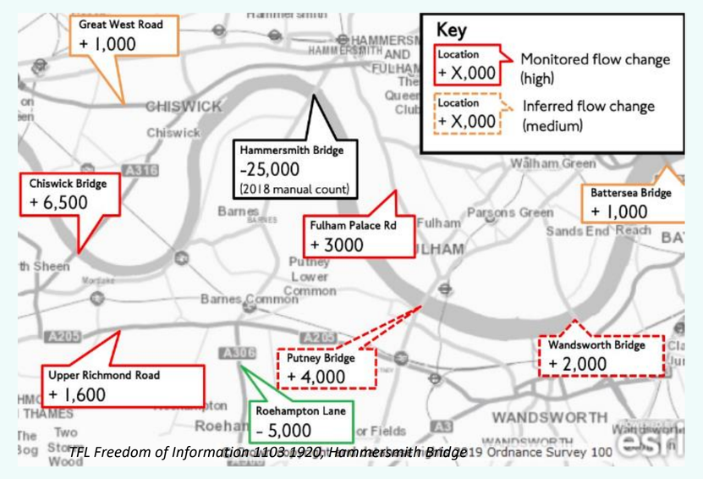
EPSILON DESIGNS: HAMMERSMITH BRIDGE

THE PROBLEM

Hammersmith Bridge is located in London, between the boroughs of Hammersmith and Fulham and Richmond Upon Thames. It was designed to carry carriage loads, and the load imposed by cars over the decades of use, as well as extreme weather events, have damaged the bridge. This damage made it unfit for use and likely to collapse. It was closed for all users in 2020., leaving its users without a way to cross the river in the area. It is crucial to find short and long-term solutions for the bridge users.



Changes in traffic in the are due to the Bridge Closure.

Motor vehicles: Congestion initially increased in the area due to the closure, but that increase slowed down with time. Journey times were also increased due to the traffic and redirection to other bridges, which is particularly an issue for emergency services which need to be able to travel fast. Buses were also impacted, and bus route alterations have greatly increased travel times (e.g., bus 533 now crosses Chiswick Bridge, adding 21 minutes to the normal commute time[1]).

Pedestrians and cyclists: 16,000 residents on each side of the river used Hammersmith Bridge daily and the closure of the bridge greatly increased their journey times there, going from 10 minutes to more than an hour on foot. Additionally, Hammersmith is well connected to public transport, but that is not the case for Barnes, south of the river, with no underground station within a walking distance. Therefore, a transport solution is needed urgently for these users.

Cost:
The cost of the proposal is crucial, as funding for this project is an issue, and all of the currently proposed solutions are too costly. This issue is slowing down this urgent project.

Timeframe:
The transport issues caused by the bridge closure have a great impact on its users lives. This makes this project a very urgent one, and a solution must be provided within weeks.

OBJECTIVES

- SAFETY AND DURABILITY OF THE STRUCTURE
- EFFICIENCY OF THE TRANSPORT SOLUTION
- SPEED OF IMPLEMENTATION
- COST EFFECTIVENESS
- HERITAGE AND LOCAL CHARACTER PRESERVATION
- INCREASE OF AREA ATTRACTIVITY
- PRIORITISATION OF PEDESTRIANS AND CYCLISTS
- ENVIRONMENTALLY SUSTAINABLE SOLUTION

STAKEHOLDERS

<u>Cyclists</u>
- Safety from motor vehicles
- Lower air pollution
- More cycling infrastructure

<u>Pedestrians</u>
- increased comfort and safety.
- More pedestrian infrastructure
- Lower air pollution

<u>Drivers</u>
- Less road congestion
- Opposed to speed limit reducing measures

<u>Mayor of London and TFL</u>

Work together on plans and strategies for transport in London:

- Reducing car use, increasing walking, cycling, public transport use, by providing safer walking and cycling spaces and improving public transport services
- Improving the attractivity of the streets and boosting the local economy.

<u>Local borough councils</u>

The local councils' main concerns are the needs of their community:

- Resolving the transportation crisis caused by the closure of the bridge
- Reinstating the footfall in the area which greatly decreased in the area due to the closure, affecting the local businesses
- Improving the quality of life of their residents by providing pleasant dwelling and living spaces;
- Promoting active and healthy lifestyles, by protecting and enhancing open and green spaces;
- Preserving the unique cultural and historical aspects of their neighbourhoods, through strict planning guidelines;
- Improving the boroughs' environmental sustainability with low carbon initiatives and policy changes.

FERRY SERVICE

An urgent need for a solution to cross the river between Barnes and Hammersmith was observed, particularly for school children, but also for workers and for leisure purposes. A ferry solution was established to be the most appropriate solution, due to its relatively low cost and speed of implementation. Thames Clipper boats for chosen as they are currently used on the Thames for similar purposes and can fit 250 people on board.

Example of a Thames clipper

Two of these clippers are to be on rotation everyday from 7AM to 7PM. The following schedule was found to accommodate for all 16,000 daily bridge users, including peak times for the 4,000 schoolchildren as well as the commuters.

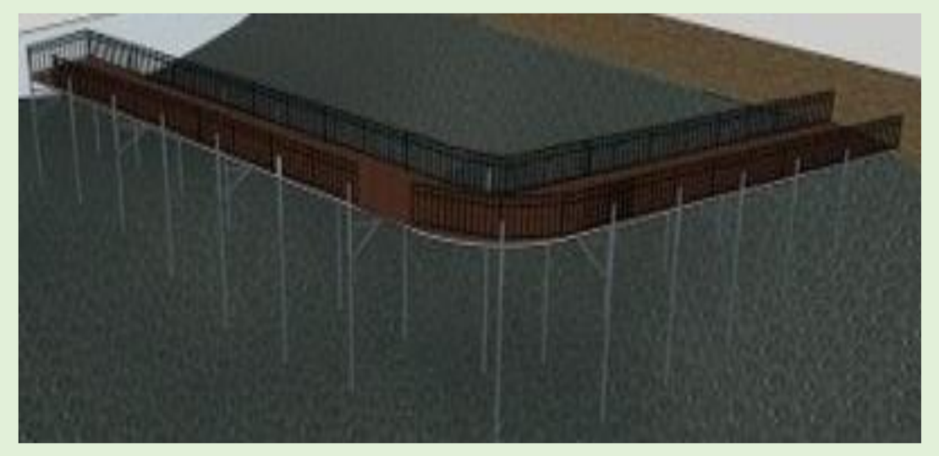
Time	Boat frequency, on each bank
7:00-9:00	Every 6 minutes
9:00-3:00	Every 20 minutes
3:00-5:00	Every 20 minutes
5:00-7:00	Every 20 minutes

Ferry schedule

To make this ferry service as convenient as possible for its users, its piers are located as close to Hammersmith Bridge as possible.

