possible that compensatory habitat may be required. Consideration of hydrological impacts of structures within the river channel would need to be examined further.	
Constructability issues	A navigable bridge of this scale would be unusual and therefore relatively high risk, but early engagement with industry suggests there are several ways to meet the requirements.	

Land and property impacts	The land and property impacts will depend on the height of the bridge deck and the extent and design of any ramps; the longer the approach ramps, the greater the potential to impact on land interests.

Bored or mined tunnel

3.36. A bored or mined tunnel could provide a direct, 24 hour accessible link connecting the two areas. This would provide a commuter link which is not susceptible to interference by weather or river traffic. Further, it would have little visual impact on the river and surrounding landscapes except during construction and around the portals.

3.37. A tunnel would need sensitive design to provide a high quality ambience to ensure it did not suffer from a perception of poor user safety which can be associated with tunnels. As per the bridge options, spatial separation between pedestrians and cyclists would be required to avoid problems of conflict between users.

Figure 3-6 A bored cycle tunnel in the Netherlands

3.38. Tunnelling can cause significant disturbance during the construction phase and difficulties often centre on finding suitable landing sites in dense urban areas.

3.39. Bored or mined tunnels are typically circular in cross-section and excavated below the river bed, without removal of the ground above. While these tunnels are often the most expensive of the fixed link crossing options, the environmental impact in the river during construction is much reduced compared with other tunnel types or bridges which require piers in the river.

3.40. A bored tunnel would require a tunnel boring machine, while a mined tunnel is similar in principle but uses smaller more conventional digging machines within the tunnel. In either case, worksites would be required at each end for construction, including worksite facilities, and space for the delivery and storage of materials to support the tunnel, and the removal of the excavated spoil.

3.41. Despite any impacts during the construction, free navigation is preserved with a tunnel option.

3.42. Users of a bored or mined tunnel would have to descend to tunnel level either by lift/stairs (as per for example the Greenwich and Woolwich foot tunnels), or with ramps, which would be significant in length for this depth of tunnel.

3.43. A tunnel would not require staff members on-site to help operate the crossing facility.

ASSESSMENT: Bored or mined tunnel		
FIT WITH THE PROJECT OBJECTIVES		
To connect the two Opportunity Areas of Canada Water and the Isle of Dogs	ü ü **Achieved**	Would provide a high quality connection between the two opportunity areas
To improve connectivity from the Rotherhithe peninsula, particularly the area beyond the walking catchment of Canada Water station	ü ü **Achieved**	Would bring the eastern side of the peninsula within walking distance of Canary Wharf
To encourage more people to walk and cycle in the area	ü ü **Achieved**	Much greater accessibility for pedestrian and cycle trips likely to encourage more local trips on foot or cycle
To provide additional capacity and routes for cyclists as an alternative option to existing crossings in the area	ü **Partially achieved**	Compared with existing routes a new tunnel would provide new capacity to cross between Canary Wharf and south London by cycle
To produce a well designed and convenient link which achieves value for money and is fundable	û **Not achieved**	A bored or mined tunnel is expected to have no impact on navigation and be a convenient link to users, given it would be available at all times. However, the cost is likely to be approximately twice as much as a bridge option
To provide an alternative link to the Jubilee line between Canada Water and Canary Wharf	ü ü **Achieved**	A new tunnel would provide an alternative means of travelling between the Canada Water and Canary Wharf areas, and be available regardless of shipping movements
FIT WITH THE CRITICAL DESIGN REQUIREMENTS		
Meets the river navigational requirements	ü **PASS**	A tunnel would meet the shipping constraints
A technically feasible alignment has been identified	ü **PASS**	A tunnel is relatively flexible in its alignment and therefore a crossing alignment is likely to be found, but there are some considerable doubts about finding acceptable worksites at both ends of a tunnel given that this would be an intrusive neighbour for a period of time adjacent to residential property
OTHER CONSIDERATIONS		
Environmental issues	A bored or mined tunnel would have little or no impact on the river. Impacts on the land would depend on the sites chosen for worksites and portals; there are likely to be considerable objections to the placement of a tunnel worksite adjacent to residential property due to the noise, dust and other impacts.	
Constructability issues	TfL has good experience in tunnelling in London conditions so there are no known constructability issues which cannot be addressed, except for the acceptability of the worksite/portal locations.	
Land and property impacts	As noted above, locating worksites at either end of a tunnel could be difficult given the proximity of residential neighbours.	

