Cardiff Council

Cardiff Bay Barrage Transport Link

Arup Feasibility Report

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Appendices

1 Introduction

1.1 The Commission

Ove Arup & Partners ("Arup") have been commissioned by Cardiff Council to undertake a feasibility study to evaluate the technical and operational viability of providing a bus-based public transport route via the Cardiff Bay Barrage. The proposed bus route consists of a western section over the existing Cardiff Bay Barrage lock bridges and embankment infrastructure, and an eastern section connecting the end of the Barrage to Hoel Porth Teigr in Cardiff Bay; this eastern section has a number of route options.

The background to the study is that bus services between Cardiff city centre and Penarth via the Merry Harrier junction (on the western end of the Cogan Spur) frequently experience severe congestion, particularly at peak times. As a result, bus services between central Cardiff and Penarth can be unreliable, suffering extensive delays at times, and there is little scope to provide sufficient bus priority measures on the existing route. The objective of the study is to examine issues associated with implementing a bus service via the Barrage, looking in particular at the following:

- The feasibility of providing an alternative transport route via the Cardiff Bay Barrage, with up to 48 buses per day using the route;
- Operational interaction between the barrage and bus schedules;
- The structural integrity of the bascule bridge; and
- Estimation of costs for any proposed structural upgrade and bus route infrastructure requirements.

The bus service proposal will be considered by Cardiff Council in the context of ongoing development of a Cardiff Bay Masterplan.

The commission included consultation with key stakeholders including a project workshop to inform the development of infrastructure and operational proposals. This report has therefore been compiled with input from the following organisations:

- Cardiff Council
- Vale of Glamorgan Council
- Cardiff Harbour Authority
- Bus operators
- Welsh Government

The meeting notes and workshop outputs have been included in Appendix B.

1.2 Project Objectives

The specific project objectives include:

- Determine whether existing bascule bridge can accommodate buses driving over the structure (48 buses per day), taking account of pedestrian and cycle movement;
- Determine possible implications for the structure after 5 years of bus service over the bascule bridge;
- Identify any costs for upgrading or improving the bascule bridge/structure to accommodate buses;
- Identify if there are any planning, environmental or health and safety requirements to implement the options;
- Investigate management/controls systems which will need to be in place to allow buses, cycles, pedestrians and boats to navigate safely over and through the lock gates and/or harbour authority land during operational hours;
- Provide outline design options with indicative costs for how buses can safely travel on to and stop at the barrage from Paget Road/Penarth Marina end including any infrastructure works necessary to improve the route(s) to the Barrage at the Penarth end;
- Provide road alignment options and indicative costs for connecting the bus link from Queen Alexandra House to Discovery Quay;
- Liaise with Cardiff Council's Economic Development, ABP and Harbour Authority to investigate and agree the specification for the design and to understand the constraints and issues in the area as well as statutory undertakings;
- Liaise with the Vale of Glamorgan to identify appropriate routes and bus priority and/or bus stop improvements;
- Quantify operational and management risks for introducing a bus link over the barrage;
- Investigate whether the existing barrage infrastructure facilities can safely accommodate a new bus link. You will need to take account of road construction, current road widths, street lighting, cyclists & pedestrian links and the open space recreational parks;
- Provide details including any associated costs to bring up the carriageway over the barrage to an acceptable standard for a bus link; and
- Investigate operational arrangements that will need to be put in place for bus services, when barrage/bascule bridge is closed for maintenance work, poor weather and events etc.

1.3 Study Content

The remainder of the report will cover the following:

- **Section 2 - Existing Conditions** will review the current constraints and existing operations for the local public transport provisions;
- **Section 3 - Existing Policies and Plans** describes the applicable local planning policies together with a review of the key points in the Cardiff Barrage Act 1993;
- **Section 4 - Bridge Structure Investigation** provides a summary of the desk study review and consultation undertaken with regard to the bridge structure;
- **Section 5 - Existing Barrage Operations** is based on discussions with the Harbour Authority, who also provided CCTV footage of the Barrage Lock and Bridge operations which give a perspective of the lifting sequence and timings;
- **Section 6 – Bus Operations Options** considers the findings of the baseline investigation which reviews and describes the various option for bus timetabling, interaction with the boat movements in and out of the bay together with highway routing options.
- **Section 7 – Infrastructure and Operations Options Development** describes and discussed the infrastructure and operations arrangements for carrying a scheduled bus service across the Barrage, including a risk assessment for delivery, and outline cost estimations
- **Section 8 – Risk Assessment and Costs** provides a list of risks in respect of deliverability of the bus service proposal, and also an outline cost estimate for infrastructure elements
- **Section 9 - Summary and Next Steps** provides a conclusion in respect of the infrastructure and operations arrangements, together with recommendations for the next steps.

2 Existing Conditions

2.1 Site Location

The Cardiff Bay barrage is a 1.1km long embankment structure which extends between Cardiff Docks (and Cardiff Bay) in the north-east and Penarth Marina in the south-west. The location of the Barrage is shown in Figure 2.1.

2.2 Barrage Infrastructure

The barrage lock system at the western end of the Barrage consists of a series of three bascule bridges (which carry vehicular traffic) and associated locks for passage of marine vessels. The three bridges are named 1, 2 and 3 (with bridge 3 at the Penarth side). Directly to the east of the bascule bridges are the sluice gates (5 no.), which allows water to flow from / to the enclosed water of Cardiff Bay (depending on the relative sea levels and river flow levels).

A control building is located adjacent to the lock facilities, from which the bridges and locks are directly operated by staff on duty in the control centre. The barrage control centre is manned for 24 hours every day, with a minimum of 2 staff present.

The eastern section of the barrage comprises of a rock-built embankment structure, carrying a two-way roadway and footpath.

The embankment section is approximately 800m long. CHA staff have identified that tidal movements alter the height of the barrage embankment by up to 5mm (although no damage to the road surface has been identified as a result of this tidal movement). The road along the embankment is in good condition generally, although the carriageway has undergone intermittent repairs of surface depressions caused by wash-away underneath the road surface. Holes of 0.5m in depth have been recorded in the past. The worst affected areas are located at the mid-section of the embankment i.e. the last section of embankment to be constructed, around halfway along the embankment. The road level and condition is monitored every six months in order to ensure that any problems in respect of the road surface condition are identified as early as possible. Discussions with CHA has indicated that the surface depressions are localised in nature and do not suggest a wider problem in respect of the structural integrity of the barrage embankment.

The top of the embankment (footway and cycleway) is currently lit with illuminating bollards. Low illuminating lighting was installed to avoid confusion for vessels entering the port.

No lighting is currently provided along the carriageway. The CHA and Association of British Ports (ABP) would need to be consulted before considering lighting along the carriageway, as lighting can distract/confuse the vessels using the port.

The Constraints Plan drawing in Appendix A provides greater detail of the site location in the context of the surrounding area.

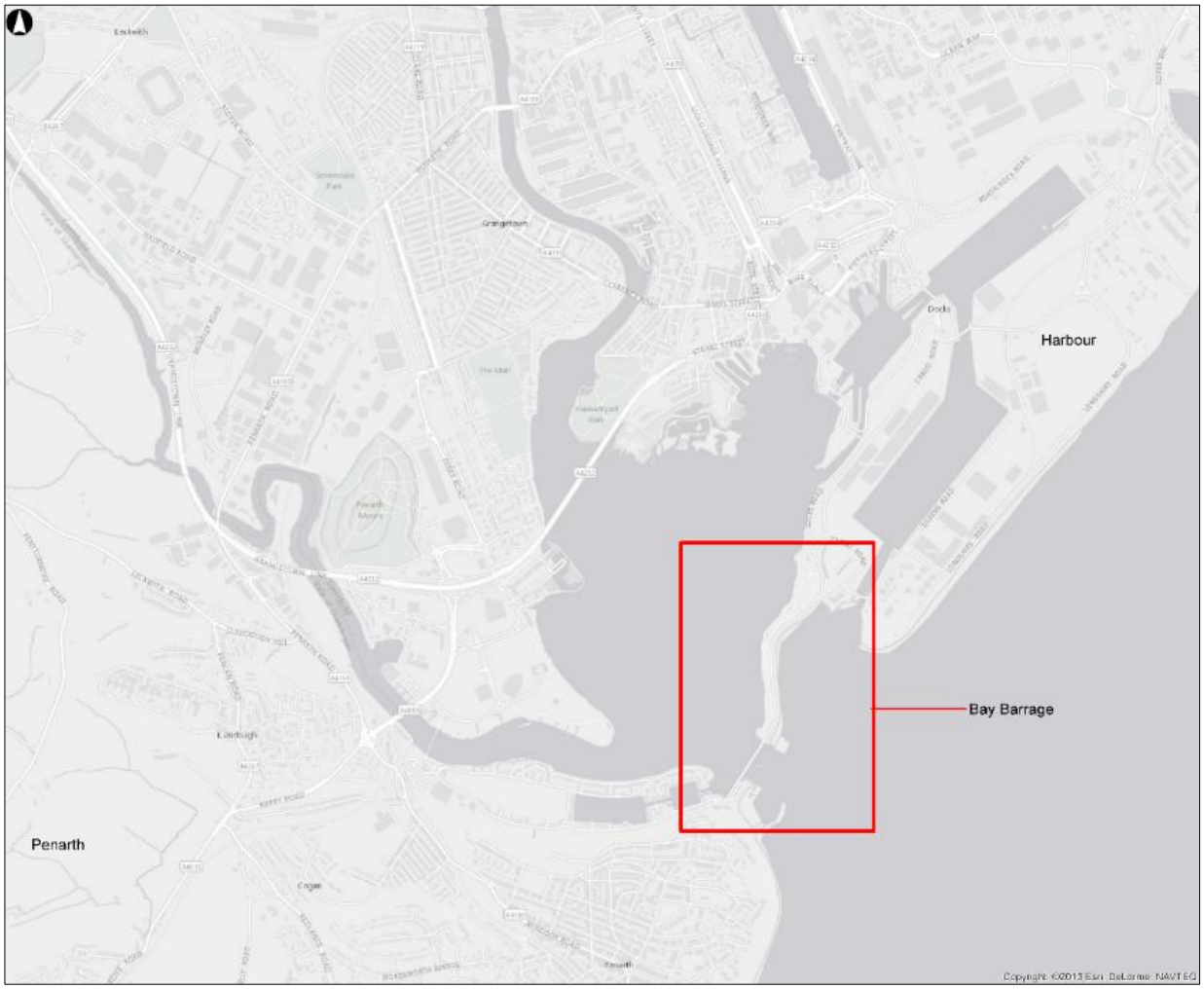


Figure 2.1 Cardiff Bay Barrage Location Plan

Figure 2.2: Aerial Image of Cardiff Bay Barrage Lock and Sluice Structures

2.3 Construction of the Barrage

Cardiff Barrage was constructed during the 1990's by Costain and Balfour Beatty, with completion in 1999. Cardiff Bay Development Corporation (CNDC) was the original operator of the barrage. Cardiff Harbour Authority (CHA) took on CBDC's duties in respect of the barrage, and are obliged to operate according to the Cardiff Bay Barrage Act 1993. CHA is part of Cardiff County Council, and hence the barrage is effectively owned by the County Council.

Key operating tasks for the Harbour Authority are:

- To maintain a constant water level in the bay of 4.55mAOD to reduce the risk of flooding to local properties.
- To ensure navigation of the barrage locks is possible at all times. The right to navigation for boats is a core aspect of the Barrage Act, and any infringement on this right would not be feasible.