Pier locations (Google Earth)

The ferry piers are designed as simple L-shaped piling piers, to withstand the Thames tidal fluctuations. They are 40m long, to reach sufficient depth in the river and allow people to wait on them before boarding. They blend into the local landscape with elegant railing and timber decking.

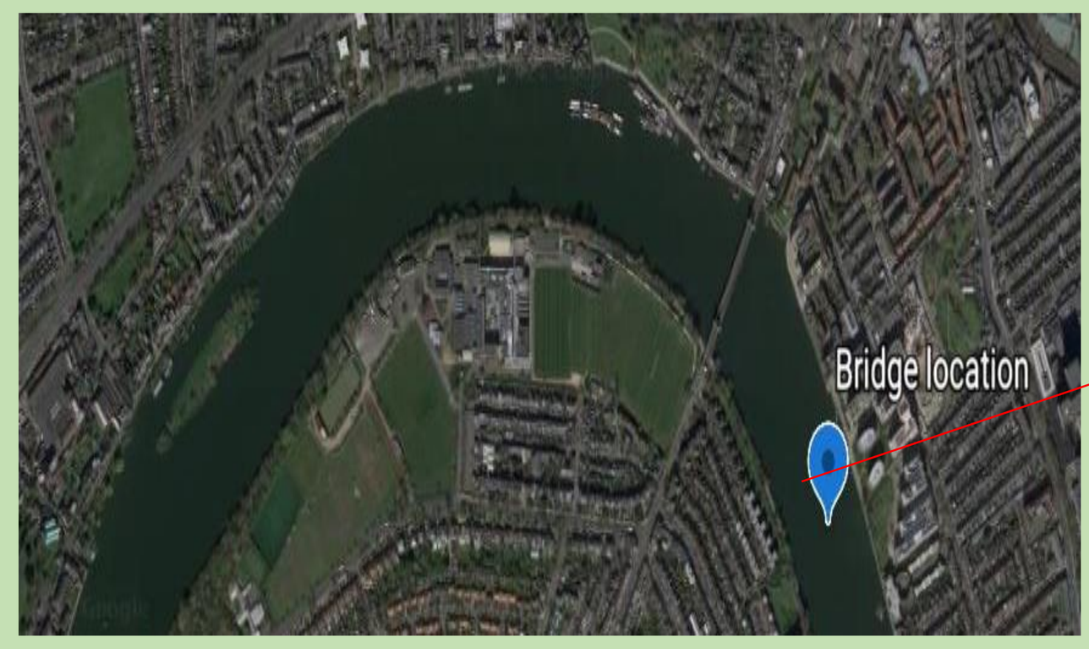


3D visuals of the piers

NEW HAMMERSMITH BRIDGE

Location of the new traffic bridge:

Having concluded that a new bridge had to be built in the area, it was necessary to find a suitable location for it. After performing an analysis on the most directly affected stakeholders and users of the new bridge, the following factors were determined as deciding for choosing the most suitable location:
- Hospitals: the new bridge should provide access for the Barnes peninsula to Charing Cross Hospital, located on the north bank
- Fire stations: there are two fire stations that can serve the Barnes peninsula: Hammersmith fire station and Fulham fire station. The new bridge should be located as close as possible to the existing bridge to provide fast connection to Hammersmith Fire Station
- Local bus network: The closure of the bridge caused the existing services either to stop at the bridge or to take long altered routes. Three locations were examined and analyzed, and from the factors listed above, the following location was chosen for the new traffic bridge (250 meters east of the existing Hammersmith bridge).



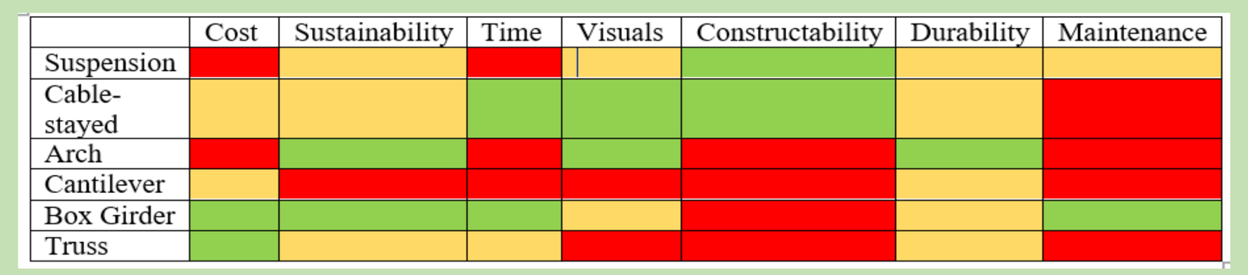
New bridge location

To connect this bridge to the existing road network, two new roads have to be carved in the area, as shown in the following figures.