Immersed tunnel

3.44. As with a bored or mined tunnel, an immersed tunnel could provide a direct, 24 hour accessible link connecting the two areas which is not susceptible to interference by weather or river traffic. It would have little visual impact on the river and surrounding landscapes in its final state except around the portals, although the construction impact on the river and navigation would be much more significant than a bored or mined tunnel.

Figure 3-7 A cycle tunnel in Amsterdam (bicycledutch.wordpress.com)

3.45. An Immersed Tunnel is constructed from individual segments that are prepared in a casting basin and floated to the tunnel site to be sunk into place on the river bed, which would need to be dredged/excavated to the required size in advance. This approach would result in only a small impact on river traffic, as these operations could be planned well in advance to minimise impact on river users. Moreover, free navigation is preserved after construction with a tunnel option.

3.46. However, the environmental impact in the river during construction would be greatest for this option, requiring careful planning to minimise the impacts on aquatic ecology and riverine habitat during the dredging works, for example dredging at a time of year to minimise impacts on aquatic species, but not all impacts could be completely avoided.

3.47. In terms of impacts on neighbouring residents, more of the work for an immersed tunnel takes place in the river (dredging and sinking the structure) or off site (construction of the tunnel segments in a casting basin). As such the nuisance around the portals, while still more significant than bridge options, would be less than with a bored/mined tunnel.

3.48. There are opportunities to provide ramp structures to link to an Immersed Tunnel in the Nelson Dock on the Rotherhithe side and below the Westferry Circus roundabout complex on the Canary Wharf side.

3.49. A tunnel would not require staff members on-site to help operate the crossing facility.

ASSESSMENT: Immersed tunnel		
FIT WITH THE PROJECT OBJECTIVES		
To connect the two Opportunity Areas of Canada Water and the Isle of Dogs	ü ü **Achieved**	Would provide a high quality connection between the two opportunity areas
To improve connectivity from the Rotherhithe peninsula, particularly the area beyond the walking catchment of Canada Water station	ü ü **Achieved**	Would bring the eastern side of the peninsula within walking distance of Canary Wharf
To encourage more people to walk and cycle in the area	ü ü **Achieved**	Much greater accessibility for pedestrian and cycle trips likely to encourage more local trips on foot or cycle
To provide additional capacity and routes for cyclists as an alternative option to existing crossings in the area	ü **Partially achieved**	Compared with existing routes a new tunnel would provide new capacity to cross between Canary Wharf and south London by cycle
To produce a well designed and convenient link which achieves value for money and is fundable	ü **Partially achieved**	An immersed tunnel is expected to have no impact on navigation and be a convenient link to users, given it would be available at all times. Whilst lower cost than a bored or mined tunnel, the cost is likely to be approximately twice as much as a bridge option
To provide an alternative link to the Jubilee line between Canada Water and Canary Wharf	ü ü **Achieved**	A new tunnel would provide an alternative means of travelling between the Canada Water and Canary Wharf areas, and be available regardless of shipping movements
FIT WITH THE CRITICAL DESIGN REQUIREMENTS		
Meets the river navigational requirements	ü **PASS**	Would provide a high quality connection between the two opportunity areas
A technically feasible alignment has been identified	ü **PASS**	Would bring the eastern side of the peninsula within walking distance of Canary Wharf
OTHER CONSIDERATIONS		
Environmental issues	An immersed tunnel would impact greatly on the river bed, aquatic ecology and riverine habitat during the construction period due to the dredging required. Impacts on the land would depend on the sites chosen for worksites and portals; there are likely to be objections to the placement of a tunnel worksite adjacent to residential property, although the disturbance would be less than bored/mined options.	
Constructability issues	Whilst this approach would be a complex engineering challenge, there are no known constructability issues which cannot be addressed, except for the acceptability of the worksite/portal locations.	
Land and property impacts	As noted above, locating worksites at either end of a tunnel could be difficult, although worksites would be less disruptive neighbours than bored/mined tunnel worksites.	

