Subject: **Corran Fixed Link - HITRANS Updated Costs Report Lochaber Members Briefing**

Date: **07 June 2024**

Assistant Chief Executive: **Place**

1 Purpose/Executive Summary

1.1 The purpose of the fixed link exercise was to determine whether a longer-term fixed link can be feasibly delivered, and the high-level estimated costs associated with this. It is important to note that the report has not developed the fixed link costs to a level comparable with the fully designed ferry solution (£55m), but it has provided a higher degree of confidence than existed in the previous report in 2020.

1.2 The Corran Fixed Link - Updated Costs Report can be found below in **Appendix 1**

2 Capital Cost / Timescale

2.1 The Project Design Unit and Wallace Stone (Marine consultants leading on the Corran Infrastructure design) have reviewed the report and have concerns regarding, timescales for delivery and the estimated costs.

2.2 With the rising costs in the construction industry because of economic and geopolitical issues, the current estimated cost for a suitable bridge solution (i.e., Skye bridge) including contingency and approach works were expected to be in the region of £90 million to £120 million. From feasibility (where we are now) to open to traffic subject to external funding becoming available, would be in the region of 10 years.

2.3 Consideration also needs to be given to the consequential pressure that a bridge would bring (i.e. traffic volumes could increase by around 130%) and the additional investment that would be required for the existing infrastructure and single-track road network on the peninsulas.

3 Longer Term - Strategic Programme

3.1 The Council has always supported a community aspiration for a longer-term fixed link solution and previously submitted the initial fixed link study (2020) to Transport Scotland for consideration within the Strategic Transport Projects Review 2 which informs the Scottish Government's transport investment programme over a 20-year period (2022-2042).

3.2 Unfortunately, a fixed link solution at Corran was not considered as a project to take forward into the STPR2 which has restricted its appraisal and proposals to only Scottish Government-owned assets.

3.3 The Council has also recently responded to Transport Scotland’s Islands Connectivity draft plan as part of the consultation process to ensure that the Mull Fixed Link work includes the potential to consider the longer-term fixed link options for Corran.

3.4 The Highland Council has no money to build a fixed link due to the upfront investment costs which would far exceed the Councils resources and therefore funding support will be required at a national level as above.

4 Short - Medium term - New Vessel / Supporting Infrastructure

4.1 The Highland Council did receive the reallocation from the UK Government of £20 million from the Inverness and Highland City Region Deal with the HC itself contributing an additional Capital amount of £10 million for new ferry infrastructure.

4.2 As agreed at the March 2024 Council meeting, a change request has been submitted to Scottish Government to consider reallocating monies from the Inverness and Highland City Region Deal to fund a new electric ferry.

4.3 It should be noted that the monies allocated from IHCRD were based on the preferred infrastructure (short - medium term) option for Corran. There are currently no additional monies available within the Deal and any becoming available would be open to all partners to “apply for”.

4.4 The investment in the shoreside infrastructure and a ferry replacement will ensure the continued operation of a resilient ferry service in the short to medium term which is fundamental to the economic viability and future sustainability of the Ardgour peninsula, Lochaber, and Mull communities.

5 **Community Engagement**

5.5 The Council recognises there are differing views in the community on the preferred solution to challenges of the Corran Narrows crossing. Recognising the project has been approved by members, we continue to work closely with the local Community Councils to provide project information and answer questions. We are also currently seeking public feedback on the design for the new infrastructure with the next consultation scheduled to take place (Fort William / Ardgour - 17 / 18 June) and welcome the views from the local community.

Designation: Assistant Chief Executive of Place

Date: 07 June 2024

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Appendix 1

Corran Fixed Link – Updated Costs

Final Report

On behalf of **HITRANS**

Project Ref: 332610240 | Date: July 2023

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Document Control Sheet

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Project Ref: 332610240

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For and on behalf of Stantec UK Limited				

Revision	Date	Description	Prepared	Reviewed	Approved
2.0	31.10.23	Final Draft	SR	SC	SC
2.1	08.11.23	Final Draft	SR	SC	SC

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1 Introduction

1.1 Overview

1.1.1 In parallel to progressing a business case and funding applications for new vessels and associated infrastructure for the Corran Ferry service, The Highland Council (THC) has, over several years, been making a longer-term case for a fixed link (a bridge or a tunnel) over the Corran Narrows. This issue has been brought into ever sharper focus by the significant recent disruption to the Corran ferry, which has heightened already prevalent community concerns about long-term dependence on a ferry service.

1.1.2 The Corran Narrows Fixed Link Feasibility Study (Stantec, 2019) identified a range of potential fixed link options and developed a set of **very high-level costs**. Since the completion of this study, the ferry business case work has proceeded apace and there is now a degree of confidence in ferry and infrastructure replacement costs. THC is therefore seeking to update the fixed link costs, contained within the HITRANS report both as a basis for comparison with the ferry option but also to inform longer-term investment planning decisions.

1.1.3 To this end, Stantec UK Ltd has been commissioned with their partners COWI to further develop the initial high-level fixed link costs to provide a greater degree of certainty, and also updating them to reflect the passage of time and prevailing high inflation. The scope involves considering **three potential fixed link options**, a:

- Tunnel
- High-level bridge
- Low-level bridge

1.1.4 It should be noted that **this exercise will not develop fixed link costs to a level comparable with the ferry options**, but it will provide a higher degree of confidence than exists at present. This is appropriate to where a fixed link is in the business case process.

1.2 The Corran Narrows and Corran Ferry

1.2.1 Found approximately seven miles south of Fort William, the Corran Narrows is the narrowest section of Loch Linnhe. The Narrows is home to the Corran Ferry service, which carries passengers and vehicles between Nether Lochaber (Corran) and Ardgour. Although a short crossing, the service provides an essential connection for the peninsular communities of Ardgour, Sunart, Ardnamurchan, Moidart, Morar, Morvern and the Isle of Mull beyond.

Figure 1-1: Location of the Corran Narrows and Community Council Areas

1.2.2 The ferry serves a wide variety of purposes including: providing access to employment, health, education, and retail for peninsular residents; facilitating THC service delivery; acting as a gateway for tourists visiting the peninsula; and meeting the supply-chain needs of communities and businesses, including those of Mull via the Fishnish – Lochaline route.

1.2.3 THC is responsible for funding and operating the Corran Ferry service, which is the busiest single vessel operated route in Scotland, carrying over **270,000** cars each year, delivering **30,000** sailings from early morning to late in the evening, **363** days of the year.

1.2.4 The alternative access route to the peninsula is via road, but journey times can be up to **two-hours longer** via the A830 and A861. This road-based access involves navigating single track roads complete with passing places, in addition to low bridges which limit access for high-sided vehicles to the peninsula. The ferry service is therefore **integral to the economic and social wellbeing** of the peninsula and the wider Lochaber and Mull areas.