Visuals of the road changes

Bridge type

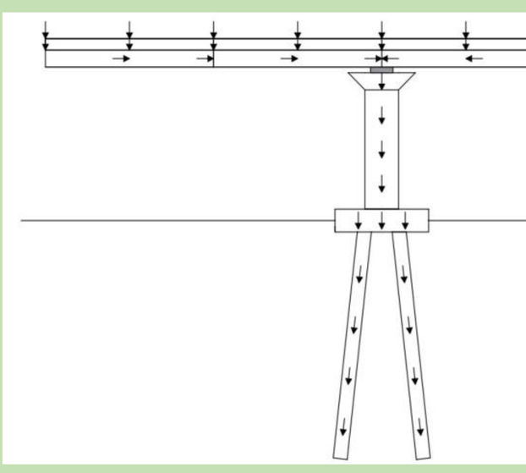
Several bridge types were compared to choose the most suitable in this case. The box girder bridge was chosen as sustainability and cost are priorities of our project. These two aspect are especially relevant for our project. The decision to build a new bridge in the area is a solution that has higher environmental impact than other options. By choosing a more sustainable bridge type option, the impact will be limited. Additionally, the available budget for this project is low and therefore a cheaper bridge is required. The box girder bridge also has high durability and requires low maintenance. Furthermore, seeing as this project is the result of Hammersmith Bridge's failure, it is especially important for the proposed design to be durable. Finally, the box girder bridge often can be constructed relatively quickly.



Box Type Comparison Matrix

Structural design

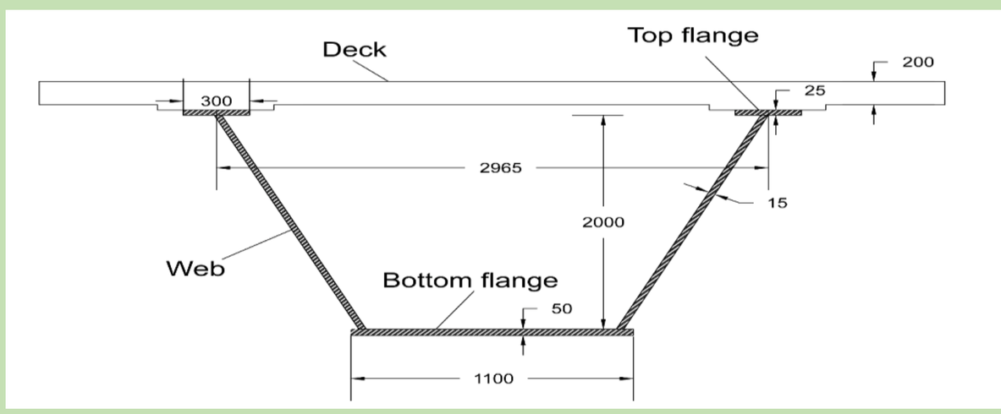
<u>Load path:</u>
The new traffic bridge is to be a composite box girder structure: a concrete deck supported by steel girders. The structure is supported by piers, which are supported by piles. As part of the initial stage of the design, the load path was examined and the following diagram was obtained:



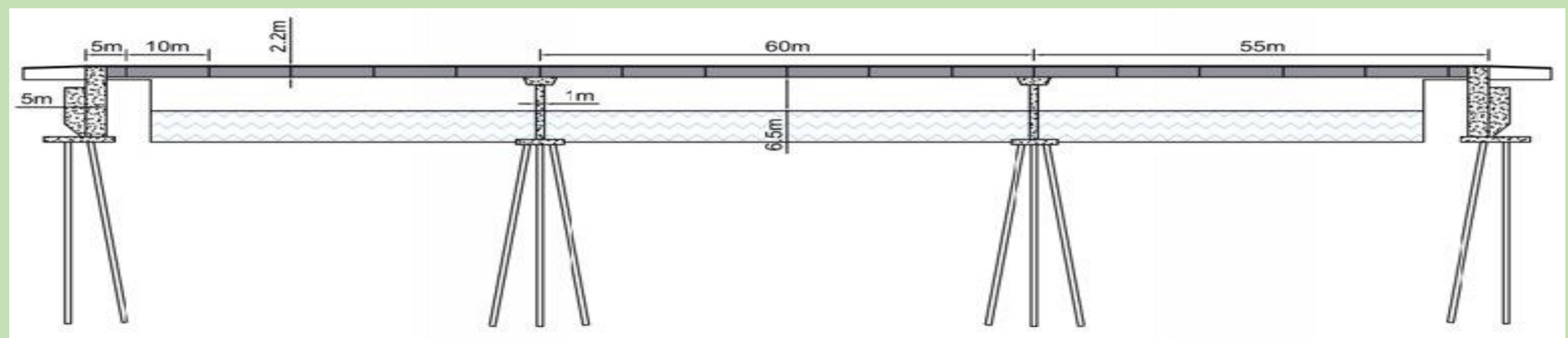
Load path

<u>Pile design:</u>
The borehole driven in the area of the bridge has showed that the most common soil types on this site are brown and blue clay (British Geological Survey). Therefore, the unit weight and unconfined compressive strength of clay will be used in the calculations. The loads combine of the live loads acting on the bridge and the self-weight of the finishes, the deck, steel girders and the pier.

<u>Box girder design:</u>
The chosen box girder type for the new traffic bridge is trapezoidal girder open at the top, which saves the weight of the top flange and is simpler to build than a closed girder. However, it requires lateral bracing while the bridge is being constructed, to prevent the girders from opening out. The girders will be prefabricated in lengths of 10 meters and then joined together on site.
The elements will be welded together, which has the advantage of better visual appearance and more flexibility in the maintenance of the protective layer.