2.4 Land Ownership and Development

The local land is owned by:

- Welsh Government
- The Harbour Authority /Cardiff Council
- Vale of Glamorgan Council
- Associated British Ports
- Igloo (Preferred Developer on Welsh Government Land)

A land ownership plan (Figure 3) is shown in Appendix A. Further information on land ownership and use is:

- The length of road (the old Locks Road) between Queen Alexandra House and the start of the Igloo owned land at the south end of the old Dry Dock (alongside the Dr Who exhibition) is owned by Welsh Government.
- The length of road between Queen Alexandra house and the Harbour Authority`s Environment Building is then leased by the Harbour Authority from Welsh Government.
- The access road between the Cardiff end of the barrage is presently being used to store contaminated material (e.g. Japanese knotweed) believed to be under an agreed license between Igloo and the Welsh Government. The HA suggested that this may be used as back fill for the proposed reconstruction of the retaining wall south east of The Doctor Who Experience.
- Cargo Road is currently owned by ABP. All land within the ABP area is within the legally defined Port of Cardiff and is subject to national port regulations. Cargo Road can only be entered via secure gates.
- A section of the land at the east end of the barrage is owned by a private developer called Igloo. There is a 5 year agreement with Igloo to maintain the cycle/footway adjacent to their land. This includes providing an alternative cycle/footway should any development obstruct the route currently in place. It is understood that a s106 development agreement is in place for financial contributions towards funding a new bus route.
- Bridge adjacent to Dr Who building is in the process of being 'adopted' by Cardiff County Council.

- The Swing Bridge at Tyneside Road is also in the process of being adopted by Cardiff Council – but only the road surface layer, with the structure remaining under the ownership (and maintenance) of ABP.

2.5 Existing Public Transport Operations

The local public transport bus and rail network across the study area is shown in Figure 2.2. In respect of this feasibility study, the primary public transport services currently operating within the Penarth-Cardiff and the Bay area are:

- Local train service between Cardiff and Barry;
- Bus Services in Penarth and Cardiff Bay (mainly operated by Cardiff Bus, but also by Watts Coaches);

Although there are opportunities for interchange, there is no formal timetable co-ordination between bus services nor for bus-rail transfers. Consequently it is likely that there are relatively few journeys which involve interchange made using the current network.

Figure 2.2 illustrates the routes of current bus and rail services, a large format version of this figure is provided in Appendix A.

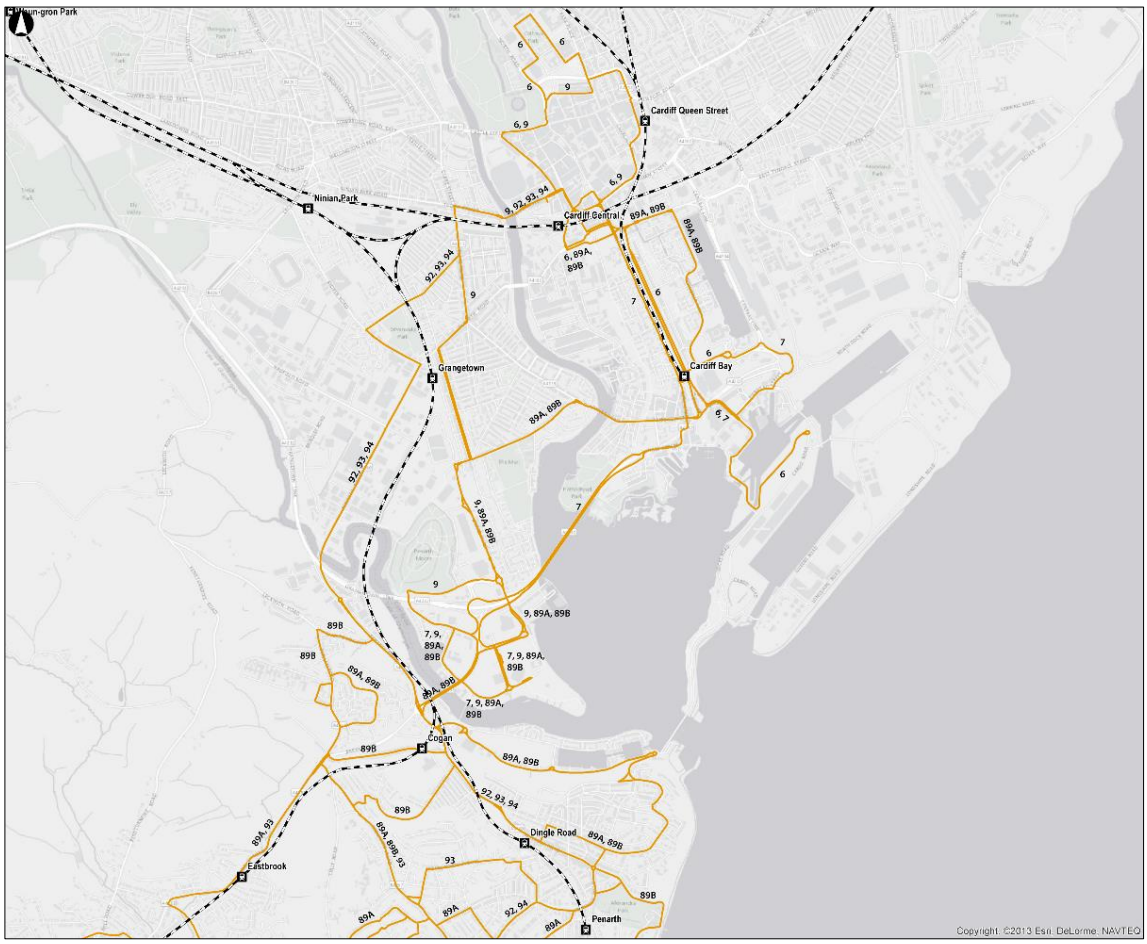


Figure 2.2: Public Transport Network in and around study area

Existing Rail Services: Cardiff is served by a combination of the South Wales Mainline (SWML),which provides for intercity journeys between London and Swansea via Cardiff Central, and the Valley Lines network which provides a regional rail service with Cardiff

Central/Cardiff Queen Street stations at the centre of a network. The Valley Lines network, operated by Arriva Trains Wales, covers much of south east Wales including stations in the Cardiff Bay and Penarth areas. The routes most relevant to this study are shown in Table 2.1, and are:

- The Cardiff Bay Line which is a short spur line between Cardiff Queen Street and Cardiff Bay;
- The Vale of Glamorgan Line between Cardiff Central/Cardiff Queen Street to Barry Island/Bridgend. This route also serves Cogan station, located around 1.3km northwest of Penarth town centre; and
- The Penarth Line which is a spur line from the Vale of Glamorgan Line serving stations at Dingle Road and Penarth. The line terminates at Penarth.

Table 2.1 Existing Rail Services between Cardiff City Centre, Bay and Penarth

Line	Key stations served[1]	Typical Service Frequency and Duration	
		Monday – Saturday	Sunday
Cardiff Bay	Cardiff Queen Street, Cardiff Bay	12 min First: 06:42 Last: 23:53	12 min First: 09:00 Last: 18:48
Penarth	Cardiff Queen Street, Cardiff Central, Dingle Road, Penarth	Daytime 15 min Evening 30 min First: 06:02 Last: 23:26	Every 2 hours First: 10:31 Last: 20:31
Vale of Glamorgan	Cardiff Queen Street, Cardiff Central, Cogan	Daytime 15 min Evening 30 min First: 05:34 Last: 23:30	3 per hour First: 08:25 Last: 22:25

The table highlights that all three of these lines benefit from high frequency services Monday to Saturday with lower frequency Sunday services.

Existing Bus Services: There are a number of services which operate between Cardiff and Penarth, which currently travel through Grangetown and onwards to Cardiff City Centre. Details of local frequent bus services are summarised in the Table 2.2.

Service 6 'BayCar' provides a good connection between Cardiff Bay, Cardiff city centre and Cathays Park area. This service calls at several stops in Cardiff Bay including the BBC Roath Lock Studio, Wales Millennium Centre and Cardiff Bay Railway station. The service currently deviates from the direct route to serve County Hall during daytime hours.

Travel by bus between Penarth and Cardiff Bay involves transfer between buses (which is most convenient near Cardiff Central Bus Station.

Table 2.2: Local Bus services

No.	Route	Typical Frequency/Duration		Operator
		Monday - Friday	Saturday	
6	Porth Teigr (BBC Roath Lock Studio) – Cardiff Bay – Cardiff city centre	Daytime 10 min Evening 20 min First: 06:28 Last: 23:05	Daytime 15 min First: 07:00 Last: 23:05	Cardiff Bus

7	International Sports Village – Cardiff city centre	Daytime 30 min First: 07:52 Last: 18:11	Daytime 30 min First: 08:01 Last: 17:31	Cardiff Bus
9	International Sports Village – Cardiff city centre	Daytime 20 min Evening 30 min First: 06:38 Last: 22:55	Daytime 20 min Evening 30 min First: 07:10 Last: 22:55	Cardiff Bus
89A	Dinas Powys – Llandough – Cardiff Bay – Cardiff	Daytime 2 hours First: 07:50 Last: 16:00	Daytime 2 hours First: 07:50 Last: 16:00	Watts' Coaches
89B	Llandough – Penarth – Cardiff	Daytime 2 hours First: 08:53 Last: 18:53	Daytime 2 hours First: 08:53 Last: 18:53	Watts' Coaches
92	St. Luke's Avenue – Penarth – Cardiff	Daytime 20-30 min Evening 60 min First: 06:17 Last: 22:48	Daytime 20-30 min Evening: hourly First: 06:17 Last: 22:50	Cardiff Bus
93	Barry – Dinas Powys – Penarth – Cardiff	60 min First: 07:32 Last: 17:34	60 min First: 07:48 Last: 17:34	Cardiff Bus
94	Barry – Sully – Penarth – Cardiff	Daytime 30 min Evening 60 min First: 06:14 Last: 22:12	Daytime 20 min First: 07:21 Last: 22:12	Cardiff Bus

The routes listed are illustrated graphically as Figure 2.2.

Collectively the services achieve a good level of coverage in terms of the destinations served and also provide services throughout the days.

The ten minute frequency of Service 6 'BayCar' provides a convenient service with short wait times making it particularly attractive travel option for journeys between Cardiff city centre and Cardiff Bay with a scheduled journey time of 16 minutes.

Furthermore, service 7 provides a quick journey time between International Sports Village and Cardiff City Centre of 16 minutes journey in peak periods.

As outlined in the tender documentation provided by Cardiff Council, severe traffic congestion exists on the route between Cogan Spur and Penarth Town Centre during the peak periods results in unreliable and delayed bus services. The existing bus services between Penarth Town Centre and Cardiff City Centre via Cogan Hill comprise of approximately 8-9 buses per hour in each direction. Feedback from Cardiff Bus suggests that there are significant 5 – 10 minute delays to bus services, and in particular there are queues at the Baron's Court junction (Cogan Spur/Penarth Road).

Integration of services: Travel between Penarth and Cardiff Bay requires passengers to transfer in Cardiff City Centre (bus-bus or bus-rail). This transfer is not specifically timetabled in an integrated manner, and also there is no convenient cross-ticketing for rail and bus travel (since PlusBus is only available for journeys beginning by rail).

2.6 Existing Cycling and Walking Infrastructure

There are several existing walking and cycling routes within and surrounding the local surrounding area which are depicted on the Constraints Plan in Appendix A. On the barrage itself, the walking and cycling routes have the following characteristics:

Penarth Marina to Locks: There is a footway on both sides of the barrage road. Cyclists on this section of the embankment would be expected to travel on the road.

Locks / Bridges: At this section there is a kerbed footway directly alongside the roadway. The footway is approximately 2.5m wide – but has intermittent pinch-points at each bascule bridge where the roadway barrier post is located in the footway.

Pedestrian gates are automatically closed when the bascule bridges are raised. From observation, some pedestrians use roadway instead of the footway – which leads to an unsafe situation due to pedestrians walking in the vicinity of the automatic vehicle barrier.

Sluice Gates: At the sluice gates structure, the footway is present on the south (sea) side and is generally an unobstructed width of around 2.5m (with some road signs poles producing slight width constructions)

Embankment (north side): On this section there is a segregated 3 mm wide footpath on the 'northern' (land) side of the embankment. Cyclists are not allowed to use this footpath and must use the main roadway.