1.2.5 Despite its importance however, there are growing pressures on the sustainability of the service. MV *Corran* is the main vessel, with MV *Maid of Glencoul* stepping in when the primary vessel is out of service for scheduled or unscheduled maintenance. The impending life expiry of MV *Maid of Glencoul* together with recent severe reliability issues with MV *Corran*; growing vehicle-deck capacity pressures; escalating maintenance costs and difficulty in sourcing spare parts has led to an increasingly urgent need for capital replacement. The vessel situation is compounded by a challenging human resource position. Recent reliability problems have had highly negative impacts on peninsular communities.

1.2.6 Since 2018, THC has been working-up vessel and infrastructure replacement plans (in parallel to considering models of ferry service delivery). The Council's preferred option is to procure two new electric vessels and associated infrastructure works. The project Outline Business

Case (OBC) has recently been signed-off and detailed design work is currently taking place with respect to both the vessel and landside infrastructure.

1.2.7 It is recognised that an immediate ferry solution is required given the lead times on a fixed link, but the design approach is intended to ensure that the vessels are cascadable elsewhere in the event that a fixed link is realised.

1.3 Report Structure

1.3.1 This report consists of a further four chapter as follows:

- **Chapter 2** sets out the further development of the tunnel option presented in the Corran Narrows Fixed Link Feasibility Study.
- **Chapter 3** undertakes the equivalent task for a bridge, considering both low-level and high-level bridge options.
- **Chapter 4** sets the fixed link options within the wider context of the proposed investments at Corran. It also includes a ‘sketch’ calculation of potential revenues from tolling.
- **Chapter 5** sets out next steps in relation to progressing a fixed link option.

1.3.2 For reference, the Corran Narrows Fixed Link Feasibility Study (Stantec, 2019) is included in **Appendix A**.

2 Corran Narrows – Tunnel

2.1 Overview

2.1.1 This section of the report revisits the high-level development of the tunnel option across the Corran Narrows, reviewing and further developing the option beyond the work undertaken in the Fixed Link Feasibility Study in 2019. For reference, the figure below highlights the proposed location of the tunnel alignment from that study.

2.1.2 It is worth noting that very few tunnels of this nature have been built in the UK, and none in Scotland since the Clyde Tunnel. There is, therefore, a risk that there would be limited local construction expertise; however, a project of this nature would be attractive to the national and international market as demonstrated on recent hydro tunnel projects.

Figure 2-1: Proposed tunnel option alignment (Stantec, 2019)

2.2 Geological Review

2.2.1 A high-level review of the general geological conditions was undertaken to identify various natural features that are known or anticipated to exist, so as to inform the risks and feasibility of a tunnel structure between Nether Lochaber and Ardgour. This review considered both geomorphological and engineering geological features and highlights the challenges that these may represent to the proposed tunnel structure.

2.2.2 With no recent geological surveys or borehole surveys undertaken to support this task, the review leans heavily on a desk-based exercise investigating all published material. On this basis, this review is primarily qualitative in nature, using best published resources and engineering geological knowledge and experience gained over the years. British Geological Survey (BGS) mapping has been used as the primary resource for identifying likely superficial and solid geology at the location of the crossing, including identification of faulting and intrusions.

2.2.3 In general, the seabed between Ardgour and Nether Lochaber steeply drops off close to the shore on both sides of the Narrows, to a maximum depth of 24 metres below Chart Datum. Shoreside, the superficial deposits vary from marine beach deposits, raised marine deposits, glaciofluvial deposits, alluvium and potentially peat. The depth of these superficial deposits is unknown and there is currently no information regarding the presence or depth of the superficial deposits offshore, although glacial landforms and features have been documented in the area.

2.2.4 With regards to rock types along the route, these are reported to be predominately metasedimentary psammite and semi-pelite of various ages, with lamprophyre igneous intrusions mapped onshore. There is, however, limited information regarding offshore geology.

2.2.5 Immediately west of the site is the Great Glen Fault (GGF), one of the largest faults in Scotland. The proposed tunnel route is approximately 200-500m from the GGF. Previous field studies of the GGF on the north-west side of Loch Lochy (20km north-east of Corran) have demonstrated that cataclastic fault rocks, associated with the Great Glen Fault Zone (GGFZ), are common to within 1 to 1.5 km from the mapped fault trace (Stewart et al., 1999).

2.2.6 The BGS map of the GGF around Loch Lochy highlights a cataclastic zone approximately 1 km wide as part of the GGFZ. Multiple episodes of movement along the GGFZ have generated structural complexity within the rocks in and around the Corran Narrows. This has led to a variable and complicated geology including steep / overturned / inclined dips of bedding as mapped on the eastern side of the crossing. There is currently insufficient information regarding the fracture system and other structural defects affecting the rock mass at depth. Therefore, a range of conditions within the fault zones may be present and need to be accounted for during tunnel design.

2.2.7 A rockhead profile is currently unknown, however, due to the presence of raised marine deposits and glacial landforms in the seabed (e.g., pockmarks), rockhead is anticipated to be variable.

2.2.8 Based on available BGS maps, the proposed route cuts through a cluster of NE-SW trending lamprophyre dykes on the eastern shore. It is anticipated that these dykes extend offshore. Dykes are generally sub-vertical as they are of igneous origin, and these features often have higher strength than the surrounding rock mass (although at shallow depths they may be weak due to past weathering). These features will represent a sudden and significant change in the material characteristics relative to the predominantly metasedimentary host rocks.

2.2.9 These features can combine to create a high level of engineering geology variability over a short length of tunnel or a single bridge footing.

2.2.10 A summary of the ground conditions is presented in Figure 2-2. It is important to note that this is a schematic sketch of interpreted ground conditions based on the desk-based review only. Intrusive ground investigation would be required to further refine and determine the true ground conditions, including the structure and variability of the geology underground.