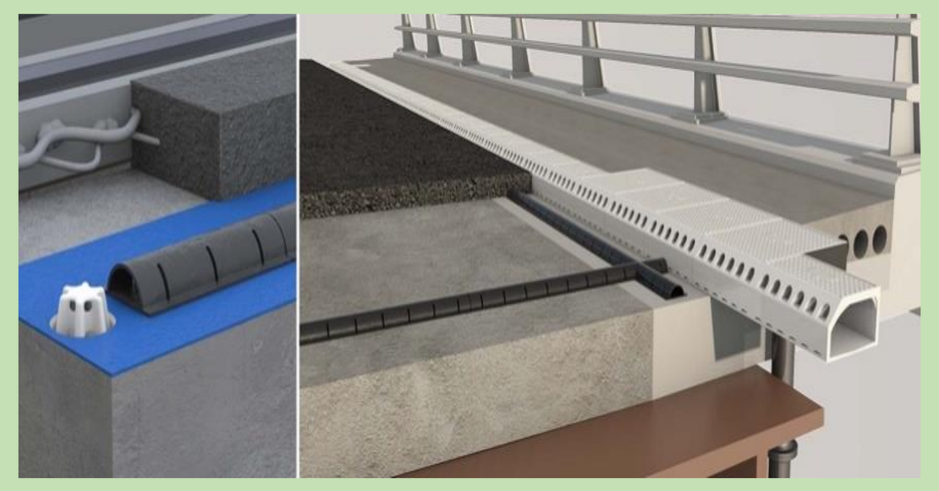


Cross-section of the box-girder



Structural elevation of the bridge

<u>Drainage design:</u>
The drainage system implemented in the new bridge is going to handle both the water from the road surface and the subsurface flow. The water on the road is to be collected by the grey element with continuous holes, shown on the schematic on the right. The element is going to collect the water and convey it down to a pipe for discharge. The subsurface water is to be collected by the series of black pipes made from graphite iron, also shown on the right.



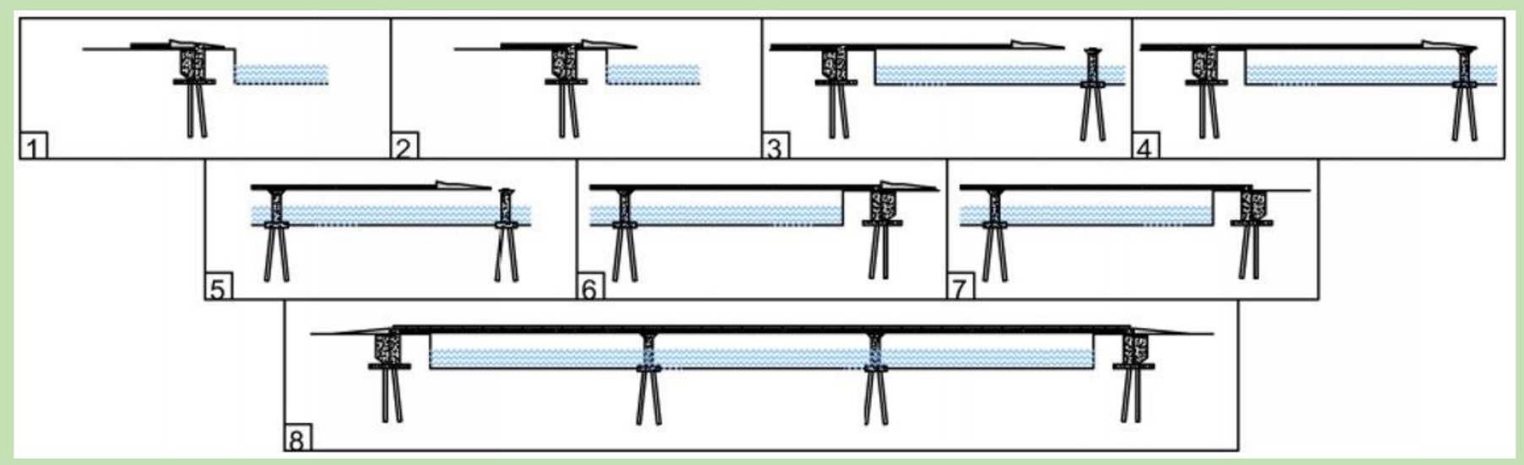
Drainage design

Construction method and schedule

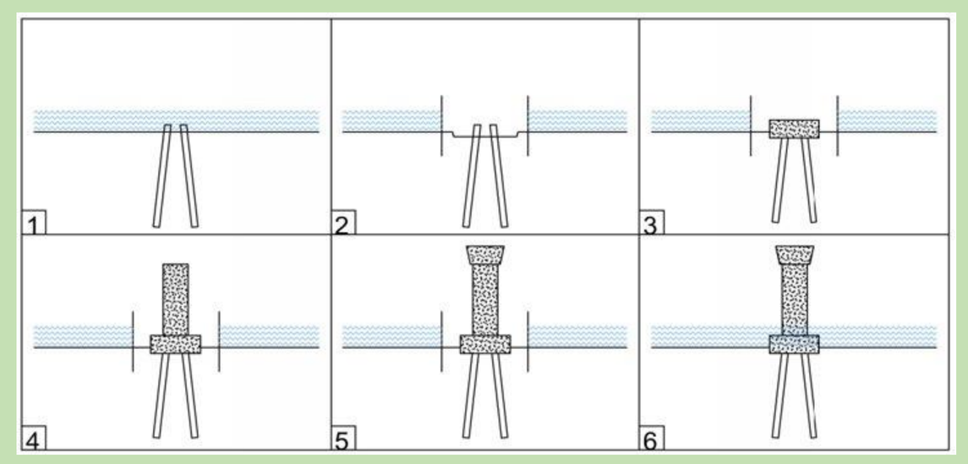
The chosen construction method was incremental launching. As the name implies, the bridge is constructed by pushing small bridge segments from one riverbank to the other. This method was identified to be the best option due to the increased worker safety, minimal disturbance in the area and the river is free for most of the construction duration. Overall, the incremental launching option best meets our outlined priorities. The construction sequence is on the right.