Embankment (south side): On this section there is a segregated 2.5m cycleway on the 'southern' edge of the 6m-wide roadway (separated from the trafficked roadway by a continuous white line marking). Pedestrians are not supposed to use this area of the carriageway. 'Cycle' logos are also present in the traffic lanes which indicates that cyclists are also able to use the normal traffic lanes.

Alexandra House to Cardiff Bay: This section mainly consists of a 4m cycleway / footpath corridor, with cyclists and pedestrian segregated by a continuous white line marking.

2.7 Existing Events and Usage of the Barrage/Embankment

Throughout the year there are events that will have a direct impact on the use of the Barrage/Embankment as well as larger events in Cardiff Bay which are likely to generate increased footfall across the Barrage. The events programmed for 2015 are listed in Table 2.3.

Table 2.3 Cardiff Bay Area Events List for 2015

Event	Date(s)	Days	Location
British Hearts Regatta	22/2	Sun	CBYC & Bay
Welsh Hearts Bunny Hop	4/4	Sat	Roald Dahl Plass & Barrage
Cystic Fibrosis Cardiff Bay 5 Mile (TBC)	4/5	Sat	Barrage & Bay
Cycling Velothon (TBC)	14/6	Sun	Barrage
Extreme Sailing Series	19–21/6	Fri – Sun	Harbour Drive, Barrage & Bay
Cardiff Triathlon	28/6	Sun	Roald Dahl Plass, Barrage & Bay
International Festival of Food & Drink	10 – 12/7	Fri-Sun	Roald Dahl Plass
Cardiff Bay Beach	25/7 – 6/9	12-days	Roald Dahls Plass
Cancer Research Pink and Blue Walk	23/8	Sun	Bay & Barrage
Harbour Festival & P1 Powerboats	30-31/8	Sun-Mon	Roald Dahl Plass, Barrage & Bay
WMC 10th Anniversary Celebration	11-13/9	Fri-Sun	Roald Dahl Plass, & Bay
Noah's Ark Charity Walk	13/9	Sun	Norwegian Church & Cardiff Bay Trail
Alzheimer's Society Memory Walk	19/9	Sat	Roald Dahl Plass and Cardiff Bay Trail
British Water Ski Race	19-20/9	Sat-Sun	Barrage & Bay
Men's Health Survival of the Fittest	27/9	Sun	Roald Dahls Plass & Bay
Cardiff Half Marathon	4/10	Sun	Barrage, Roald Dahl Plass
Welsh Hearts Santa and Elf Dash (TBC)	6/12	Sun	Roald Dahl Plas & Barrage

The majority of events that directly affect the barrage operation occur at weekends with some events commencing on a Friday – and it is concluded that events do not generally coincide with a weekday commuter peak periods.

However, it is clear that the barrage is often unavailable as a 'through road' for vehicular traffic on a number or weekends and bank Holidays (or at least for part of these days). As for other events currently occurring within the Cardiff area (e.g. Rugby international matches), a special 'event' bus service with alternative routing will be needed for a new bus service over the barrage. A 'special event' arrangement for buses which would normally use the barrage could include the following:

- Buses travelling from Penarth make a stop at the Penarth end of the Barrage for un-loading and/or collecting passengers;
- Buses will then follow Penarth Portway/Terra Nova Way onto the A4055 and over the A4232 bridge towards Cardiff. Given that the events are likely to occur at a weekend, the background level of traffic is significantly reduced and the journey time would not be as delayed as during a typical Monday-Friday commuter timetable.
- There are then two destination options for the event bus routes.
    - Either a direct service into Cardiff Bay via Stuart Place, Bute Place and onto Pierhead Street if the intended destination is Mermaid Quay and the Bay area; or
    - An alternative route would be through the A4232 tunnels and into the Cardiff Bay via Tyneside Road. This alternative route could link back to the eastern side of the Barrage embankment and make a stop here before recommencing the typical bus route through the Bay and into Cardiff City Centre.

2.8 Existing vehicular use of the Barrage/Embankment

The barrage roadway has a width of 6m, plus an at-grade 2.5m wide cycle strip, and is subject to a 20mph speed limit along the embankment, and a 5mph limit along the sluice and lock structure, which has automatic barriers at each of the three bridges (with separate smaller barriers at the pedestrian walkways); a photograph of this location in shown in Figure 2.3.

The 'lock/bascule bridge' section has a one-way 'give-way' shuttle operation at its western end (with automatic barrier operation, see Figure 2.4). This arrangement allows vehicles to be stopped from entering the Barrage (from the Penarth end) when the bascule bridges are raised (and there are separate half-length barriers at each side of the road to stop traffic from entering each of the three bridges).

Currently there are a number of permitted vehicles that use the route over the Bay Barrage:

- Occasional tourism related vehicles;
- Employee cars;
- Heavy Goods Vehicles for maintenance and deliveries to Alexandra House;
- Cars accessing the sailing school (but vehicle numbers are limited); and
- Emergency Vehicles.
- The Vale of Glamorgan has previously operated a bus which entered the barrage car park (on the Penarth side) and turned around there; this is no longer operating in this way. School buses occasionally pass over the lock and sluice bridges – carrying school children to the sailing school area. This usage has reduced due to financial cuts to school budgets.

The employee cars have not been counted but from visual observations the maximum normal volume is estimated at 10-20 vehicles per hour. From observation it is noted that pedestrians generally walk on the footways adjacent to the road, with occasional pedestrians walking on the roadway across the bascule bridges and sluice gate structure during periods when no vehicles are passing along the barrage.

At weekends and during busy periods such as Bank Holidays and 'events', the access road along the barrage is often heavily used the public both on foot and on bicycles.

Figure 2.3: Bascule Bridges and Automatic Barriers

Figure 2.4: Photograph of Vehicle Access to Western End of Barrage

2.9 Car Parking

At the western end (towards Penarth) there is a Pay & Display public car park. At the eastern end of the barrage embankment there is also a car park area adjacent to Queen Alexandra House (in which the Cardiff Bay Harbour Authority (CHA) are based). This is not presently a publically accessible parking area as it can only be reached either from the Barrage or through Cargo Road (via ABP port land).

There is a short section of on street parking on the embankment directly to the east of the sluice gate structure – with a single disabled parking bay.

2.10 Bay Road Train

The bay road train runs across the embankment (from Cardiff) onto the large quay area just east of the Barrage Control centre (and turns around there without crossing the bascule bridges). The road train is a privately owned business, and operates (with the agreement of ABP) via Cargo Road. It is typically operated between April and September and is most well used during school holiday periods. The train is often pre-booked for parties such as schools, clubs, associations, senior citizens, and educational groups.

The road train leaves Stuart Street opposite Techniquest on the hour from 11am until 4pm and also from the Penarth end of the Barrage half past the hour from 11.30am until 4.30pm. Live commentary is provided to the Barrage. The round trip takes approximately 50 minutes with a 10 minute break at the Barrage.

The road train travels via Cargo Road and hence has to drive through the secondary secure gate entrance just north of the Sailing School / Environment Building. The road train driver has keys opens and closes the gate on every journey, and has to leave the driving position to do this every trip.

The Bay Road Train has a charge of £4 per adult (return trip) and £3 (return trip) for a junior.

Figure 2.5: Photograph of Cardiff Bay Barrage Road Train

3 Existing Policies and Plans

3.1 National Transport Plans and Planning Policy

Transport policy and proposals for Wales are supported through a number of different national transport plans and planning policy strategies namely the:

- The National Transport Plan;
- The Wales Spatial Plan (WSP);
- Planning Policy Wales (PPW);
- Technical Advice Note (TAN) 18;
- Regional Transport Plan, South East Wales Transport Alliance, 2010;
- South Glamorgan (Cardiff Area) Replacement Structure Plan, Cardiff Council. 1991-2011;
- Cardiff Council Deposit Local Development Plan, Cardiff Council. 2006-2026.

Some relevant overarching objectives are as follows:

- Reducing greenhouse gas emissions and other environmental impacts from transport;
- Integrating local transport;
- Improving access between key settlements and sites;
- Enhancing international connectivity; and
- Increasing safety and security.

The South East Wales Transport Alliance- Regional Transport Plan sets out a regional focus for the Wales Transport Strategy and furthers the aspirations of the Wales Spatial Plan. The Regional Transport Plan outlines a commitment to improving the reliability and running times of buses and to improve the quality of many services, to integrate bus services and expand the coverage of the bus network.

3.2 Local Planning Policy Documents

Local planning policy documents have been reviewed and items relevant to the barrage bus service proposal have been identified, as set out in the following paragraphs.

South Glamorgan (Cardiff Area) Replacement Structure Plan 1991-2011: The development plan for Cardiff Council comprises the South Glamorgan (Cardiff Area) Replacement Structure Plan 1991-2011[1] and the City of Cardiff Local Plan 1996.

Of relevance to the Cardiff Barrage proposals, Policy MV3 of the Structure Plan supports highway and public transport developments which will enhance the regeneration of Cardiff Bay, including its linkages to and within the City Centre.

Additionally, Policy MV8 promotes the provision of an integrated transport system within Cardiff Bay and particularly emphasises high priority for the provision of public transport and facilities for those wishing to travel to the Bay by modes other than car.

[1] South Glamorgan (Cardiff Area) Replacement Structure Plan, Cardiff Council. 1991-2011

Cardiff Council Deposit Local Development Plan 2006-2026: The Cardiff Council Deposit Local Development Plan 2006-2026 is currently at Examination Stage and therefore could be considered as a material consideration for the proposed bus route at Cardiff Barrage.

The plans emerging policy EC1.2 Cardiff Port (& Heliport and surrounds), allocates the land at Cardiff Port for B1, B2 and B8 uses and states this area will be protected for B Use Class employment generating uses (together with ancillary and/or complementary uses and activities as referred to in Policy EC2).

Policy EC2 supports the provision of complementary facilities for employees in business, industrial and warehousing developments in Cardiff Port.

Policy T2 supports strategic rapid transport and bus corridors. The policy states that to avoid car-based developments and maximise use of sustainable transport, infrastructure and associated services will be introduced to develop strategic rapid transport and bus corridor enhancements.

Additionally, Policy T8 looks to maintain strategic recreational routes including The Bay Trail. The policy states that a strategic network of recreational routes will be maintained and developed to link Cardiff's coast, river corridors, open spaces, countryside, and the regional network of routes, facilitating access to them by local communities, and forming an integral part of the wider cycling and walking network in Cardiff.

Vale of Glamorgan Adopted Unitary Development Plan 1996-2011: The development plan for the Vale of Glamorgan comprises the adopted Unitary Development Plan (UDP) 1996-2011.

The UDP identifies Cardiff Barrage within an area of Developed Coast, which may provide opportunities for restructuring and regenerating existing urban areas. Additionally, Penarth and Cardiff Barrage are located within an Aviation Safeguarding Zone.

Policy REC 12(ix) protects and maintains the footpath around Penarth Head including the provision of a cycle path. Additionally, Policy TRAN 9 protects the barrage land and makes provision for cycle routes between the Vale of Glamorgan and Cardiff.

Policy TRAN 7 promotes the Vale of Glamorgan's strategic public transport and states that land will be protected and provision made for the development of facilities for bus operations including between Penarth and Cardiff.

Vale of Glamorgan Deposit Local Development Plan 2011-2026: The Vale of Glamorgan Deposit Local Development Plan is currently at late stages of preparation and therefore could be considered as a material consideration for the proposed bus route at Cardiff Barrage.

Emerging Policy MG 16(01) allocates and safeguards national cycle network Route 88 and associated local urban and rural connections. Policy MG 16(11) further allocates Lavernock Road to Cardiff via the Barrage as a bus route. This allocation is supported by the authorities' need to consider a park and ride facility at Cosmeston to cater for buses accessing Cardiff via the Barrage.