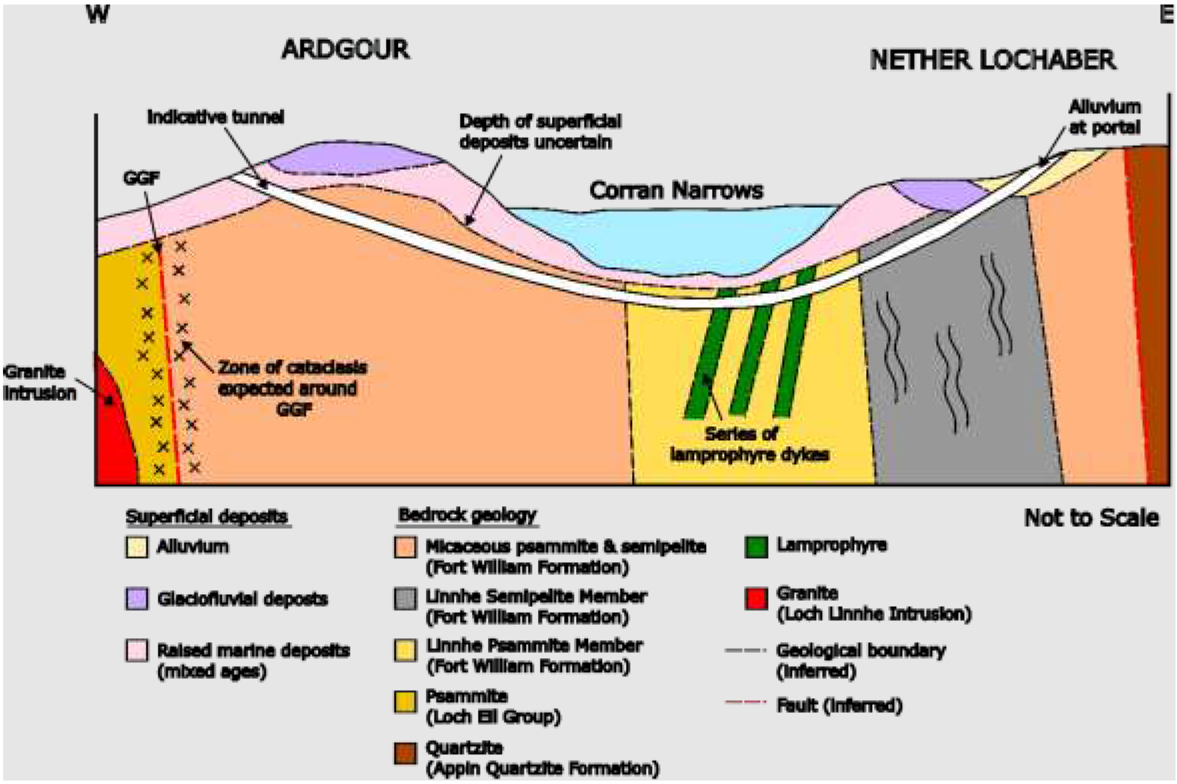


Figure 2-2: Schematic cross section (desk-based review)

2.2.11 A summary of the engineering geological risks associated with the identified ground conditions, in addition to their potential impacts on the construction of a tunnel structure, are captured in Table 2-1. Again, this information is derived from the desk-based review and thus would need to be fully investigated before being considered as part of any detailed design work.

Table 2-1: Geological risks and impacts on a tunnel

Hazard Description	Risk	Impacts on Tunnel
Glacial and periglacial deposits and landforms – sudden change in ground conditions	Glacial deposits can be highly variable and can change entirely in type and thickness over a short lateral distance, from a clay to a sand for example. The geomorphology of post-glacial landforms (such as morraines, pockmarks) are known to be present, however, their exact location, density and dimensions are not currently known.	**Medium risk** that this would slow progress
Faulting – instability and sudden change / variability in ground conditions	Larger faults can be very variable both laterally and with depth, and the materials within a fault zone can have very different properties. Presently no data are available with regards to the structure or materials that make up the onshore fault zones. Furthermore, no information is available for offshore fault zones. Faults can also form preferential pathways for groundwater (or conversely a barrier to groundwater movement).	**High risk** that the temporary or permanent support quantities will increase.
Steeply dipping geology – sudden change in ground conditions	The number of and nature of the faults that may be encountered are uncertain, particularly at depth and offshore.	**High risk** that more involved tunnelling techniques are required.

Hazard Description	Risk	Impacts on Tunnel
Igneous intrusions – sudden change in ground conditions and material properties	The metasedimentary rocks are commonly steeply dipping, or inverted with complex fault geometries (hanging walls, inversions etc.). These features can combine to create a high level of engineering geology variability over a short length of tunnel or a single bridge footing.	**Medium risk** overall, may slow progress where encountered
Various water inflow pathways – risk of flooding	Dykes and other igneous intrusions are mapped onshore. However, on land, where buried, and offshore there is little certainty as to the locations of these features. These features will represent a sudden and significant change in the material characteristics relative to the predominantly metasedimentary host rocks.	**High risk** that additional water control measures would be required
Variability in rockhead profile – challenging design conditions	Areas of stronger rock may result in increased tool wear during tunnelling, drilling and excavation. Excavation may take longer than anticipated or progress may not be possible / impractically slow.	**Medium risk** which may lead to a deeper tunnel
Insufficient knowledge of the rock mass – unknown parameters for design feasibility	The nature of the faulted rock can be variable. In some cases, discontinuities caused by faulting may be tight (not open with low permeability) and / or infilled with impermeable clayey material (i.e., relatively low permeability). In others the fault zone may be wide (metres across) and the fault matrix granular in nature and hence porous. This could potentially lead to very high, and difficult to control, groundwater inflows.	**Medium risk** of factors which increase tunnel cost.

2.2.12 Whilst several risks have been identified from the desk-based review, it is recommended that, if this option was to proceed into a business case, major site-specific ground investigation surveys are undertaken to better inform on the geological and geotechnical conditions. This would reduce the unknowns, uncertainties and risks to produce a more robust cost certainty for a tunnel.

2.3 Tunnel Alignment Review

2.3.1 Considering the geological risks identified above, the vertical alignment proposed in the previous feasibility study appears to now be too optimistic with approximately 5m ground cover to the lowest point in the seabed. Given the uncertainties over the precise bed depth, the depth of superficial deposits on the seabed, variability of rock head and the potentially heavily jointed nature of the rock, it would be prudent to proceed with a greater depth of tunnel. The proposal is to now reduce the depth at the lowest point by a further 4m. This would give greater confidence that the alignment is both feasible and buildable.

2.3.2 The potential for hydraulic connectivity with the sea due to faulted rocks and igneous intrusions mean that, even with additional depth, grouting of the rock mass ahead of excavation may be required to improve stability of the rock and control water ingress. In particularly weathered areas other interventions may be required such as the use of canopy tubes and steel ribs for temporary support during excavation.

2.3.3 For every metre of additional depth to the tunnel, there is a correlated increase in length required to the tunnel of 25m. This is constrained by the maximum gradient of 8% adopted in the previous study, which is the maximum permitted by standards and is greater than the desirable maximum gradient. This would, therefore, add a further 100m onto the previously scoped tunnel.

2.3.4 To accommodate this additional 100m in length for the additional 4m in depth, there would be a requirement to move the junction with the A82 eastwards on the Nether Lochaber side and an increase to the radius of the curve towards the A861 on the Ardgour side.

2.4 Tunnel Option

2.4.1 Based on the review of the previous study and desktop exercise as part of this commission, it is proposed that the most applicable option for constructing a tunnel option is as follows:

- **Tunnel Construction:** The proposed construction method is drill and blast.
- **Tunnel Structure:** The anticipated traffic volumes do not justify a twin-bore tunnel; therefore, a single bore tunnel is anticipated. It will have a single carriageway with one lane in each direction which is consistent with the highways at both sides of the crossing. Emergency escape provision will be within the same tunnel bore. Provisions in the DMRB relating to twin bore tunnels would be adapted to suit a single bore tunnel.
- **Tunnel Approaches:** The tunnel approaches are envisaged in open cut then cut and cover until sufficient depth in rock to allow the drill and blast tunnelling method to be adopted. The profile would be a horseshoe type profile which will accommodate the DMRB traffic envelope with additional provision for footway/cycleway to one side. The footway/cycleway would be partitioned from the traffic cell and would double as an emergency escape corridor.
- **Traffic Speeds:** The tunnel is anticipated to be a low-speed tunnel with a speed limit of 3-40mph[1]. This is considered a reasonable assumption given that it will be accessed from a junction at either end, which will necessitate traffic slowing. This would be evaluated further as part of the overall risk management strategy for operation of a highway tunnel but is beyond the scope of the current commission and current level of design.
- **Gradients:** Approach gradients would be explored in further detail if a tunnel option was subject to detailed design works. Bathymetry and thickness of superficial soils would need to be considered to firm up tunnel levels and allow gradients to be investigated further. This could have a +/-10% impact on cost, which is within the expected variance at this stage of development.