1. Assemble steel nose and fix the first segment to it.
2. Launching the first space, then fixing the next span behind it
3. Repeat launching and fixing
4. Steel nose reaches piers with bearings
5. Critical stage, highest hogging moment
6. Launching is finished
7. Disassemble steel nose and fix bridge to abutment
8. Approach roads are constructed, and finishes are applied

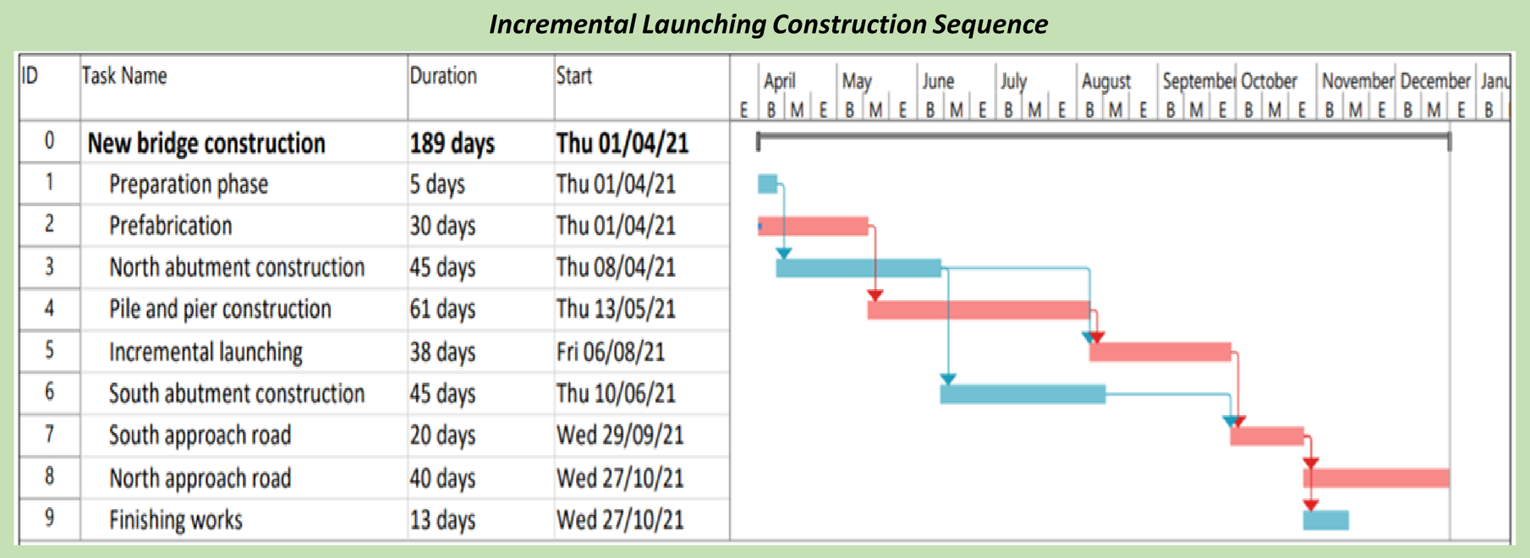
The construction schedule is shown on the right. Overall, the construction of the new bridge will last 189 days. The construction phase will commence with north abutment construction and then pile and pier construction. The north abutment and piers are the most important part of the construction process. As soon as these two parts are constructed, the bridge can be launched. As a result, they are constructed first. The next step is to then construct the south abutment. While the launching of the bridge can commence as soon as the piers are completed, due to the speed of the launching process, the south abutment would not be ready. Besides, it is sensible to leave some leeway to ensure this schedule works. Finally, the approach roads and finishing works are completed once the bridge has been fully launched.



Incremental Launching Construction Sequence

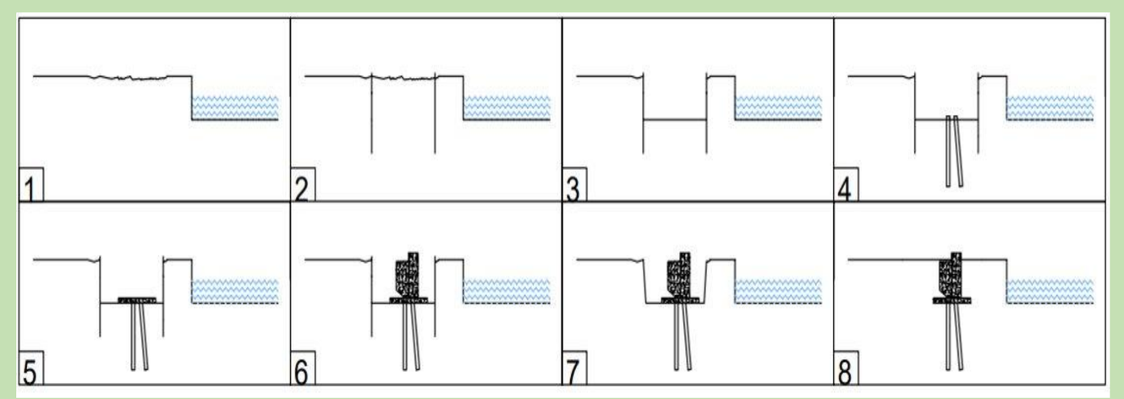


Piers Construction Sequence



ID	Task Name	Duration	Start
0	**New bridge construction**	**189 days**	**Thu 01/04/21**
1	Preparation phase	5 days	Thu 01/04/21
2	Prefabrication	30 days	Thu 01/04/21
3	North abutment construction	45 days	Thu 08/04/21
4	Pile and pier construction	61 days	Thu 13/05/21
5	Incremental launching	38 days	Fri 06/08/21
6	South abutment construction	45 days	Thu 10/06/21
7	South approach road	20 days	Wed 29/09/21
8	North approach road	40 days	Wed 27/10/21
9	Finishing works	13 days	Wed 27/10/21