Policy SP7(9) also prioritises the delivery of strategic transportation and allocates the Lavernock Road to Cardiff via the Barrage as a bus priority measure.

3.3 Cardiff Barrage Act 1993

3.3.1 Carrying Out Works

The scope for carrying out works associated with implementing a bus service across the barrage has been investigated. The Town and Country Planning (General Permitted Development) Order (GPDO) 1995[2] sets out permitted development rights for certain types of development, and Part 11 of Schedule 2 affords permitted development under Local or Private Acts or Orders. Under Part 11: Class A permitted development is authorised by:

a) a local or private act of parliament;

b) an order approved by the both Houses of Parliament; or

c) an order under section 14 or 16 of the Harbours Act 1964 (orders for securing harbour efficiency etc…, and orders conferring powers for improvement, construction etc. of harbours)

Which designates specifically the nature of the development authorised and the land upon which it may be carried out.

In accordance with Part 11 of the GPDO and the extract from the Cardiff Barrage Act outlined below, it is considered that the proposed development may be constructed under permitted development rights where it falls within Cardiff Harbour Authorities land ownership (previously Development Corporation land ownership).

Extract of Cardiff Barrage Act 1993[3]

Schedule 1 Construction of barrage etc. and other works.

(1) The Cardiff Bay Development Corporation (referred to in this Act as "the Development Corporation") may in the City of Cardiff and the Borough of the Vale of Glamorgan, in the County of South Glamorgan, execute the works specified in Schedule 1 to this Act, being the construction of—

(a) a barrage across the mouth of Cardiff Bay, with an outer harbour, and

(b) certain associated structures.

(2) The Development Corporation may also—

(a) maintain, and

(b) (where appropriate) alter, replace or re-lay,

(3) Subject to subsection (4) below, works authorised by subsection (1) or (2) above shall be executed in the lines or situations shown on the deposited plans and according to the levels shown on the deposited sections.

(4) The Development Corporation may—

(a) deviate laterally from the lines or situations shown on the deposited plans to any extent within the limits of deviation, and

[2] The Town and Country Planning (General Permitted Development) Order 1995
[3] The Cardiff Barrage Act 1993

(b) deviate vertically from the levels shown on the deposited sections to any extent not exceeding three metres upwards and to any extent downwards.

(5) The Development Corporation may, within the limits of deviation or elsewhere within the inland bay, execute any building or other construction works (including installing any apparatus and providing, or securing the provision of, any services) which may be necessary or expedient for the purposes of, in connection with or in consequence of the works authorised by subsections (1) and (2) above.

(6) In this Act "the inland bay" means the area bounded—

(a) by the seaward face of the barrage or, before the barrage is completed, by the line of construction of the seaward face of the barrage as planned at the commencement of its construction, and

(b) otherwise by the inner edge of the line shown coloured pink on the inland bay map;

and in this subsection "the inland bay map" means the map marked "Inland Bay Map" which was deposited in November 1991 in connection with the Cardiff Bay Barrage Bill in the office of the Clerk of the Parliaments and the Private Bill Office of the House of Commons.

Schedule 24 Planning Permission

(1) Planning permission shall be deemed to have been granted under Part III of the Town and Country Planning Act 1990 for any development of land consisting in the carrying out of any works or other operations authorised by this Act or the making of any change in the use of land by the carrying out of any such operations.

(2) Nothing in section 91 of that Act (limit on duration of planning permission) shall apply to the planning permission deemed to have been granted under subsection (1) above.

It is considered therefore that certain works as part of the proposed development that fall within the Harbour Authority land holding could be delivered through the GPDO.

However, it is important to note that these permitted development rights are not afforded to the Welsh Government or ABP and therefore a full planning permission will be required for any development within their land ownership boundaries and/or outside of land owned or operated by the Harbour Authority.

3.3.2 Passage of Vessels

As well as certain powers to undertake operations on the barrage, the Act also legislates the operation of the barrage in relation to the passage of vessels which could impact on the future operation and timetabling of any bus route using the barrage.

Section 7 of the Act provides the Power to Operate the Barrage and states:

(1) The Development Corporation shall have power to operate the barrage; and in this Act references to operating the barrage are references to—

(a) opening or closing any lock gates, sluices or gates in the barrage,

(b) controlling the flow of water in the fish passes in the barrage, or

(c) managing any roadway, bridge or other structure or equipment forming part of the barrage.

Section 13 of the Act covers Use by vessels and for recreational purposes and states:

(1) The Development Corporation shall manage the inland bay and the outer harbour so as to facilitate their use—

(a) by pleasure craft and other vessels, and

(b) for water sports and other open-air recreational activities.

(2) In managing the outer harbour the Development Corporation shall secure that it is at all times available for use by pleasure craft and other vessels which—

(a) are about to pass to, or have recently passed from, the inland bay, or

(b) need to use it as a harbour of refuge.

It is clear therefore that the Harbour Authority has a duty to allow vessels to pass unhindered through the Barrage, and that a bus operation along the Barrage would need to be subservient to the passage of vessels.

3.4 Environmental Constraints

The bus route corridor is not within an area that is designated for environmental or landscape protection, or situated within a Conservation Area.

Two Grade II listed buildings, Penarth Dock Custom House and Penarth Dock Marine Building, are located within 40m of Cardiff Barrage however the proposed bus service would not adversely impact on their setting. The Severn Estuary Special Protection Area, Special Area of Conservation, Special Site of Scientific Interest and Ramsar Site are located south east of the Barrage. Additionally the Cardiff Bay Wetlands Reserve is located north of the Barrage. Figure 01 in Appendix A shows all relevant constraints in respect of environmental characteristics.

Both the Severn Estuary and Wetlands Reserve would have to be considered in light of any proposed works to prevent any adverse effects; however a bus service would not be expected to present any negative impacts.

Surface water run-off from the carriageway currently drains into the bay with no filtration in place. CHA are aware that a low risk exists of a possible oil spills into the enclosed bay from a vehicle incident on the barrage. A scheduled bus service would be operated using vehicles subject to regular maintenance, and driven by trained professional drivers; hence a risk of an incident with fuel or oil spillage is considered to be highly unlikely to occur on the embankment road. The embankment road is subject to a 20 mph speed limit, whereas the section through the Bascule Bridges is subject to a 5 mph limit.

3.5 Conclusions (Policies and Plans)

A review of the local policies and Barrage Act has established that there are no significant obstacles preventing implementation of a new bus route over the barrage. The passage of vessels will need to be prioritised in when considering a timetabled schedule of bus movements and this is described in section 5.0.

4 Bridge Structure Investigation

This section provides a summary of the desk study review and consultation undertaken with regard to the bridge structure.

4.1 Description of the Structures

The structures at the western end of the Cardiff Bay embankment consist of the following elements:

- 3 separate, single span Bascule Bridges; these comprise of steel superstructure and towers supported on reinforced concrete piers (see photograph in Figure 4.1), which are in turn supported on pad foundations. One of the pads is supported on H piles. The deck comprises of a steel plate with trough stiffeners welded to the underside. Known as orthotropic deck.
- The spans between the bascule bridges are constructed of reinforced concrete and share foundations with the bascule bridges.

No details were provided on the Sluice gate structures at the eastern end of this section. A site walkover identified the visible parts of the structures as consisting mainly of reinforced concrete. No significant defects were reported by CHA.

Figure 4.1: Bascule Bridge at Cardiff Bay Barrage

4.2 Investigations

An investigation of the condition of the bridge, and its ability to carry buses on a regular basis, was carried out on a 'desk study' basis; with no in-situ testing of materials or detailed inspection carried out.

In respect of input information, records were requested from the Cardiff Council and the Cardiff Harbour Authority, as a result of which an incomplete set of as-built drawings (see Figure 4.2) were provided by the Cardiff Harbour Authority. These do not give details of the steelwork forming the deck of the bridges. No other information was provided for review. In particular the Health and Safety Files for the structure were not available. It is understood that these document have been lost over the period after construction - and have been subject to previous searches prior to this study.

The Health and Safety Files would provide information on the designed loads and design life of the structures, as well as a record of the inspections undertaken and a full set of as-built drawings.

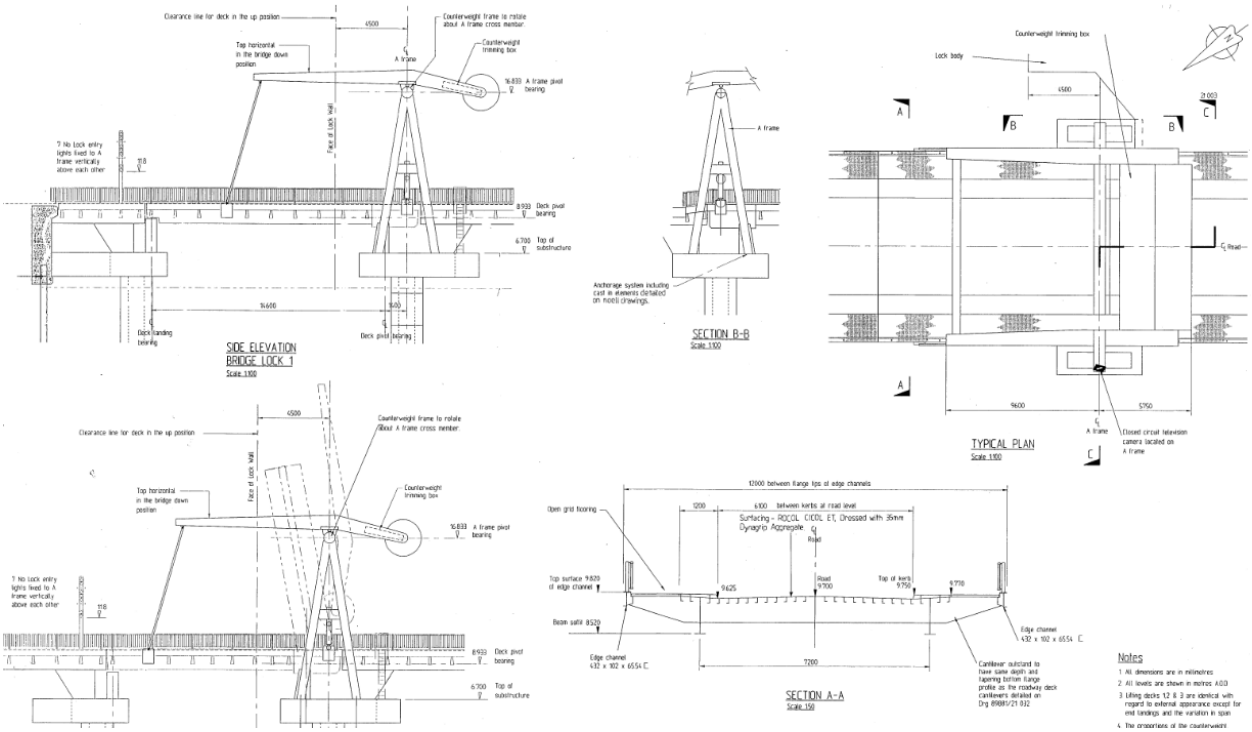


Figure 4.2: Excerpts from As-Built Drawings for Bascule Bridge

4.3 Site Visit with the Harbour Authority

A site visit was carried out with Chris Seddon from Cardiff Harbour Authority. Visual inspection of the bridge and sluice gate structures shows that there were no significant visible defects to the paintwork and no large areas of rust observed.

The Cardiff Harbour Authority representative advised the following:

- The bridges do carry large vehicles (cranes, lorries, coaches and buses), but not regularly.
- There are no known significant defects in the concrete bridges sections between the bascule bridges.
- There are no known significant defects affecting the carrying load capacity of the sluice gate structures.