2.5 Outline Costings

2.5.1 Having considered the geological constraints and subsequent review of the tunnel alignment, the original cost of the tunnel option (2019) has been considered and recalculated using the March 2023 Construction Output Index, to inflate both the excavation and inflation rates to materials. The rationale for using this index is that it represents the true measure of productivity within the industry currently and, therefore, encompasses all the lengthened supply-chain delivery times and material price challenges.

2.5.2 The tunnel option costs have also been updated to reflect the revised highway works required to accommodate the additional depth of the tunnel by 4m. The revised alignment has moved the tunnel deeper and in doing so, has created more constructability certainty, however, at this stage the allowance for optimism bias has not been reduced. Ground investigation cost provisions have also been included within this estimate.

[1] The Clyde Tunnel and Tyne Tunnel (Northbound) have a 30mph limit, while Tyne Tunnel (Southbound) is 40mph.

2.5.3 Considering the above elements, the base cost of the tunnel option is now **£74m**[2] (an increase of **£9m** from 2019) and a total cost including optimism bias of **£122m** (**£14m** more than the 2019 equivalent).

Table 2-2: Outline Costs for Tunnel Option[3]

Item	Outline Cost
Base cost Tunnel Structure only including 10% contingency	£74.2m
Optimism Bias for Tunnel Structure only – 55%	£40.8m
Highways connections base costs	£4.9m
Optimism Bias for highways – 46%	£2.3m
Total Cost	**£122.2m**

2.6 Timescales

2.6.1 Indicative timescales are provided below based on previous experience of similar scale projects of this nature, including pre-planning, consenting, detailed design and construction. Procurement activities are assumed to run alongside the consenting and / or process and will not therefore be on the critical path. It is common for this type of project to appoint a single entity for the detailed design and construction; however, the design and construction durations are likely to be of similar overall magnitude. It is important to note here that the timescales presented assume all **activities are end-on and proceed without delays related to approvals, funding, consents etc**.

2.6.2 The next immediate step for a project of this nature would be to undertake an Outline Business Case (OBC) for the tunnel, including identifying potential funding mechanisms. The OBC would take approximately **10 months** to complete due to the work already completed to date on fixed links across the Narrows. A further period of approximately **6-12 months** should then be provided to secure funding and obtain planning to support the transition towards construction.

Pre-Planning

2.6.3 On the basis that the OBC for the tunnel is established, in addition to developing and defining procurement and funding strategies, a pre-planning phase of between **18-24 months** would be anticipated for a project of this scale.

2.6.4 Site investigations (e.g., ground investigation), site surveys and environmental impact assessments would be carried out during this phase to assist in informing the development of the business case options further, leading to the identification of a preferred design solution and eventual detailed design.

2.6.5 Akin to a RIBA Stage 3 design or similar, this stage should include pre-application dialogue, which would be crucial in engaging all project stakeholders, both statutory and non-statutory, with the developing design. This process would significantly de-risk the formal consenting period for the design.

[2] This latest estimate includes the latest benchmark drill and blast advance rates from 2021.

[3] As is normal practice in a high-level costing exercise, other costs are based on benchmarked data for tie ins for these types of costs and we have included a percentage cost for these in the overall estimate. This includes GI, PM, Design, Consenting, Licencing, EIA etc.

2.6.6 The business case process would then proceed to the next stage, Final or Full Business Case (FBC).

Consenting

2.6.7 Consenting periods vary by local authority and are wholly dependent on the consenting approach required by both regional and national guidelines. On the assumption that THC would support the project and with the pre-application demonstrating stakeholder engagement and feedback, a local planning consent could be provided within a **6-month** timescale.

Design

2.6.8 On the assumption that robust preliminary design has been undertaken and received planning consent, a detailed design phase of between **12-16 months** could be assumed. This would include independent 'Category 3' checking, and technical approval authority sign-off.

Construction

2.6.9 For a project of this scale, a construction period of between **24-26 months** could be expected. However, this would be heavily dependent on the method related works adopted by the Main Contractor.

Conclusion

2.6.10 Based on the above estimates, the overall time from a decision to progress with a fixed link to the link being open to traffic could be **6-7 years**. This is a realistic scenario, although the duration of the project is ultimately subject to emerging environmental factors, land acquisition discussions, funding and affordability challenges as the scheme is developed and progressed.

2.7 Embodied Carbon

2.7.1 Limited benchmarking data are available for the carbon assessment of tunnels. Therefore, a high-level approach has been adopted to consider the main activities involved in construction of the tunnel in order to assess the upfront carbon (i.e., the carbon associated with construction of the tunnel corresponding to life cycle modules A1 to A5 of PAS 2080, as shown in the figure below).

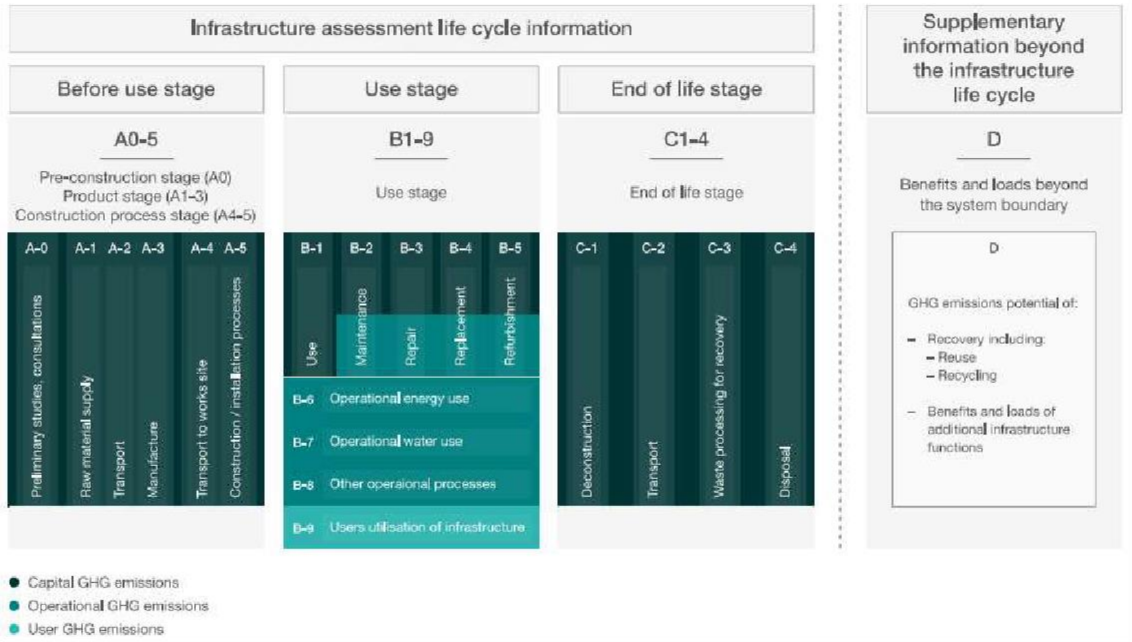


Figure 2-3: Life cycle stages as defined in PAS 2080

2.7.2 The early stage of the project allows only a crude assessment to be made based on a high-level estimate of the quantities of the materials and processes with the highest embedded carbon. This inevitably means that there is a considerable error margin in the value. If this design option is further developed, greater certainty on embodied carbon should be developed.