Cable car

3.50. The Emirates Air Line is a gondola, or cable car, system crossing the Thames between North Greenwich and the Royal Docks, and opened in 2012. It provides a link between the two areas at a height which exceeds the clearances required to allow shipping to pass below, and was built rapidly and at a much lower cost than an equivalent bridge.

3.51. A similar system linking Rotherhithe and Canary Wharf could be considered, to provide a direct link for pedestrians and cyclists.

Figure 3-8 A cyclist using the Emirates Air Line

3.52. A cable car would need to span the whole navigational channel at a height sufficient to allow for tall ships to pass below. Given that the profile of a cable system is that it sinks in the centre, the towers on each side would need to be around 90 metres in height (based on the Emirates Air Line- this height would increase slightly if a longer span were needed between main towers, or reduce slightly if a shorter span were provided).

3.53. A straight corridor free of obstructions or residential buildings of considerable distance is required, including the descent from the main cross-river passage back to ground level at each end. A suitable alignment has not been identified within the wider catchment outlined in Figure 2-1, given the densely built up nature of the corridor and the numerous committed development sites. Whereas the Emirates Air Line was built over vacant or brownfield land, that potential does not exist on a plausible straight alignment in this area.

ASSESSMENT: Cable car		
FIT WITH THE PROJECT OBJECTIVES		
To connect the two Opportunity Areas of Canada Water and the Isle of Dogs	ü ü **Achieved**	Would provide a high quality connection between the two opportunity areas
To improve connectivity from the Rotherhithe peninsula, particularly the area beyond the walking catchment of Canada Water station	ü **Partially achieved**	Could connect the peninsula to Canary Wharf, but potentially not in a convenient manner given the difficulty in siting an alignment or stations on the eastern edge of the peninsula
To encourage more people to walk and cycle in the area	ü **Partially achieved**	May attract some new walk/cycle trips, although it is likely to be less well used than a bridge or tunnel, especially if a charge were made for its use
To provide additional capacity and routes for cyclists as an alternative option to existing crossings in the area	ü **Partially achieved**	Compared with existing routes a new cable car would provide new capacity to cross between Canary Wharf and south London by cycle, although capacity would be finite, depending on the capacity of the system
To produce a well designed and convenient link which achieves value for money and is fundable	ü **Partially achieved**	A cable car would cost less than bridge or tunnel options, and has more potential to incorporate charging to cover operational costs (the Emirates Air Line makes an operating profit). However it would be less convenient for users than other options
To provide an alternative link to the Jubilee line between Canada Water and Canary Wharf	ü ü **Achieved**	A new cable car would provide an alternative means of travelling between the Canada Water and Canary Wharf areas
FIT WITH THE CRITICALREQUIREMENTS		
Meets the river navigational requirements	ü **PASS**	A cable car would be designed to meet the shipping constraint
A technically feasible alignment has been identified	û **FAIL**	A feasible alignment which is straight, has the requisite length to rise over the shipping channel and back to ground level, which is free of buildings has not been identified
OTHER CONSIDERATIONS		
Environmental issues	The environmental footprint of a cable car system is small; there would be some impacts on aquatic ecology and riverine habitat if one or more tower were located within the river.	
Constructability issues	The technology for such systems is largely standard and well understood; in this corridor the key constructability constraint is obtaining the necessary land.	
Land and property impacts	A cable car system requires a land corridor in which the system can be constructed, within which the necessary land and air rights can be obtained. No such corridor of sufficient size has been identified.	

Enhanced ferry

3.54. Thames Clippers currently operates a cross-river pedestrian and cycle ferry service on a commercial basis between Nelson Dock Pier (DoubleTree Docklands Hotel) and Canary Wharf Pier. This service utilises a single vessel, which runs approximately every 10-15 minutes between 06:00 (09:00 at weekends) and 00:00 (22:30 on Sundays) and has a three minute journey time. Both of the piers are privately owned and the service receives no TfL subsidy.

3.55. One crossing option is to invest in enhancing the infrastructure and service of the cross river ferry connecting the Rotherhithe peninsula with Canary Wharf.