Incremental Launching Gantt Chart



Abutment Construction Sequence

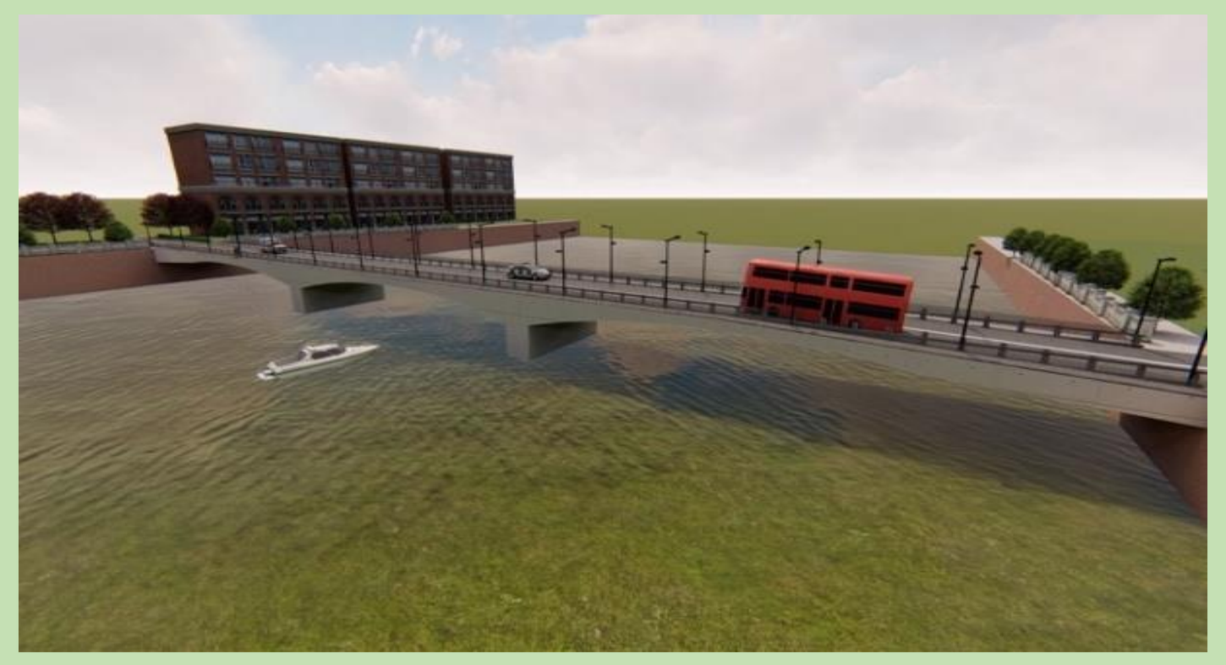
Final Design of the new Hammersmith Bridge

The architectural aims for this bridge are:

<u>Harmony</u> → The bridge should blend into the architectural style of the area, as per the requirements of the local authority. The northern area, Hammersmith, is quite modern with new buildings, while Barnes, on the south, is more traditional with older buildings. A pure, simple looking box girder bridge would not stand out from either of these styles.

<u>Simplicity</u>→ In this case, the goal is not to make the bridge a landmark, but rather to preserve local character and heritage, by shining a light on Hammersmith bridge itself. This bridge should thus not stand out but rather compliment and not obstruct Hammersmith Bridge. The flatness of a box-girder bridge (as opposed to a taller type of bridge) would limit the disruption of the view of Hammersmith Bridge

<u>Visually Engaging</u> → While the bridge should not be extravagant, it should not be an eyesore, therefore details are to be added to enhance its appearance such as lighting and railings.



3D Visuals of the proposal design for the new Bridge

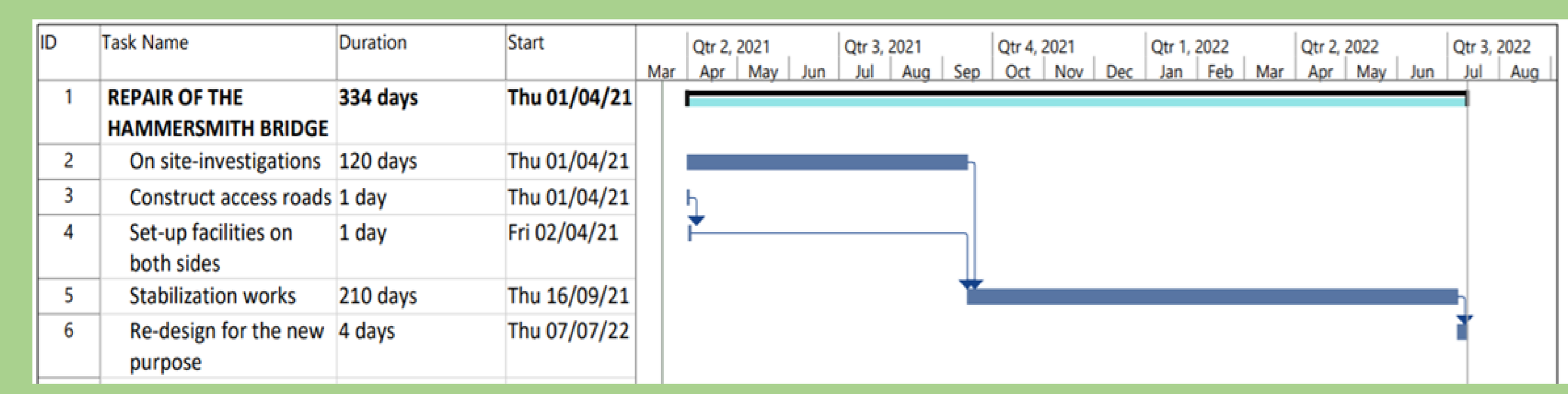
REPAIRS TO HAMMERMITH BRIDGE

Repairs

Based on the objectives defined in the problem formulation phase, the bridge will be repaired for pedestrians and cyclists only. Therefore, the repair will not take as long as anticipated and the costs will be reduced. Since the structure is highly damaged and corroded, it needs to be repaired. There are many transverse cracks, which are the worst type of cracks that could appear (which makes the repair more complicated). The repair will be divided in 3 stages: in depth understanding and investigating the condition of the bridge, stabilisation works (needed to stabilize the bridge and prevent from collapsing) and changes to the architectural design for the new purpose. The Hammersmith Bridge will reopen 15 moths after the start of the project.

It is crucial to ensure that the previous structural problems do not reoccur and that there it will not be needed to furtherly repair the bridge.

Therefore, the following measures are taken: by completely removing the vehicle traffic, the hourly live load acting on the bridge will be reduced by 98%. This will ensure that the bridge will finally be exposed to the loads it was designed for and will be able to withstand those loads once the cracks are repaired. Moreover, the parts of the bridge, which have contact with water, will be covered with anti-corrosion paint. The condition of the paint will be systematically monitored after the opening of the bridge and repainting will be done if needed.