2.7.3 As with most large infrastructure projects, the items with the highest embedded carbon are the concrete and steel reinforcement, used in the tunnel case for temporary and permanent ground support. The other significant item is for the excavation itself, removing and disposing of the material excavated to form the tunnel.

2.7.4 The estimated embodied carbon for modules A1-A5 is **22,800 te CO2e**. The largest contributors are concrete and reinforcement and tunnelling, i.e., excavation and removal of material.

2.7.5 Average carbon factors associated with materials have been used to estimate the carbon associated with material manufacture, with additional factors used to assess the impact of transport to site. The carbon factors are based on the IStructE's *How to Calculate Embodied Carbon (HTCEC)* Guide, followed by the *Inventory of Carbon and Energy* (The ICE Database) V3 and then V2. Further allowances are made for construction methodology and material wastage.

2.7.6 The COWI Carbon Tool, which follows the methodology set out in HTCEC and which is aligned to PAS 2080, was used to calculate a baseline figure for the principal materials and methods. An uplift was then applied to this to account for other activities where direct calculation is not feasible at this stage.

2.7.7 There has been no attempt to minimise embodied carbon of the tunnel option at this stage due to numerous uncertainties. However, there are expected to be significant opportunities to reduce carbon if the scheme is developed further. This may include using electric powered plant, cement replacement in the concrete and optimising supply-chains and delivery routes.

In subsequent stages of the project, other modules of PAS 2080 should be considered to include the use stage and potentially the end-of-life stage.

3 Corran Narrows – Bridge

3.1 Baseline

3.1.1 The bridge options considered in this exercise have originated from the 2019 fixed link study and the characteristics underpinning their design features are listed below. Additionally, the route corridors considered as part of that 2019 study are presented below for reference, as is the alignment of the bridge option.

Figure 3-1: Corran Narrows Route Corridors (Stantec, 2019)

Figure 3-2: Proposed bridge option alignment (Stantec, 2019)

3.1.2 There are both risks and opportunities with each of these characteristics which have been summarised in the Risk and Uncertainties, which are set out in Section 3.4. It is important to note that any alterations to these characteristics, could lead to different conclusions from this costing exercise and thus it is important to state what has been considered at the beginning of this process.

Table 3-1: Design characteristics for bridge options

High-Level Bridge	Low-Level Bridge
Route Corridor RC3 is used	Ground and seabed profiles from Route Corridor RC3 are used
Navigation channel is assumed to be 100m wide and to range from -12mCD to +32mCD to account for both the air draught and seabed depth	Navigation channel is assumed to be 100m wide and to range from -12mCD to +32mCD to account for both the air draught and seabed depth
Initially, main bridge supports could be located within the channel where the average seabed is at -5mCD	Main bridge supports could be located 10m on either side from the limits of the navigation channel
A functional cross-sectional width of 14m is assumed (see **Figure 3-24**)	The soffit of the bridge is assumed to be located at +4mCD (i.e., 4m above the average water level)
	A functional cross-sectional width of 14m is assumed (see Figure 3-24)

High-level Bridge

3.1.3 As a result of these characteristics, the proposed baseline bridge requirements are:

- Alignment #3 with Layout #1 needs to be raised by approximately 4.5m if the following conditions are to be met: (1) soffit of deck to be located at +32mCD; and (2) minimum deck depth of 2.5m, which is equivalent to 1/100 of the span for a cable-stayed bridge (other bridge typologies would lead to thicker deck depths; however, this depth could potentially be reduced to 1/150 if the number of stay cables is increased and additional measures such as introduction of uplift resisting piers are introduced in the side spans).
- Main bridge span of 250m. This is based on the raised Alignment #3 and Layout #1 and with the assumption that pier foundations would be placed where the seabed depths are 5m on average.

3.1.4 This is illustrated and described below.

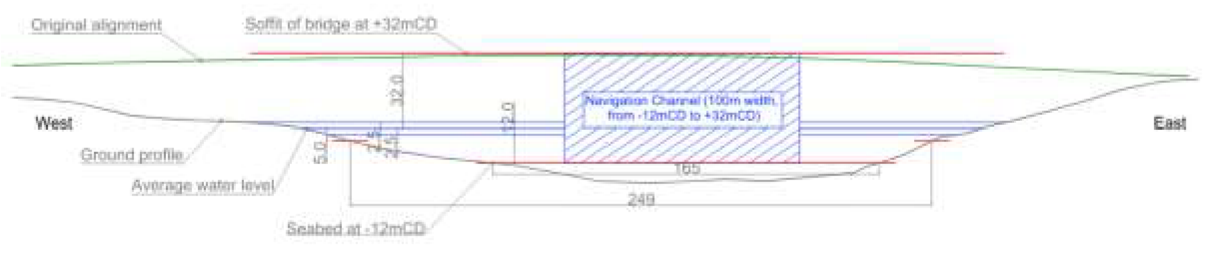


Figure 3-3: Alignment and bridge requirements for the high-level crossing

- Ground profile is shown in grey colour and corresponds to Alignment #3 and Layout #1.
- Original bridge alignment is shown in green colour; this needs to be raised to meet the navigation channel requirements.
- Three water levels are shown in blue colour. The intermediate one represents the average water level at 0mCD; the other two are the low and high tide levels with a total tidal range of 5.0m.
- The upper and lower limits of the navigation channel are shown in red colour and are located at +32mCD and -12mCD, respectively.
- The previous limits and a 100m width define the navigation channel, represented by the blue box. This channel can be moved transversely.
- Finally, the approximate pier or pylon support positions are shown by the smaller red lines; these are located 5m below the average water level.

Low-level Bridge

3.1.5 With the information available and using the characteristics listed in Table 3-1, the following bridge requirements are:

- Pivot-to-pivot length or distance of 120m. This is assuming the moving bridge supports can be located where the average seabed depth is 20m.