3.56. Pier upgrades at Canary Wharf and Nelson Dock could include new pontoons and an additional access brow to accommodate the new cross river ferries, increased passenger demand, and make the ramp a lower gradient and therefore more accessible. Both piers would be designed to accommodate roll-on / roll-off cycle vessels, learning from best practice elsewhere in Europe including Rotterdam. This would help provide ease of access for cyclists and facilitate the efficient and rapid boarding and alighting needed.

3.57. New vessels could provide a higher frequency service than the current service through provision of two or even three vessels to reduce waiting times, while a subsidy could potentially allow the fare to be reduced or eliminated to encourage greater use of this link. Making the crossing free is likely to encourage some more local trips on foot or cycle, but likely fewer than with bridge or tunnel options given a ferry is not a permanent structure.

3.58. It is assumed that even with an increased frequency of service, there would be no disruption to navigation along the river in the event of a larger vessel passing up or downstream (because the larger vessel would have priority over the ferry).

3.59. An enhanced service could be introduced within two years which would link cycle routes north and south of the river, and help to demonstrate whether there is significant latent demand for a potential future bridge or tunnel at this location.

3.60. However, a ferry service is less attractive to potential users than a bridge or tunnel, given the need for cyclists to dismount, the guaranteed wait to board/alight, and the potential for unplanned disruption due to mechanical issues, staff shortages, poor weather conditions (e.g. fog) and tide issues.These could all happen without prior warning, and without the opportunity to mitigate against any inconvenience.

3.61. These factors combined with the fact that the service would not operate 24 hours a day mean it would be a less effective connection, compared to other options.

3.62. It is assumed that in the event of an alternative option being implemented, the operation of the existing ferry service is likely to cease.

ASSESSMENT: Enhanced ferry		
FIT WITH THE PROJECT OBJECTIVES		
To connect the two Opportunity Areas of Canada Water and the Isle of Dogs	ü **Partially achieved**	An enhanced ferry, running at higher frequencies and free of charge, would improve the connection between the two opportunity areas, but less effectively than bridge or tunnelled options given it would not operate 24 hours a day
To improve connectivity from the Rotherhithe peninsula, particularly the area beyond the walking catchment of Canada Water station	ü **Partially achieved**	Improving frequencies and eliminating the fare would improve the transport options from the eastern edge of the peninsula, although it is unlikely to be seen as a significant change in accessibility (compared to the current situation)
To encourage more people to walk and cycle in the area	ü **Partially achieved**	Making the crossing free is likely to encourage some more local trips on foot or cycle, but likely fewer than with bridge or tunnel options given a ferry is not a permanent structure
To provide additional capacity and routes for cyclists as an alternative option to existing crossings in the area	ü **Partially achieved**	An enhanced capacity could be provided with larger vessels and a more frequent service, although capacity is limited to the capacity and number of vessels provided
To produce a well designed and convenient link which achieves value for money and is fundable	ü **Partially achieved**	Enhancing the ferry service would cost considerably less than bridge or tunnel options, although it would offer a less attractive connection for users than a fixed link, given the need to dismount and wait to board/alight
To provide an alternative link to the Jubilee line between Canada Water and Canary Wharf	ü **Partially achieved**	Enhancing the ferry service is likely to make it more attractive for those within an easy walking distance, but it is not likely to provide a significant improvement to the current situation
FIT WITH THE CRITICAL DESIGN REQUIREMENTS		
Meets the river navigational requirements	ü **PASS**	A ferry would be designed to meet the shipping constraint
A technically feasible alignment has been identified	ü **PASS**	Concept designs for enhanced piers have been prepared
OTHER CONSIDERATIONS		
Environmental issues	The environmental impact of this option is minimal, largely limited to the construction phase when modifications to the piers could require dredging and piling. New vessels could potentially reduce emissions compared with the current ferry service if new engine technologies are deployed.	
Constructability issues	Concept designs for enhanced piers have been prepared and no constructability issues are foreseen.	
Land and property impacts	No significant land or property issues are foreseen, although some local agreements may be needed to amend access to the piers, particularly on the southern side.	

Complementary measures

3.63. Across all crossing options, TfL would need to work with local authorities to maximise the benefit of any new crossing, for example though improving cycle and pedestrian access to the crossing.

3.64. While an important aspect to consider as part of the project in due course, this is not considered a differentiating factor between the alternative options for the crossing itself at this stage of the appraisal process, and therefore is not considered further within this report.