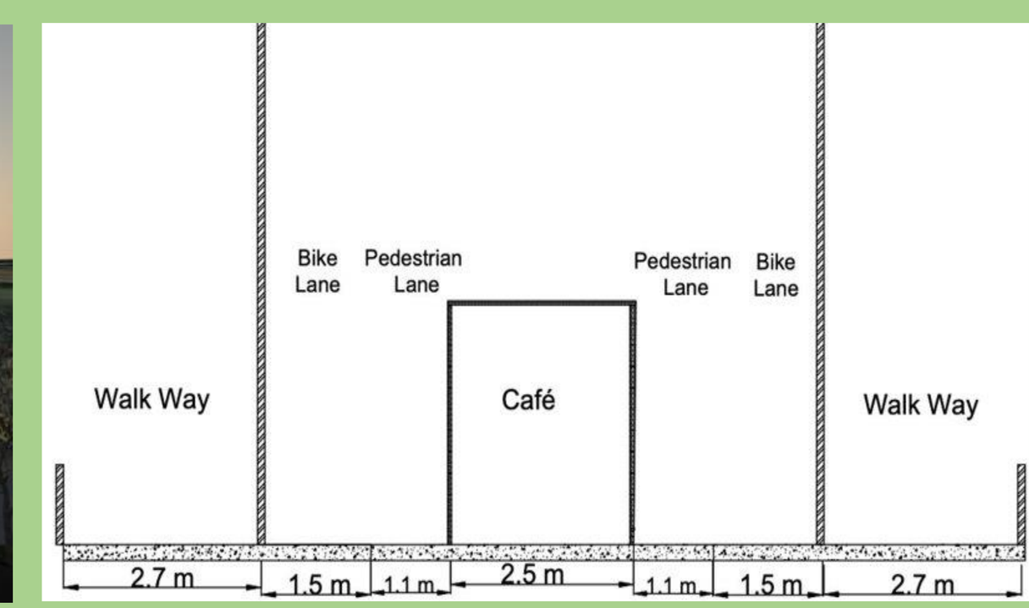
ID	Task Name	Duration	Start
1	**REPAIR OF THE HAMMERSMITH BRIDGE**	**334 days**	**Thu 01/04/21**
2	On site-investigations	120 days	Thu 01/04/21
3	Construct access roads	1 day	Thu 01/04/21
4	Set-up facilities on both sides	1 day	Fri 02/04/21
5	Stabilization works	210 days	Thu 16/09/21
6	Re-design for the new purpose	4 days	Thu 07/07/22

Construction sequence of the repairs

Remodel of Hammersmith Bridge

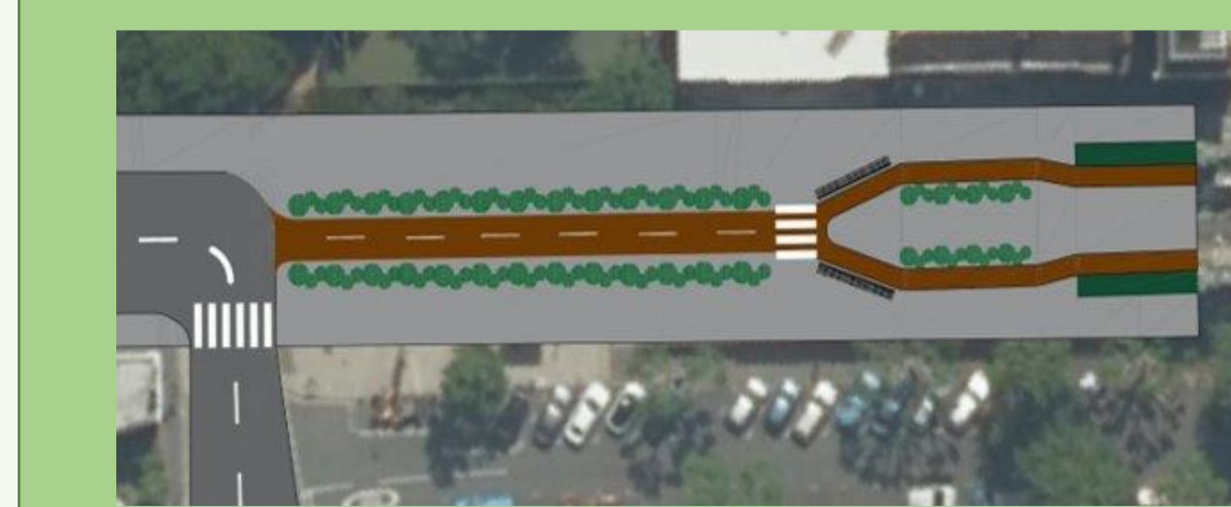
The bridge will be remodelled for pedestrians and cyclists. A simple, low cost and fast to implement redesign is chosen. It includes two cycles lanes on either side of the centre part of the bridge, and between them, a café area. A cafe kiosk is placed in the middle of the bridge, with a seating area. The café is linked powered by the bridge's electricity source, and its water tank can be refilled manually depending of the consumption. Benches and trees in pots are added along the bridge. Bike racks will be available at each entrance of the bridge, and next to the kiosk. This redesign thus only includes the repainting of the roads, as well as the installation of vegetation, café booths, bike racks, and benches.