3.1.6 The resulting requirements are illustrated and described below.

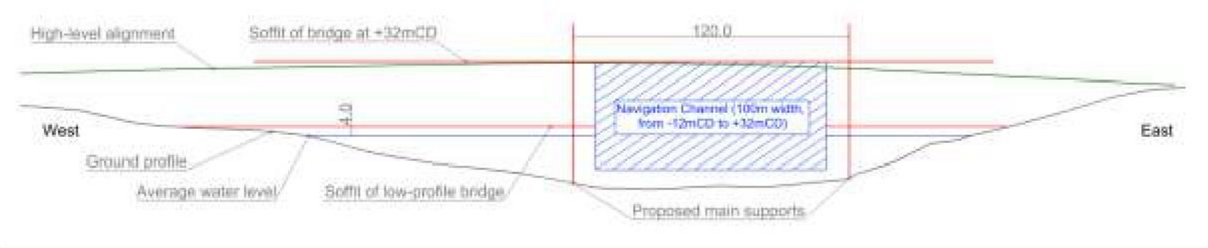


Figure 3-4: Alignment and bridge requirements for the low-level crossing

- Ground profile is shown in grey colour and corresponds to Alignment #3 and Layout #1.
- High-level alignment is shown in green colour.
- The average water level is at 0mCD is shown in blue.
- The upper and lower limits of the navigation channel are shown in red colour and are located at +32mCD and -12mCD, respectively.
- The previous limits and a 100m width define the navigation channel, represented by the blue box. This channel can be moved transversely.
- The soffit of the low-level bridge is shown in red colour.
- Finally, the proposed bridge supports are assumed to be located 10m from the edges of the navigation channel; these are represented by the red vertical lines.

3.2 Optioneering for high-level crossing

3.2.1 All of the typical bridge typologies have been considered in the optioneering exercise. Given that the baseline **main span is 250m**, all of the standard bridge types could be used for the high-level crossing option.

Truss Bridge

3.2.2 Although truss bridges are generally used for shorter spans, there are some recent precedents where trusses have been used for a similar range of spans. The proposed steel truss is located below the deck (i.e., the deck will be located above the top chord) and has a variable depth (i.e., haunches) with deeper sections over the main pier sections to reduce the depth over the channel as illustrated in Figure 3-5. Relatively large and rigid piers are proposed, so that the construction can be completed by using the balanced cantilever method.

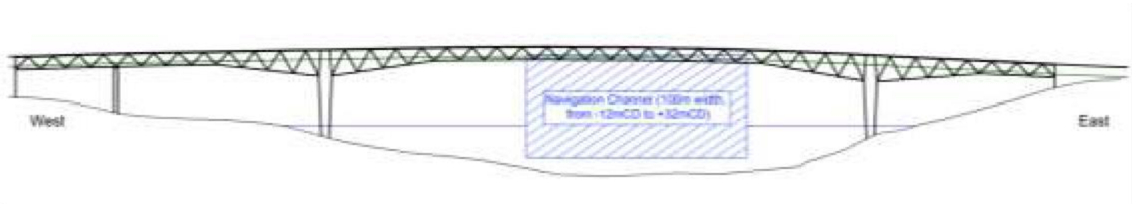


Figure 3-5: Truss Bridge option

3.2.3 Well known examples of this type of bridge include the Ulla Viaduct in Spain[4] (Figure 3-6) and two more local examples, Ballachulish Bridge (Figure 3-7) and Connel Bridge (Figure 3-8).

[4] High-speed railway bridge with a main span of 240m completed in 2015

There are also further examples in both Japan and North America where main spans of 350-400m have been achieved.

Figure 3-6: Ulla Viaduct (Spain)

Figure 3-7: Ballachulish Bridge

Figure 3-8: Connel Bridge

3.2.4 The advantages and disadvantages of this type of bridge are captured below.

Table 3-2: Advantages and Disadvantages of Truss Bridge Option

Advantages	Disadvantages
Structural efficiency: Structural members acting mainly in tension and compression allows for an efficient use of materials.	**Reduced clearance:** The below-deck solution reduces the space available under the bridge, so the alignment would need to be raised when compared to other more slender solutions. An alternative could be placing the trussed structure over the road level, but this would lead to a much taller and visually obstructive bridge and it would also potentially be more challenging to build as the balanced cantilever method would be more difficult to implement.
Transparency: The trussed structure would allow for visual transparency when compared with a completely solid deck, especially when the high-level option already obstructs views of the surroundings.	**Increased whole life cost:** This bridge would need to be constructed from steel using built-up sections and erected using bolted connections. Welding would generally not be preferred due to the large volume of connections. The large number of connections in a marine environment can lead to increased maintenance costs and future painting would be a maintenance liability.
Construction: The proposed balanced cantilever method is efficient and safe. Sections of the truss could be brought to site on barges and then be lifted as full sections, minimising crane requirements and allowing for off-site manufacturing.	
Heritage: Other truss bridges exist in the surroundings of the Corran Narrows, such as Ballachulish and Connel Bridges. As a result, the truss option would be respecting the local heritage and would result in a common design language.	

Girder Bridge

3.2.5 Box girder bridges with variable depth could be feasible for the span length available at the Corran Narrows. Box girders could be made of post-tensioned concrete, steel or composite (steel box with concrete slab on top). The 250m span is at the upper bound of feasibility, but there are multiple built examples with similar spans. The proposed method would also be balanced cantilever, where segments could be potentially precast off-site. Maximum span, and hence depth of section, could be reduced by employing inclined legs.

Figure 3-9: Box girder bridge with conventional piers

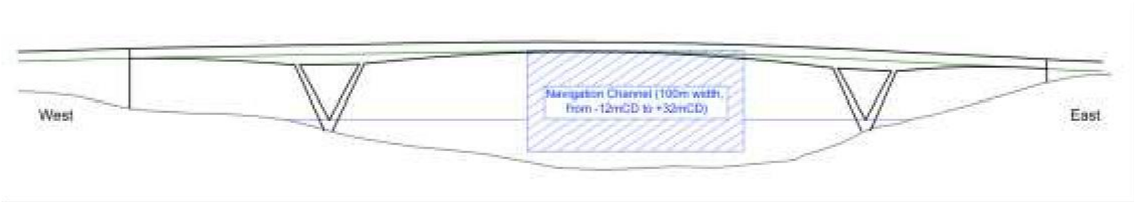


Figure 3-10: Box girder bridge with inclined legs to reduce maximum span

3.2.6 A good example of this type of bridge is the Skye Bridge, which has a main span of 250m using a post-tensioned concrete box method, built in 1995. There are multiple other examples worldwide where spans of over 350m have been achieved, although other structural forms become more efficient as length increases.

Figure 3-11: Skye Bridge

3.2.7 The advantages and disadvantages of box girder bridges are outlined below.

Table 3-3: Advantages and Disadvantages of Box girder Bridge Option

Advantages	Disadvantages
Construction: The proposed balanced cantilever method is efficient and safe. Precast segmental construction could be employed to bring segments to site on barges and then be lifted into place.	**Lack of transparency:** Box girders do not provide much transparency and they can really obstruct the views and reduce the visual transparency (due to their bluff cross-section). Depth increases with spans and the spans required at Corran to achieve a clear span over the loch corridor would be significant.
Standard solution: Box girders are well-known and widely used standard bridge solutions.	**Reduced clearance:** Given the deck depth required, girder bridges reduce the space available under the bridge, so the alignment would need to be raised when compared to other slenderer solutions (alignment raises of the order of 6m over the already raised alignment).
Maintenance: Maintenance requirements are reduced when compared with other solutions that require exposed connections (e.g., truss bridges) and cable-stay systems.	