Summary of assessment

3.65. The table below summarises how each option performs against the project's objectives and critical design requirements.

Table 3-1 Fit of crossing options with project objectives and requirements

ASSESSMENT	Non-navigable bridge	Navigable bridge	Bored or mined tunnel	Immersed tunnel	Cable car	Enhanced ferry
FIT WITH THE PROJECT OBJECTIVES						
To connect the two Opportunity Areas of Canada Water and the Isle of Dogs	ü ü Achieved	ü ü Achieved	ü ü Achieved	ü ü Achieved	ü ü Achieved	ü Partially achieved
To improve connectivity from the Rotherhithe peninsula, particularly the area beyond the walking catchment of Canada Water station	ü ü Achieved	ü ü Achieved	ü ü Achieved	ü ü Achieved	ü Partially achieved	ü Partially achieved
To encourage more people to walk and cycle in the area	ü ü Achieved	ü ü Achieved	ü ü Achieved	ü ü Achieved	ü Partially achieved	ü Partially achieved
To provide additional capacity and routes for cyclists as an alternative option to existing crossings in the area	ü ü Achieved	ü Partially achieved	ü Partially achieved	ü Partially achieved	ü Partially achieved	ü Partially achieved
To produce a well designed and convenient link which achieves value for money and is fundable	ü ü Achieved	ü Partially achieved	û Not achieved	ü Partially achieved	ü Partially achieved	ü Partially achieved
To provide an alternative link to the Jubilee line between Canada Water and Canary Wharf	ü ü Achieved	ü Partially achieved	ü ü Achieved	ü ü Achieved	ü ü Achieved	ü Partially achieved
FIT WITH THE CRITICAL DESIGN REQUIREMENTS						
Meets the river navigational requirements	û FAIL	ü PASS	ü PASS	ü PASS	ü PASS	ü PASS
A technically feasible alignment has been identified	ü PASS	ü PASS	ü PASS	ü PASS	û FAIL	ü PASS

3.66. The table illustrates that:

- A **non-navigable bridge** would achieve the project objectives, but would not be compatible with maintaining navigation on the River Thames;
- A **navigable bridge** would meet the project objectives and requirements;
- A **bored or mined tunnel** would meet most of the project objectives except that for achieving value for money, given that it is likely to be more costly than all other options while not providing more functionality than the closest alternative option (an immersed tunnel);
- An **immersed tunnel** would achieve the project objectives and requirements;
- A **cable car** would meet the project objectives, but a technically feasible alignment has not been identified; and
- An **enhanced ferry** would meet all the project objectives and requirements.

4. Conclusion

4.1. This Option Assessment Report has considered the Long List of options against the project objectives and critical design requirements to identify a Short List of crossing options.

4.2. The Short List of options will then be considered in more detail in a subsequent Option Assessment Report including further modelling, engineering and environmental assessments. The Option Assessment Report- Short List will inform the Strategic Outline Business Case.

Short List

4.3. The Short List proposed to be taken forward is presented in Table 5-1.

Table 5-1 Short List of crossing options

Option	Description and rationale for inclusion
Navigable Bridge	This option appears to best meet the project objectives of the options considered, while also meeting the critical design requirements. There are alternative means of building a navigable bridge; the bascule and swing bridges may be the most appropriate options to test navigable bridges in greater depth in the next phase of work, although other structural solutions could also be considered in the design phase.
Immersed Tunnel	A tunnel could also meet the project objectives well, although most likely at a higher cost than a bridge. Of the two tunnel types considered, an immersed one appears to be the most feasible tunnelling technique at this location as it can be delivered at a lower cost than a bored tunnel option. Moreover, an immersed tunnel method can provide a horizontal box cross section which offers more efficient space than a bored tunnel and can be placed closer to the surface.
Enhanced Ferry	An enhanced passenger ferry service could include Pier upgrades, improved access points, roll-on / roll-off cycle friendly vessels and an increased frequency. This option meets the project objectives, be it less strongly than the bridge or tunnel options given the need for cyclists to dismount, the constricted capacity and the non-permanency of the infrastructure. However, this option would be considerably cheaper and faster to implement.