3D Visuals of the redesign of the Hammersmith bridge

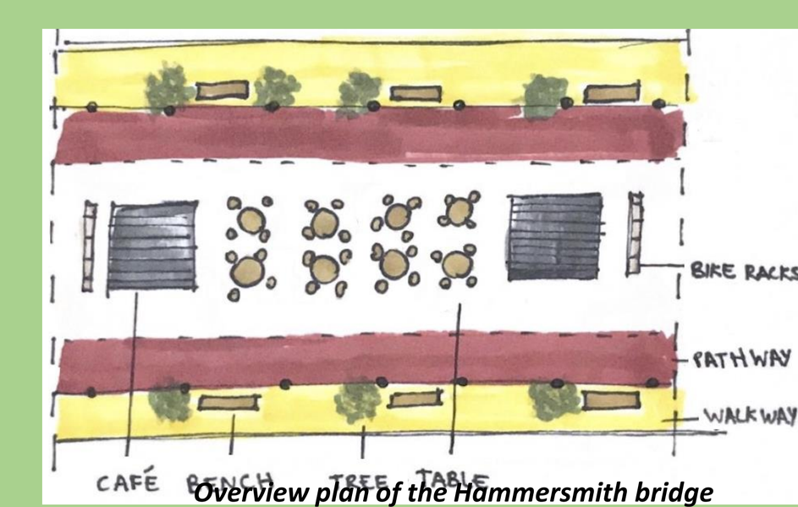


Cross section of the Hammersmith bridge

The two entrances of the bridge are also redesigned to be better suited for the bridge's new purpose. On the north bank of the river, the whole width of the road is no longer needed since cars will not use it. It is therefore possible to prolong the bridge's cycle lanes and to widen the sidewalks by joining the two cycle lanes together, providing more dwelling space and potential outdoor seating space for the local businesses on the road. The pavement can be extended by 3m on each side. On the south bank of the river, few changes are made on the road approaching the bridge: Parking spots are provided along the side of the road to replace the spots removed from the neighbourhood roads, with crosswalks to reach the sidewalk from the parking spots. Vegetation and bike racks are also added on this side.

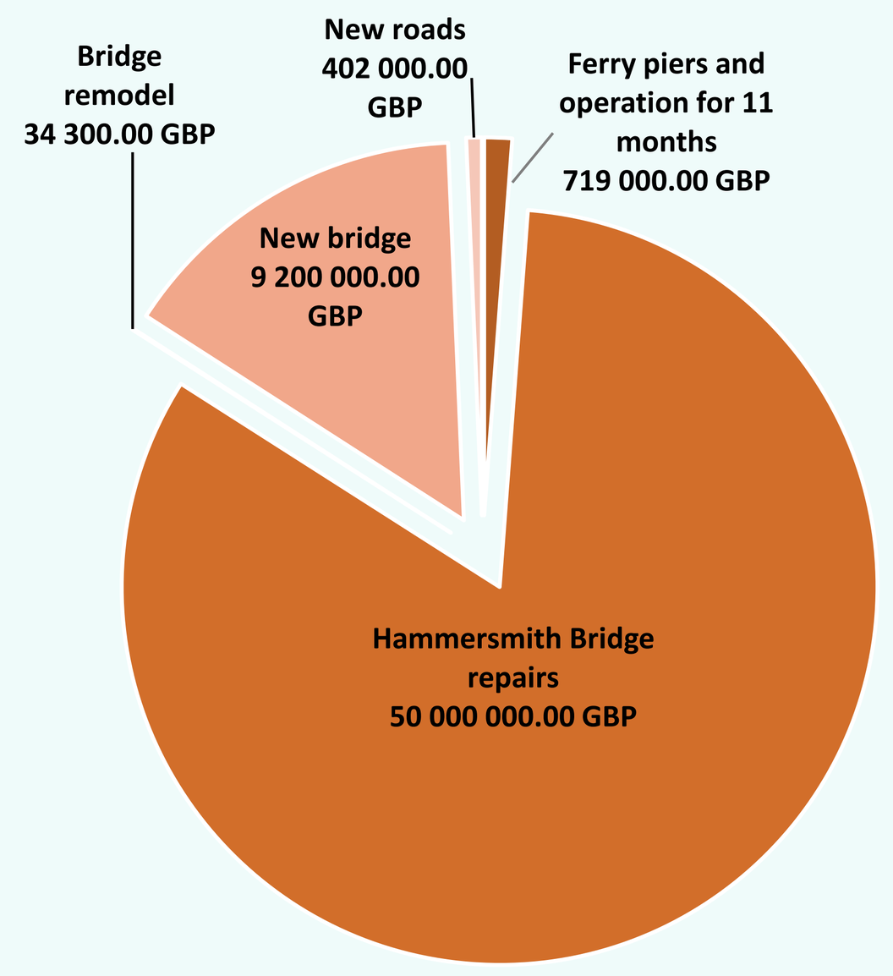


Overview of the North and South entrance of the Hammersmith Bridge



Overview plan of the Hammersmith bridge

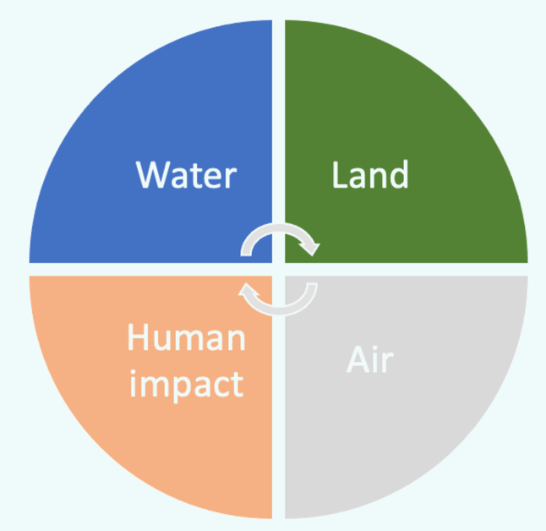
Cost



Environmental Impact Assessment

Different factors were taken under consideration for this assessment The possible challenges are:

- Accidental spills
- Water Quality
- Waste management
- Earthwork
- Air quality (pollution)
- Nuisance (noise, disruption)



<u>Mitigation</u>:
- Prefabricating the new bridge will reduce the amount of work on site. This will reduce the risk of oil spills, reduce the disruption on site (less plant is required).This will also reduce the amount of waste created, which will improve the waste management on site.
- To limit the damages and amount of soil moved during earthworks, we will use the cut and fill method. For the trees that are placed on the road connecting the new bridge, rather than cutting them, they will be moved to be replanted in the existing green area adjacent to the road.
- Air quality will be monitored during the whole project, in order to keep track of the possible air pollution caused by this project.
- Nuisance: parking spots were removed to link the new bridge to the road. New parking spots are added next to the Hammersmith bridge.