The Cardiff Harbour Authority have informed Arup of an issue with all bascule bridges, which resulted in the requirement for strengthening works. No documentation has been provided, but Arup's understanding of the issue, based on various discussions and a site visit is as follows:

- Cracks in sections of the steel deck were found during an inspection. These were found in the crossbeam connecting the hydraulic lifting arm to the longitudinal beams in the bridge.
- An assessment revealed that the cracks were related to the stresses caused by the bridge lifting mechanism.
- An assessment involves using the detailed drawings and site inspection of the bridges condition to numerically calculate the bridges weight limit.
- Strengthening works were undertaken.
- The strengthening works were local to the crosshead only.
- No general assessment has been carried out for the bridges and the weight limit is unknown.

4.4 Issues to consider for bus operation

There are two main factors to consider when determining the traffic weight limit of the bridges:

- **Ultimate Limit State:** Defined as the requirement for the bridges strength and stability to support their self-weight and imposed loadings such as vehicles. Whilst the carrying capacity of the bridges are unknown, the Cardiff Harbour Authority have advised that the bridges do carry heavy vehicles.
- **Fatigue:** Fatigue arises from cyclic or repeated loading from heavy vehicles. Orthotropic deck plates are well known for fatigue failures (for example the Severn Bridge, which required extensive remedial works). The repeated loading associated with a regular bus service increases the fatigue risk.

4.5 Conclusions (Structures)

The Cardiff Harbour authority have advised that the bridges accommodate heavy vehicles on a relatively infrequent basis. A visual inspection of one of the bascule bridges found no significant visual defects to the paintwork or areas of corrosion.

However, no information has been provided that either states the design carrying capacity of the bridges. Furthermore, the level of detail shown on the as-built drawings provided is not sufficient to be able to calculate the carrying capacity. Therefore, the carrying capacity of the bridges at ULS or fatigue loading conditions could not be determined from this investigation, although it should be noted that a regular bus service will increase the frequency of loading on the bridges, which does increase the risk of fatigue.

To better understand the bridges, the following recommendations are proposed:

- **Locate the Health and Safety Files or missing as-built information for the bridges.** If not already done so, it is recommended that the companies involved with the design and construction of the structures are contacted and information requested from them. Further information on the carrying capacity of the bridges could then be determined, depending on the level of information found from this search.
- **Undertake further structural investigations.** This would involve detailed inspections of all bridges to record their condition and identify the critical deck details. Strain gauges could then be installed on the critical details. The results from the strain gauges could be used to assess for both the fatigue and ULS capacity of the bridge decks.

5 Existing Barrage Operations

The section reviews the existing bridge lifting operation and information regarding the general operational management and maintenance of the Barrage/Bridge structure together with the sluice gates.

5.1 Lock / Bridges Operation

The boat locks and bascule bridges operate together to allow boats to navigate between the Severn Estuary and the enclosed water of Cardiff Bay. The sequence of operation includes periods when one or more of the bascule bridges are in the 'up' position with automatic barriers across the barrage roadway (at both ends of each bascule bridge) to stop traffic and pedestrians. The lock operation has a formal schedule based on the following schedule:

- Boats moving out to the Severn Estuary at 00 and 30 minutes past each hour
- Boats moving in to the enclosed Cardiff Bay at 15 and 45 minutes past the hour

It is important to note that the bascule bridge operation schedule is separate from the lock gate operations; that is, the bascule bridges have to be open to allow boats to move from (or to) Cardiff Bay, but they do not need to be raised when the lock water levelling is in process. Consequently, the 30 minute lock schedule set out above effectively creates a 30 minute cycle for movement or road traffic across the bridges. The length of time for which the bridges are raised is they key determinant of whether bus movements could be accommodated..

In practice, the timing of the lock and bascule bridge operations varies from the formal schedule (especially at periods of medium/low movement of boats), and some variation of the schedule occurs e.g. lengthening of a lock gate opening period to allow late arrivals to avoid missing the 'slot'. This ad -hoc variation from the formal schedule is possible since traffic movement across the barrage is relatively low – and consists mainly of employees from the Harbour Authority.

5.2 Lock / Bridges Operations Timing

The sequence of operation of the bridge lifting and closing is replicated in the indicative stage sequence in Figure 5.1. The diagrams/timings/outputs are based on CCTV footage of the Barrage and consultation with Harbour Authority, and on surveys of bridge access periods.

A typical schedule of 'traffic access' (i.e. bridges in 'down' position) is set out in Table 5.1. This shows that the bridges are raised generally for periods of up to 15 minutes, with an average of 6-7 minutes; that is, the length of time for Phases 4,5 and 6 (in Figure 5.1) is around 6-7 minutes, during which time the bascule bridges are raised and hence closed for passing vehicular traffic. As can be seen by Table 5.1, on the day of the survey the period between vehicular access closures was recorded as around 30 minutes; however, at busy periods this would be expected to be around 15-20 minutes.

In respect of the potential to carry a scheduled bus services, from discussion with CHA, the 'maximum' lock schedule would result in a '30 minute' schedule of raising/lowering the bascule bridges (based on 'in' and 'out' vessel movements at 00 / 30 minutes and 15 / 45 minutes past the hour respectively, as described in Section 5.1). Assuming that the bridge access survey is a good representation of the vehicular access period, it is concluded that a maximum practical vehicle access schedule would consist of closures of say 10-15 minutes every 30 minutes (and hence an access period of around 15-20 minutes every 30 minutes.

A review of CCTV footage provided by the Cardiff Harbour Authority was undertaken and a snapshot phased bridge lifting sequence was estimated based on the available data.

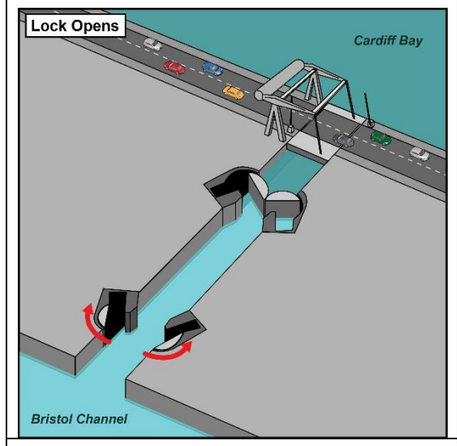
The time for which the bridge is lifted and closed for traffic is approximately 6-8 minutes. Figure 5.2 represents an indicative sequence for a single lock carrying vessels in both directions, giving a 38 minutes cycle, for which the bridges are available for traffic access for around 30 minutes.

Figure 5.2: Indicative Sequence for Bascule Bridge based on CCTV survey

Typical Single Lock Sequence	Road Access Open / Closed	Minutes	Comments
1 Estuary Lock Gates open		2	*Road access*
2 Vessels Enter Lock (towards Bay)		12	*Open 30 minutes*
3 Vessels in Lock / Water Raised		7	
4 Bascule Bridge Raised		2	
5 Bay Lock Gates open / Vessel exits to Bay		2	*Road access*
6 Vessels Enter Lock (towards Estuary)		2	*closed 8 minutes*
7 Bascule Bridge lowered		2	
8 Vessels in Lock / Water lowered		7	
9 Estuary Lock Gates open		2	
Total Cycle Time		**38**	

It should be noted however that at busy periods the Harbour Authority utilises two or three locks to enable a higher movement of vessels to be accommodated.

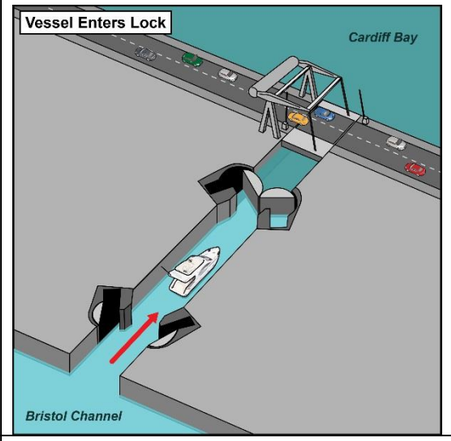
Figure 5.1: Lock and Bascule Bridge Sequence of Operation



Phase 1

‘Estuary’ lock gates are opened.

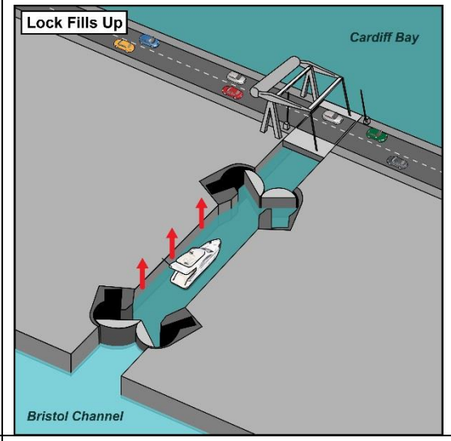
Bascule bridges in ‘down’ position (and open to road traffic)



Phase 2

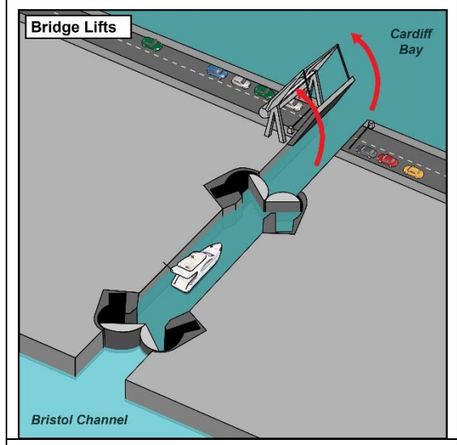
Boats move into lock from Estuary.

Bascule bridges in ‘down’ position (and open to road traffic)



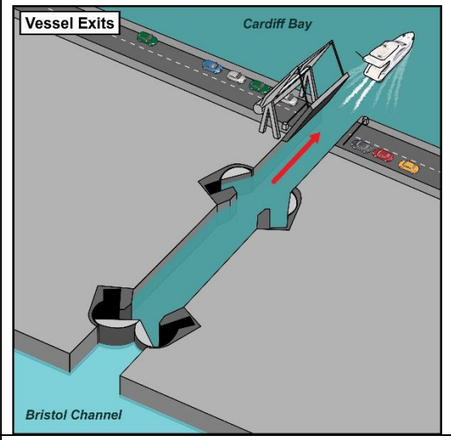
Phase 3

Water level is adjusted while the vessel is in the lock



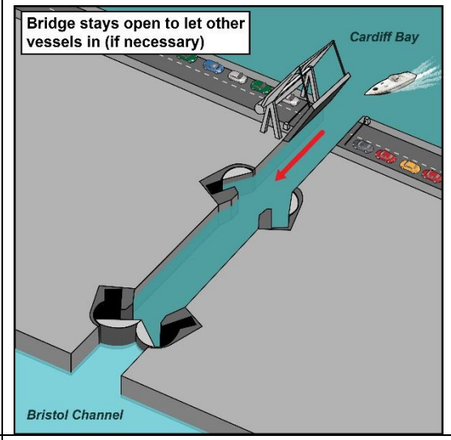
Phase 4

The Bascule Bridge is raised to allow vessels to pass



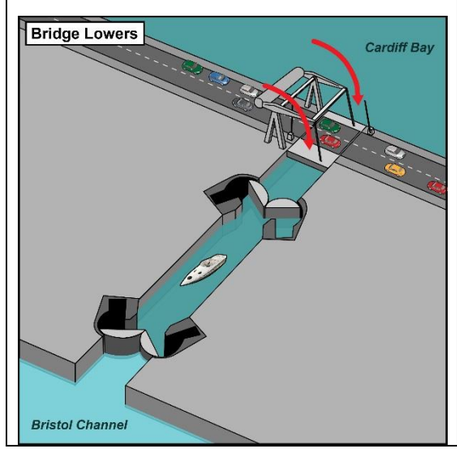
Phase 5

When water level matches with the adjacent water level, the lock gates are opened.