Arch Bridge

3.2.8 Arch bridges could also be a competitive solution for the span length available. Three main arch bridges have been considered, where the difference is the position of the load-carrying arch relative to the deck.

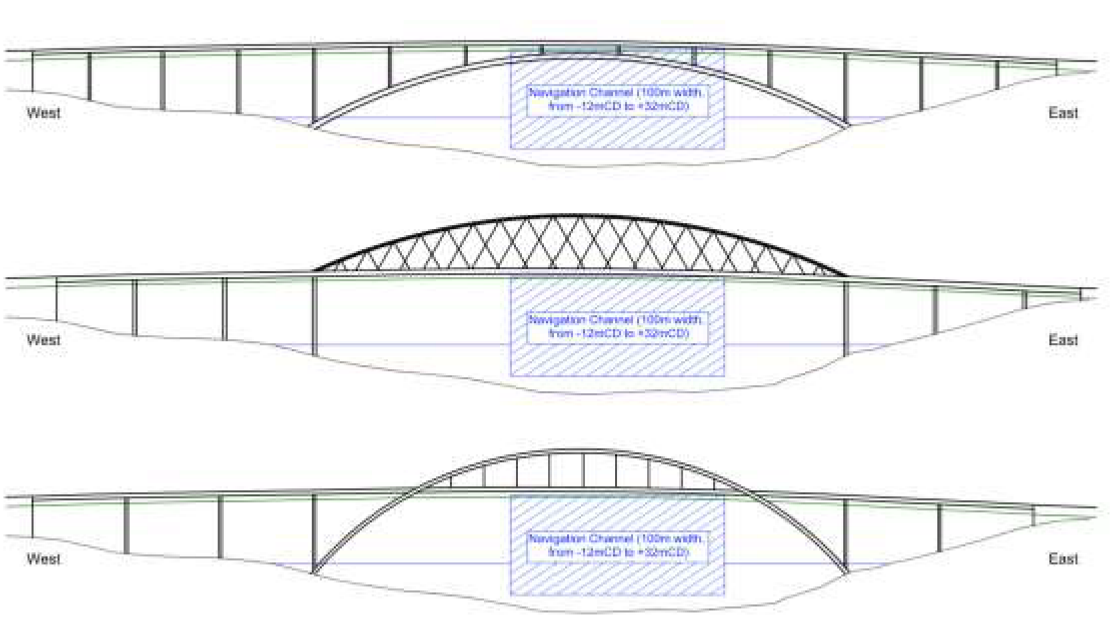


Figure 3-12: Arch Bridge options

- **Low arch:** Given the navigation channel requirements, this solution is discarded although it does have some notable advantages, including efficient construction by cantilever construction and visual transparency and slenderness.

- **High arch:** This solution would be more suitable for the navigation channel requirements, but would have some disadvantages, such as: complex construction and visually more obstructive where the tip of the arch would stand over 60m above water level, although the hangers of the arch provide great transparency.
- **Intermediate solution:** the bottom image would be an intermediate solution that still meets the navigation channel requirements, but the arch would be positioned at an overall lower level. Although construction would still be complex, the effective span of the portion of the arch located above the deck would be reduced to approximately 150m. Hence, this last solution would be the more suitable of the arch solutions.

3.2.9 The Vicaria Bridge[5] in Spain is an example of a shorter span version of this type of bridge, whilst the Caiyuanba Bridge in China is an example of a longer span at 420m.

Figure 3-13: Vicaria Bridge, Spain

3.2.10 The advantages and disadvantages of Arch bridges are outlined below.

Table 3-4: Advantages and Disadvantages of Arch Bridge option

Advantages	Disadvantages
Cost competitiveness: The 250m span is a length where arches become competitive from the cost point of view.	**Construction:** The construction of an arch, especially with a portion that is located above the deck level could lead to complex lifting operations and temporary works.
Transparency: Slender structural elements and the use of hangers leads to a transparent structure that minimises the visual impact of the bridge.	**Loads on foundations:** Arch legs supported on ground introduce relatively large horizontal reactions. If ground conditions are very competent, this arrangement should not be an issue; but there is a risk that this type of foundation might not be feasible on this location. There is an alternative, which is adding an additional inclined strut element that can take that horizontal load back to the deck and have a deck-tied arch.

Extradosed Bridge

3.2.11 The first of the cable supported bridges is the extradosed bridge solution. Although usually proposed for shorter spans, spans of up to 310m have been achieved, which would make the

[5] Road bridge with a main span of 170m built in 2009

solution suitable for this location. An advantage of this type of solution is that the bridge can be built symmetrically by the balanced cantilever method.

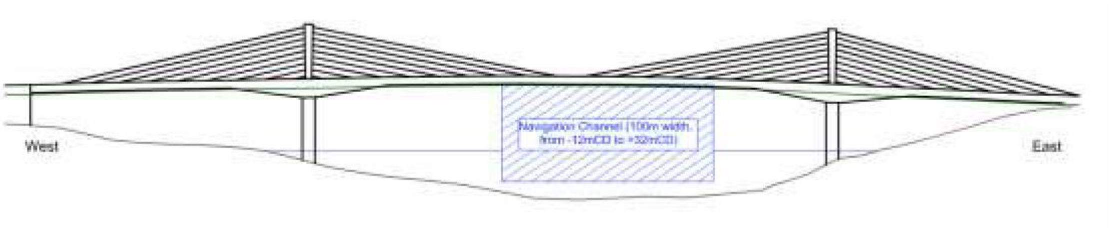


Figure 3-14: Extradosed bridge option

3.2.12 The Rose Fitzgerald Kennedy Bridge in Ireland is one example of this type of bridge, with a span of 230m and built in 2020.

Figure 3-15: Rose Fitzgerald Kennedy Bridge (Ireland)

3.2.13 The advantages and disadvantages of this type of bridge are:

Table 3-5: Advantages and Disadvantages of Extradosed bridge option

Advantages	Disadvantages
Construction: Balanced cantilever construction allows for an efficient construction method.	**Deeper decks:** Extradosed bridges tend to have deck depths that are approximately double that of cable-stayed bridges, although a haunched deck is proposed. As a result, the alignment would need to be raised in relation to other slenderer solutions such as arch, cable-stayed and suspension bridges.
Visual impact: Although pylons and cables are placed above the deck level, the pylon heights are generally half of that for cable-stayed bridges (portion located above the deck). In addition, cables provide a very transparent appearance.	**Cost:** Given that the maximum span is on the upper bound, this solution could result in a more expensive outcome.
	Added future maintenance: demand associated with replacement of cable stays within the life of the bridge (120 years).

Cable-Stayed Bridge

3.2.14 For this main span length, a cable-stayed bridge option would be an efficient and economical design and this typology has the advantage that it can be adapted to longer spans should the support positions have to be changed. A more suitable cable-stayed configuration with two towers would be proposed, rather than a single taller tower, on the basis that a taller single tower may appear more incongruous against the natural background; see Figure 3-16. As with some of the other solutions, the efficient balanced cantilever construction method could be used.