Phase 6

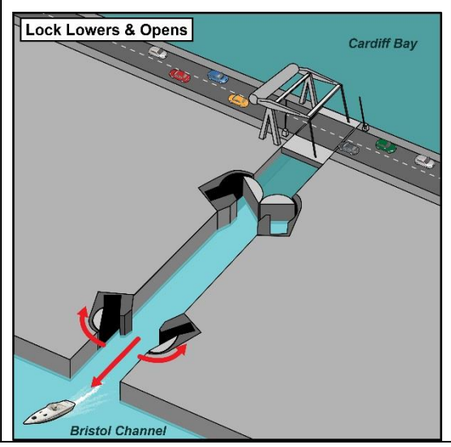
Bridge is lowered or remains in raised position if vessels are waiting to exit



Phase 7

Bridge is lowered

Lock water level lowered



Phase 8

Lock opens to allow vessel out to Estuary

Bascule bridges in ‘down’ position (and open to road traffic)

Table 5.1: Vehicle Access Survey

Time of Vehicular Access			Time between Vehicular Access restrictions
Access Closed	**Access Opened**	**Access Restriction Period**	
07:03	07:06	00:03	-
07:24	07:32	00:08	00:21
07:51	07:57	00:06	00:27
08:19	08:34	00:15	00:28
08:52	09:01	00:09	00:33
09:03	09:06	00:03	00:11
09:12	09:14	00:02	00:09
09:15	09:25	00:10	00:03
09:53	09:58	00:05	00:38
10:24	10:31	00:07	00:31
10:51	10:57	00:06	00:27
11:49	11:55	00:06	00:58
12:25	12:37	00:12	00:36
12:57	13:09	00:12	00:32
13:36	13:46	00:10	00:39
14:24	14:33	00:09	00:48
15:04	15:11	00:07	00:40
15:41	15:48	00:07	00:37
16:23	16:32	00:09	00:42
16:55	17:01	00:06	00:32
17:15	17:19	00:04	00:20
17:54	18:01	00:07	00:39
	Average	**00:07**	**00:31**
	Min	**00:02**	**00:03**
	Max	**00:15**	**00:58**
	SD	**00:03**	**00:13**

Note: Survey undertaken by Cardiff County Council, 18.08.2012

5.3 Scheduled Maintenance

All five sluices require maintenance every year for a number of weeks. During this work, which mainly takes place over the Spring/Summer period, the northernmost lane of the barrage roadway is coned off adjacent to the sluice being worked on (and the coned area 'moves' along the roadway over a period of months).

Lock maintenance requirements involves scheduled closures of one of the three locks for a period of days – which can extend the closure time of the vehicular access due to the reduced operational flexibility with only 2 locks in operation.

5.4 Other Barrage Operational Issues

A number of issues which could have impacts on a proposed bus service have been identified as follows:

- High numbers of pedestrians on the bascule bridges during certain periods (especially at weekends and for events, with a typical Sunday footfall peak of around 400/hr);
- Movement of salt water is an issue which has to be addressed carefully by CHA, and the maximum 15 minute schedule of lock gate opening / closing also limits the time available for salt water ingress into the bay;
- There are particular occasional high tides which precludes operation of the locks (for a period of around 4 hours) to avoid salt water ingress into Cardiff Bay;

5.5 Conclusions (Barrage Operations)

Key conclusions relevant to operating a schedules bus service are as follows:

- A review of the lock and bascule bridge operations indicates that a vehicular access time would be around 15-20 minutes every 30 minutes i.e. the roadway would be closed to traffic for 10-15 minutes every 30 minutes;
- This 30 minute schedule would operate with ‘priority’ to seagoing vessels in order to comply with the Barrage Act; that is, any cases of interruptions or delays in the schedule would be resolved with priority given to boat movement at the expense of vehicular movement;
- It is clear that there are likely to be occasions when vehicular access across the barrage would be subject to delay due to unscheduled occurrences such as higher than normal boat movement, slow movement of boats through the locks, and reduced capacity of the locks during maintenance periods.

Overall therefore, the ‘maximum’ bus service that could theoretically be operated is a 30 minute frequency service, with a ‘window’ of opportunity’ for vehicle movement across the lock/bridges structure of around 15-20 minutes every 30 minutes.

A theoretical 60 minute schedule of lock operation (based on the harbour Authority’s current formal schedule) is illustrated in Figures 5.2 and 5.3, for two operational scenarios as follows:

- Lock Schedule for Single Lock Operation; that is, with boat movements in both directions carried within the same lock (Figure 5.2); and
- Lock Schedule for Two Locks in Operation; that is, with boat movements in one direction in each lock – either In or Out of the Bay (Figure 5.2).

Both of these arrangements provide an approximate 15 minute ‘window’ for bus movement, twice per hour.

Figure 5.2: Possible Lock Schedule for Bus Operation (Single Lock Operation)

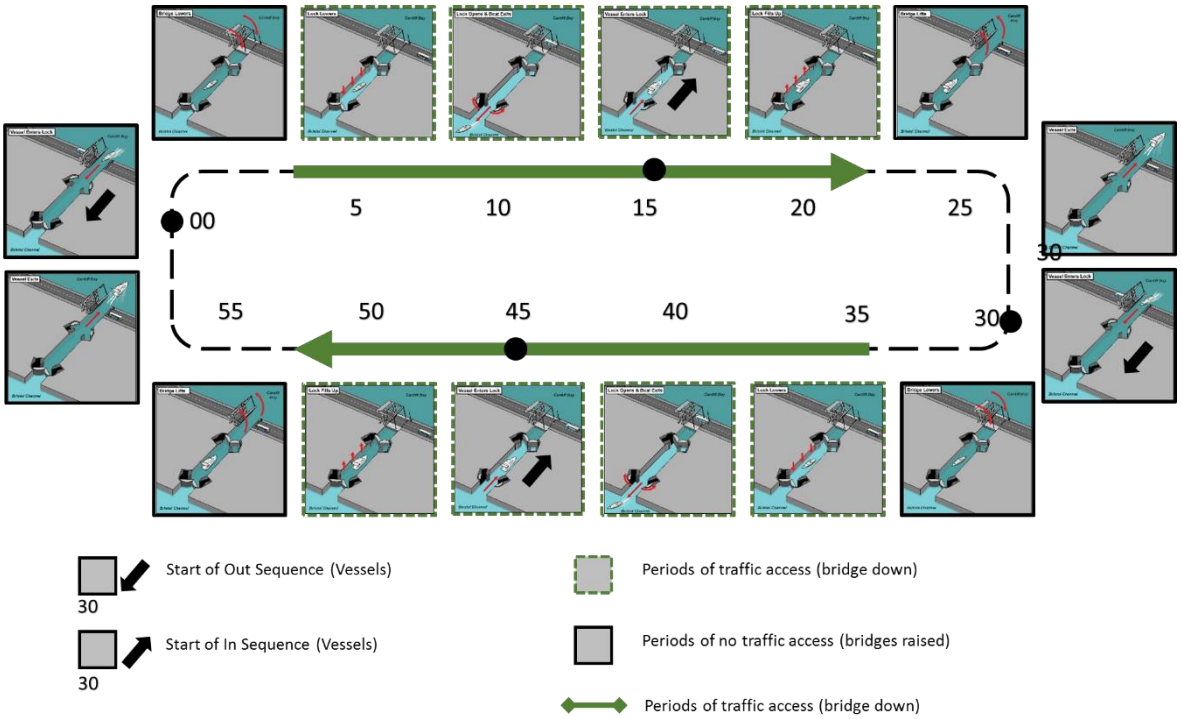
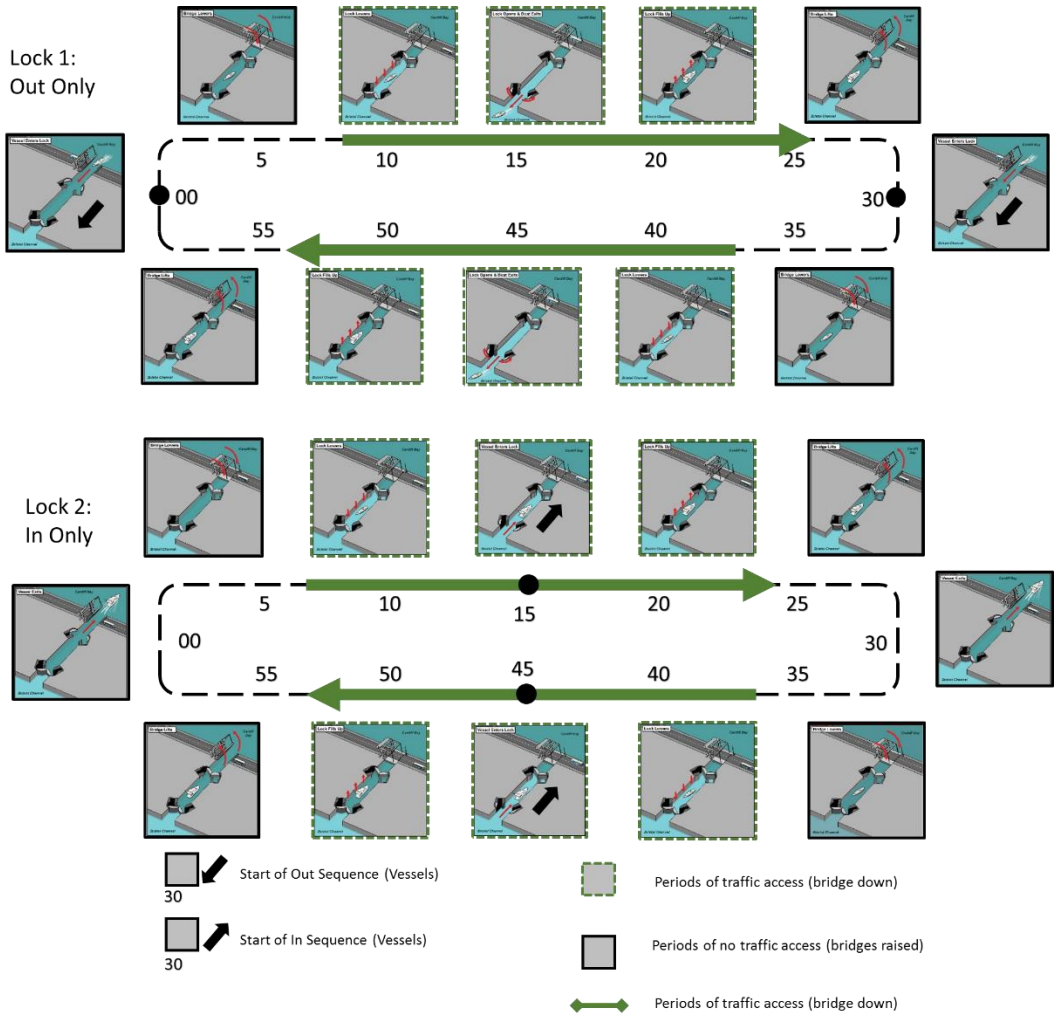


Figure 5.3: Possible Lock Schedule for Bus Operation (Two Locks Operation)



6 Bus Operations Options

This section considers the findings of the baseline investigation and identifies an outline arrangement for bus operations in respect of frequency and related scheduling issues.

6.1 Outline Bus Service Types

It is useful to initially outline a potential bus service which may use the barrage route in order to assess the feasibility of operating the service. From the Brief, a schedule of 48 services per day was set out as an objective. During the study inception process it was agreed to assess a wider range of service provision. Hence, for purposes of this study, a range of notional services have been identified – and are used in this study as the basis for assessing the feasibility of establishing a bus service.

Bus Service Type	Services per Day (two-way)	Outline Bus Schedule
15 minute frequency commuter bus service	108	Based on 7am – 7pm at 4 services per hour, plus half-hourly for 3 hours)
Half-hourly shopper / community bus Service	48	Based on 7am – 7pm at 2 services per hour)
Hourly shopper / community bus service	24	Based on 7am – 7pm at 1 services per hour)

A low frequency tourist-type service or 2 hourly service could also be considered if higher frequency services are found to be unfeasible.

6.2 Bus Scheduling Constraints

A key aspect of a barrage bus service is the potential for delays to occur when the Bascule Bridges are ‘open’ for boats and hence closed for traffic. The ’30 minute’ service would be required to adhere to a timetable at all points of the service route; this is important both to attract passengers and to ensure that the service complies with regulations in respect of adhering to its published timetable. It would be necessary therefore for the bus movement through the bascule bridge section to be managed in a systematic way to ensure that passage of the buses is carried out in an organised manner to achieve (as far as possible) compliance with the service timetable.

Similarly, an hourly service would need to adhere to their published timetables; however, there may be scope to have a ‘slower’ journey speed compared to a half-hourly service with some ‘slack’ built in to the timetable. This may require the bus to occasionally ‘dwell’ at bus stops on its route to re-coordinate with the timetable.

A commuter orientated 15 minute frequency service is considered to have a risk of delay due to lock operations, and hence it is recommended that its implementation is considered further only if (and after) a 30 minute bus service has been successfully operated for a period (say 1 year).

6.3 Bus Stops

For a scheduled bus service, it would be possible to locate bus stops at locations as follows:

- Doctor Who Experience;
- Queen Alexandra House (at around 650m from Doctor Who Experience); and
- Barrage Car Park (at western end, about 1700m from Doctor Who Experience).

It may also be feasible to locate a bus stop on the barrage embankment adjacent to the embankment covered shelter – although a pedestrian link between the roadway and the shelter would be required.

Bus stops at each end of the barrage could be used as dwell points to enable buses to re-calibrate to their schedule.

6.4 Special Events

Section 2.7 provides details of numerous public and sporting events which either require the barrage to be closed to vehicular traffic or result in very large volumes of pedestrians – both of which are unlikely to be compatible with operating a scheduled bus service. It would thus be necessary to set out clear arrangements for bus services during these periods – which will mainly be at weekends or on Bank Holidays. It is suggested that an 'alternative' timetable and route could be formally set out and shown on published information. An 'alternative' service could be operated as follows:

- Bus route from the western end of the Barrage at Paget Road (in Penarth Marina) to Cardiff Bay in the vicinity of Britannia Quay/Harbour Drive
- Via Penarth Marina, Cogan Hill, A4232 PDR, and into Cardiff Bay via Stuart Street
- Approximately 5km route length (compared to 2km via the Barrage)
- Could operate a reduced or modified timetable to allow for longer route length
- Generally would only be operated at weekends when congestion delays would be less than those at peak weekday periods.

7 Infrastructure Option Development

This section considers the infrastructure and routing options for operating a bus service according to the notional bus service arrangements set out in Section 6. The infrastructure-related issues are considered in 'sections' – from the southwest side of the barrage (Penarth) through to Heol Porth Teigr at the north-western end.

7.1 Penarth to the Barrage Section

The current '89' service (operated by Watts Coaches) travels via Paget Road and through Penarth Marina. This indicates that the relatively steep incline of Paget Road is able to be negotiated by buses. It can thus be concluded that it is feasible for buses to travel from Penarth to the western end of the barrage.

7.2 Lock/ Bascule Bridge Section

Review of the current traffic management arrangements for the lock/bridges roadway suggests that the current road layout operates well, with a short give-way one-way section at the western access point onto the barrage (which is barrier controlled).

For a scheduled bus service, the number of buses per hour (of between 1 and 4 in each direction) would not be a significant change from currently observed levels of traffic, and hence the barrier systems and interaction with other road users are not considered as major obstacles to implementation. In particular, it is noted that pedestrians are currently supposed to use the footways on the bascule bridges – since walking on the road is unsafe due to both interaction with vertically rising barriers, and with passing occasional traffic. With a bus service in place, the current arrangements for pedestrian movement would remain unchanged.

For cyclists, the current arrangements whereby cyclists travel on the roadway will remain in place, with a 'bypass' of the vehicle entry barrier at the western end.

7.3 Sluice Section

Review of the current traffic management arrangements for the sluice roadway suggests that the current road two-way layout operates well. For periods of the year when a length of the northern lane is coned off for plant maintenance purposes, it is considered feasible to operate a one-way shuttle with priority given to vehicles travelling towards Cardiff. The one-way shuttle would operate 'by eye' and would not need to be signal controlled due to the low levels of traffic flow.

A pedestrian footway is present on the southern side of the roadway – with a metre-strip on the northern edge (and hence not suitable for walking). This arrangement would continue to operate as at present. At the eastern end of the sluice section it would be advantageous to improve the signs and road markings associated with assisting pedestrians to cross the roadway (between the sluice footway) and the embankment footpath on the eastern side of the embankment.

7.4 Embankment Section

On the embankment, the current 6m wide roadway would provide a safe route to carry two-way bus traffic. It is considered advantageous that a greater level of segregation is offered between the roadway and the at-grade cycleway alongside it. This will improve conditions for cyclists using this facility – which will generally be children or slow/leisure cyclists (since commuter cyclists will generally travel on the main trafficked roadway).

7.5 Alexandra Head - Heol Porth Teigr Section

Two main options exist for provision of a bus route from Cardiff Bay (at Heol Porth Teigr / Harbour Road) to the barrage – either via a new busway adjacent to the existing footpath/cycleway, or via Cargo Road (owned by ABP). Use of Cargo Road would require the agreement of ABP – since it is part of the 'secure' port area (and hence subject the national port security regulations).

Figure 7.1 shows two options:

- **Option A** via Cargo Road, with a short new section of road linking the Heol Porth Teigr / Harbour Road roundabout with Cargo Road, and
- **Option B**, via a new busway through land currently owned by Welsh Government but subject to future development plans.

These options are shown in more detail in Appendix B. For this present study, the two options are both considered feasible. Option A is clearly only deliverable with agreement and co-operation from ABP – and is likely to require an automated gate at the entry points onto Cargo Road (see example in Figure 7.2 showing automatically operated bus gates in Swansea).

Figure 7.1: Bus Route Options for Alexandra Head - Heol Porth Teigr

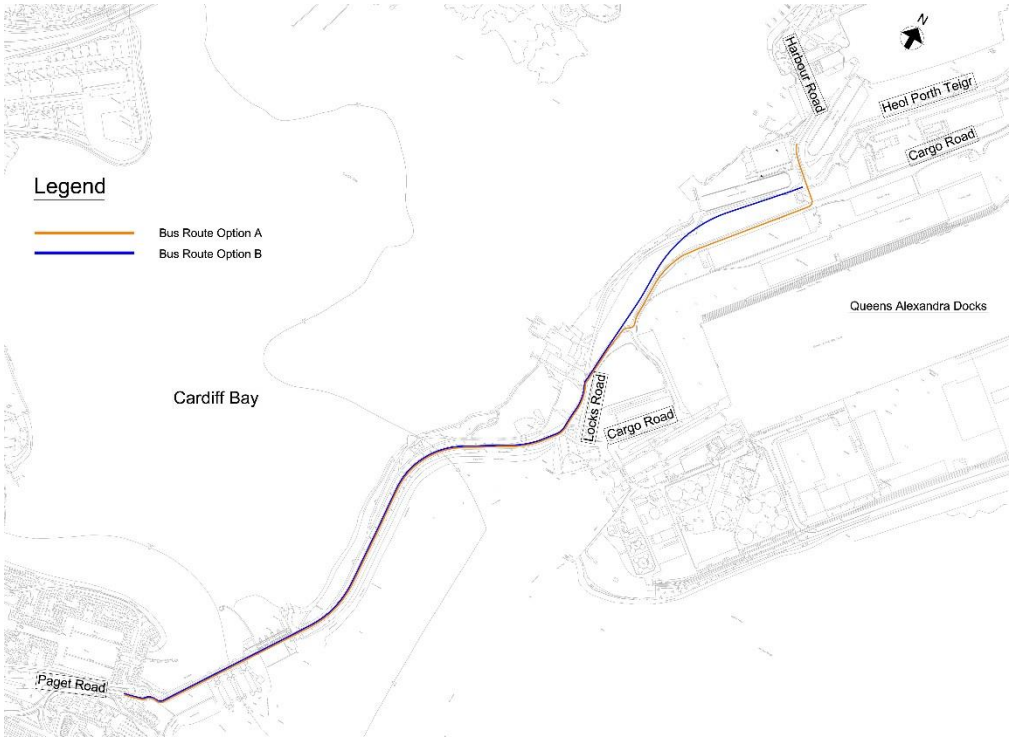


Figure 7.2: Example of Automated Security Gates for Buses

Further discussion of options A and B, for bus routes between Locks Road and Heol Porth Teigr, is set out as follows:

- **Option A** utilises the existing Cargo Road carriageway and from a highway infrastructure perspective would provide the easiest solution as can be seen on drawing SK-008. Given that this route is on ABP land it would need their agreement given the security implications for providing a bus route through a secure port environment. A new highway connection to the existing roundabout at Hoel Porth Teigr would be required and this would require only nominal adjustment to the existing carriageway as shown on drawing SK-002. A potential solution to overcome concerns regarding security access have been shown in Figure 7.2 which show the automated security gate solution. Option A would not require and amendments to the existing footway/cycleway alongside Cardiff Bay.

  Bus Option A would require the formation of a new junction and replacement of the existing security gates at Cargo Road as noted on drawing SK-008.

- **Option B** proposes a new bus route as can be seen on drawing SK-009. The new carriageway would be constructed within Welsh Government owned land but close to the ABP boundary at Cargo Road (see Figure 7.3 and 7.4). This would therefore provide potential land for future development. The new bus route would then tie back into Hoel Porth Teigr existing junction arm of the roundabout. The alignment is proposed to follow as close to the footway/cycleway as possible to ensure developable land is maximised between the new route and Cargo Road. The alignment of the route adjacent to the Channel Dry Dock is proposed over an existing mound that is believed to contain Japanese Knotweed. As described in section 2.4, this land believed to be under an agreed license between Igloo and the Welsh Government. The Harbour Authority have suggested that this may ultimately be used as back fill for the proposed reconstruction of the retaining wall south east of The Doctor Who Experience. The new bus route would require two existing areas of the footway/cycleway to be demolished and re-aligned to remove the existing 'kink' that exists. The re-aligned footway/cycleway would need to be constructed on landscape areas and would need further detailed investigation to understand whether any minor retaining structures would be required given that the path will be situated close to both the Channel Dry Dock and also Cardiff Bank stone revetment at the two respective locations.

  At the western end of this section, a new 2-way bus route is required on the line of the existing undesignated footway/cycleway. A separate footway/cycleway is therefore proposed to be constructed in parallel to the new bus route as shown on drawings SK-004 and SK-005 in Appendix A. This would involve creating a new cycleway/footway on part of the land currently used as open car parking.

  The Locks Road connections into the Cardiff Sailing Centre would need to be adjusted to make connection from the new proposed road, together with crossing provisions for the re-aligned footway/cycleway.

  As can be seen on SK-005, bus route option B would necessitate removal and closure of the existing gated vehicular access onto Cargo Road.

Both bus route options would require site clearance works to remove any landscaping on the line of the new carriageway together with proposed security fencelines.

Figure 7.3: Existing path that requires re-alignment for Bus Route Option B

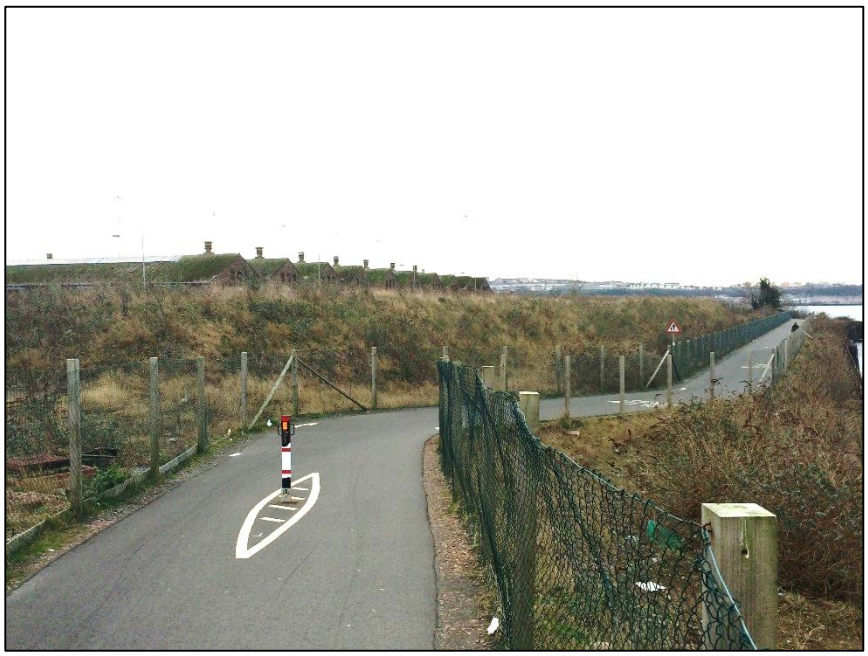


Figure 7.4: Illustrative image of bus route alongside existing walk/cycleway

8 Risk Assessment and Costs

8.1 Risk Assessment for Delivery

A preliminary risk assessment has been undertaken as part of this feasibility study which addresses both the high-level project risks together with operational risks for a new bus route.

An industry-standard approach has been taken to assessing risk in terms of Likelihood (i.e. Probability of Outcome) and Impact (i.e. Severity of Outcome). A range of 'categories' of risk has been utilised, as indicated in Tables 8.1 and 8.2 for Likelihood and Risk respectively.

Table 8.1: Risk Likelihood Classifications

Likelihood	Classification				
	1	2	3	4	5
	Remote	Unlikely	Possible	Probable	Almost Certain
Typical Range (Low)	0%	10%	35%	65%	90%
Typical Range (High)	10%	35%	65%	90%	100%
Score For Risk Assessment	5%	23%	50%	78%	95%

Table 8.2: Risk Impact Classifications

Impact	Classification				
	1	2	3	4	5
	Minor	Moderate	Significant	Major	Severe
Score For Risk Assessment	0.05	0.1	0.2	0.4	0.8

The overall risk is assessed on the basis of the product of ***Likelihood x Impact*** as indicated in Table 8.3. The scale of risk is indicated in colour-code (i.e. Green – minor, Yellow – moderate, Orange – significant risk, Red – major risk).

Table 8.3: Impact and Likelihood Combined Risk Product

		Likelihood of Risk Occuring				
		1	2	3	4	5
		Remote	Unlikely	Possible	Probable	Almost Certain
1	Minor	0.0025	0.0113	0.0250	0.0388	0.0475
2	Moderate	0.0050	0.0225	0.0500	0.0775	0.0950
3	Significant	0.0100	0.0450	0.1000	0.1550	0.1900
4	Major	0.0200	0.0900	0.2000	0.3100	0.3800
5	Severe	0.0400	0.1800	0.4000	0.6200	0.7600

Impact

Table 8.4: Risk Assessment for Implementing barrage Bus Service

Ref.	Key Risk Event	Primary Category	Potential Mitigation	Risk Likelihood	Risk Impact	Risk Product
1	Delay to buses due to lock operations	Barrage Operations	< Requires full co-operation of Harbour Authority to operate barrage to carry bus services	4	4	0.31
2	Impact on passage of vessels through locks	Barrage Operations	< Ensure that bus service is a lesser priority than sea vessels and that flexibility for occasional delay built into bus operations	2	5	0.18
3	Annual maintenance of locks limits capacity to carry buses across bridges	Barrage Operations	< Requires full co-operation of Harbour Authority to operate barrage such that lock maintenance profile can be arranged to manage impact on bus services. Alternative bus routes may need to be operated for periods (via non-barrage route).	3	4	0.20
4	Inclusion of bus traffic management within the Harbour Authority's operational duties.	Barrage Operations	< Requires full co-operation of to operate barrage to carry bus services. Cardiff County Council, as owners of the barrage, will need to ensure that Harbour Authority pro-actively manage the movement of buses across the barrage.	3	5	0.40
5	Opposition from boat operators	Barrage Operations	< Ensure that the management of bus movement does not impinge on the lock opening schedule i.e. no change from current schedule of 'in' or 'out' boat movements every 15 minutes.	4	3	0.16
6	Impact of bus services on commuting cyclists	Cyclists	< Cyclists can continue to use roadway as at present. The impact of buses on cyclists will not be significant as a maximum of 4 buses per hour per direction will be less than existing peak movements.	2	3	0.05
7	Impact of bus services on leisure cyclists	Cyclists	< Cyclists can continue to use at-grade cycleway alongside roadway as at present.	2	3	0.05
8	Land ownership issues create delays or obstacles	Land owners	< Forward planning with developers to ensure buy-in and physical provision of space	3	4	0.20
9	Port security issues limit feasibility	Land owners	< Ensure that a route exists which does not fully rely on ABP co-operation	4	2	0.08
10	Impact of weather limits usage of roadway for bus services	Other	< No record of any significant weather impact	1	3	0.01

			on vehicle usage of barrage			
11	Impact of high tides on roadway usage	Other	< No record of any significant tide impact on vehicle usage of barrage	1	4	0.02
12	Impact of events create problems for bus operations	Other	< Alternative Bus Service Route will be required for Event Days.	4	3	0.16
13	Disabled access issues	Pedestrians	< General provision for disabled users will be as at present (although difficulty of travelling over steel grille at bridges will remain). Bus service will provide disabled access.	3	3	0.10
14	Pedestrian safety	Pedestrians	< Pedestrians will be encouraged through signage to use pedestrian facilities and not walk on roadway	2	4	0.09
15	Ability of bridge structure to carry bus traffic	Structure	< Detailed intrusive surveys required to establish bridge capability	3	5	0.40

8.2 Conclusions from Risk Assessment

The preliminary risk assessment above indicates that the most significant risks are associated with the barrage structure and operations.

- The ability for the bridge structure to carry the additional bus traffic has been assessed as a potential significant risk and therefore it would be prudent to undertaken further fatigue bridge analysis to provide quantitative evidence to confirm the bridges' structural capacity.
- The Harbour Authority's agreement to effectively manage the interaction and timings for bridge lifting alongside the proposed bus scheduled timetable is a key risk item. Their co-operation will be required to effectively manage the interaction of the new bus routes not only with the locks but also the pedestrians and cyclists. The consultations with local stakeholders have commented on the high level of pedestrian activity at weekends and therefore it may not be advisable to run the bus service at weekends to mitigate the risk.
- Delay to buses is an identified risk – and the study of the lock operations indicates that a 30 minute frequency bus service should be able to be accommodated without significant delay risks.

Other risks are classified as either moderate or minor and are not anticipated to impact on the project viability or operation of a new bus service.

8.3 Route Option Indicative Costs

Preliminary assessments have been made of infrastructure costs for the bus route options A and B. All the cost estimates in this Study are preliminary in order to identify a scale of cost and will be subsequent to further review at the detailed design stage.

Table 8.1: Indicative Assessment of Infrastructure Costs of Route Options

Description	Option A:Bus Route on Cargo Road (ABP Land)	Option B:New Bus Route on Welsh Government Land
Site Clearance	£19,500	£199,250
Traffic Management	£34,000	£49,000
New Highway/Footway Construction	£322,000	£684,500
Lighting/Electrical	£38,500	£110,000
New Bus Gates	£50,000	£0
Highway Drainage	£79,000	£209,500
Earthworks	£49,900	£127,000
Contractors Preliminary Items	£118,500	£275,800
Utilities Provision	£12,500	£25,000
Total Works Costs	**£723,900 Excl VAT**	**£1,680,000 Excl VAT**

Notes:

1) Costs are current at first quarter 2015 and does not allow for: demolition; land costs; inflation; non highways clearance or VAT.

2) The cost estimate allows for: removal of existing highway, new highway. Allowances have been made for lighting / drainage / ITS equipment however this is subject to detail design by appropriate engineers.

3) Costs do not include Consultants and Local Authority Fees or statutory bodies associated with Detailed Design, Approvals or an overall project contingency allowance.

4) The Infrastructure costs associated with amendments at the barrage and embankment are assumed to be negligible and provision of £25,000 excl VAT should be made for a pedestrian crossing demarcation and segregation of the cycle lane.

5) No Allowance has been made for the removal costs associated with contaminated material & Japanese Knotweed believed to be in the existing mound within Igloo developable land. (Bus Route Option B).

9 Summary and Next Steps

As part of this feasibility study a number of consultation meetings and workshops have been held with key stakeholder from local authorities to bus operators.

The general consensus has been of support for the scheme and although the study has primarily focussed on the technical feasibility for providing a new bus route over the barrage, a wider bus route need has been identified. A review of the risks, together with any planning, environmental or health and safety requirements have not highlighted any obstacles for the implementation of the options.

Bascule Bridge Review

A technical review of the bascule bridges found no significant visual defects to the paintwork or areas of corrosion. However, no information has been provided that either states the design carrying capacity of the bridges or fatigue loading conditions and therefore further structural investigations are recommended. This would involve detailed inspections of all bridges to record their condition and identify the deck details. Strain gauges could then be installed at the critical locations, and the results from the strain gauges would be used to assess for both the fatigue and ULS capacity of the bridge decks.

Barrage and Bus Service Operational Review

The sequencing of a scheduled bus service will need full co-operation and support of Cardiff Harbour Authority who control the timing of vessels entering and exiting Cardiff Bay. A review of the existing bridge operation, relevant for a scheduled bus service, has identified that the 'maximum' practical bus service that could theoretically be operated is a 30 minute frequency service, with a 'window' of opportunity' for vehicle movement across the lock/bridges structure of around 15-20 minutes every 30 minutes. For this schedule the roadway would be closed to traffic in line with the 'fixed' schedule for boat movement.

It is clear however that there are likely to be occasions when vehicular access across the barrage would be subject to delay due to unscheduled occurrences such as higher than normal boat movement, slow movement of boats through the locks, and reduced capacity of the locks during maintenance periods.

A theoretical 60 minute schedule of lock operation (based on the harbour Authority's current formal schedule) indicates that the bus movement could be accommodated for single lock operation (with boat movements in both directions carried within the same lock), or with a two-lock operation (with boat movements in the In or Out direction in each lock).

It is recommended that the feasibility of operating a 4-bus / hour frequency is considered in future after a period of operating a 2-bus/hour service, at which time the operational interactions between the lock operations and bus services will be clearly understood.

Bus Route Layout Options

An infrastructure assessment was made for the highway section from the Penarth side of the Barrage through to the Heol Porth Teigr existing highway network. There have been two separate options investigated which are as follows:

- **Option A** via Cargo Road, with a short new section of road linking the Heol Porth Teigr / Harbour Road roundabout with Cargo Road (with an approximate £1M cost), and
- **Option B**, via a new busway (of approximate £2M cost) through land currently owned by Welsh Government but subject to future development plans.

On review of both scheme options, including indicative costs, the Option B would have the greater project capital cost but significantly Option A deliverability is subject to agreement with ABP and the financial land contribution is unknown.

Whilst the route through ABP land would appear to provide the least cost option, there are several high-level Cardiff Bay masterplanning decisions and agreements to be undertaken which would affect the programme deliverability of Option A.

In respect of deliverability, Option B is thus the preferred option. However, as part of the early phasing of a new bus route, it could be agreed with ABP to use part of Cargo Road as temporary route whilst the new bus route carriageway is under construction.

Option B's precise alignment would be subject to detailed design considerations, and the location would ideally be situated close to the ABP land boundary to ensure as much developable land is available close to the Cardiff Bay water edge side.

Appendix A

Drawings

Appendix B

Consultation & Meetings

- Inception Meeting Notes (20th Jan 2015);
- Belfast Harbour Authority Meeting (30th Jan 2015);
- Cardiff Council Meeting (3rd Feb 2015);
- Stakeholder Agenda and Notes (26th Feb 2015).