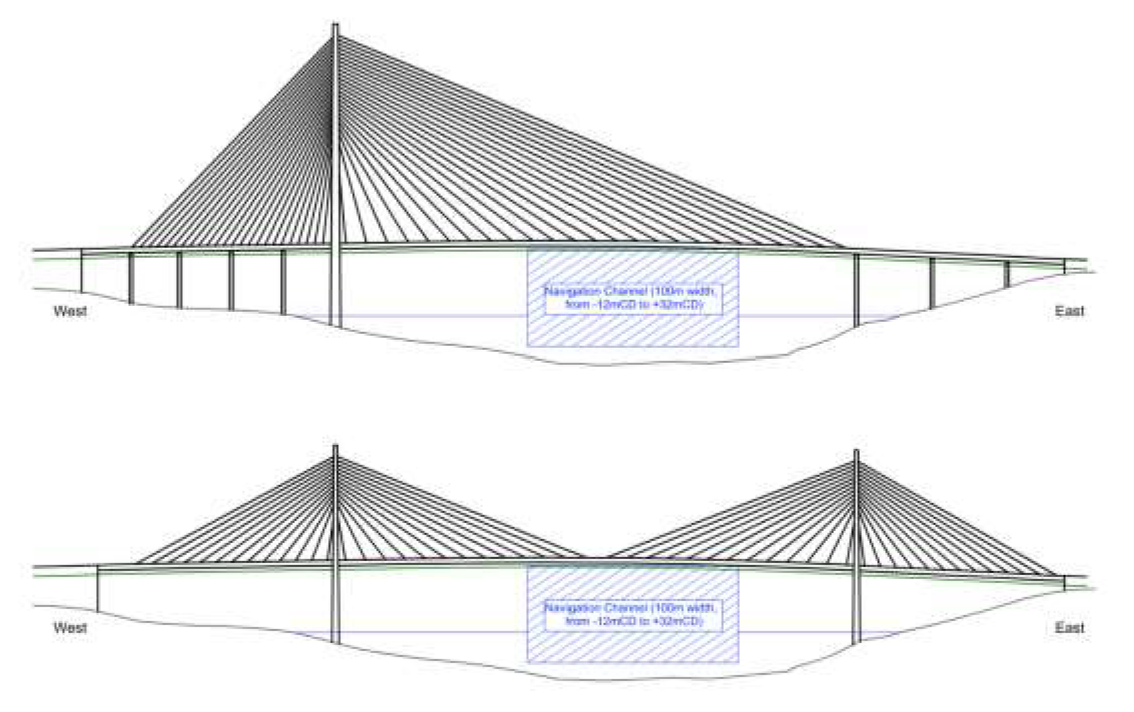


Figure 3-16: Cable-Stayed Bridge Option

3.2.15 The Salah Bey Viaduct (Constantine Bridge) is a cable-stayed bridge with a main span of 245m built in 2014 in Algeria. Multiple other examples also exist both in the UK (such as Mersey Gateway with a maximum span of 318m) and worldwide due to their popularity in recent years.

Figure 3-17: Salah Bey Viaduct (Constantine Bridge) in Algeria

3.2.16 Advantages and disadvantages are:

Advantages	Disadvantages
Construction: Balanced cantilever construction allows for an efficient construction method.	**Visual impact:** Although the two pylons reduce the overall height of them, the cable-staying system would still have a big visual impact, that might not be the most appropriate solution for a high-level crossing.
Structural efficiency: By activating the axial response (with cables in tension and pylon and deck in compression) and reducing the flexural response, an efficient use of materials is achieved leading to a slender bridge solution as a result. May be constructed in either steel or concrete.	**Added future maintenance**: demand associated with replacement of cable stays within the life of the bridge (120years).

Suspension Bridge

3.2.17 The last bridge typology reviewed is the suspension bridge. This type of bridge is usually employed in very long spans, and the 250m span at the Corran Narrows is not long enough to justify this type of bridge. One of the challenges of this type would be the need for anchor blocks to resist the load from the main cables. Cables could potentially be self-anchored on the deck, but this complicates the construction and would increase the depth of the deck. However, suspension bridges provide flexibility if the main span had to be increased.

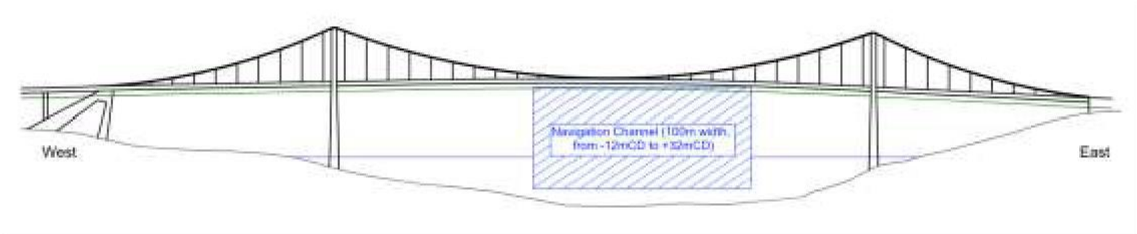


Figure 3-18: Suspension Bridge Option

3.2.18 The Sorok Suspension Bridge with a main span of 250m and built in 2008 in South Korea is an example of this type of bridge. Multiple other examples exist worldwide with spans that can go above 2,000m. In the UK, there are some notable examples, such as: Menai, Clifton, Humber, Severn and Forth Road bridges.

Figure 3-19: Sorok Suspension Bridge (South Korea)

3.2.19 The advantages and disadvantages of a suspension bridge include:

Table 3-6: Advantages and Disadvantages of Suspension Bridges

Advantages	Disadvantages
Visual impact: Although pylons, cables and hangers are placed above the deck level, the pylon heights are generally half of that for cable-stayed bridges (portion located above the deck). In addition, cables and hangers provide a very transparent appearance.	**Cost:** Given that the maximum span is on the lower bound, this solution would be more expensive than the other solutions reviewed in previous sections.
	Future maintenance: demand in that suspension bridges are generally not designed for replacement of their main cable and therefore to reduce future maintenance liability, dehumidification systems are often specified on new suspension bridges. These come with added operational costs compared with other bridge forms.

3.3 Optioneering for low-level crossing

3.3.1 An alternative to a high-level crossing is a low-level crossing where the required clearance or air draught is achieved by employing a moving bridge. Only two types have been considered feasible at this stage given a main span of 120m: a swing bridge and a lifting bridge. Other options, such as bascule bridges are suitable for shorter spans. Examples of bascule bridges located on one side of the channel with 60m spans exist (e.g., Boulevard Bridge in Willebroek, Belgium), but two of these bascule parts would be required at the Corran Narrows and the lack of intermediate support makes them infeasible.

Swing Bridge

3.3.2 Swing bridges are those that rotate around a vertical axis. In this case, two portions of the bridge rotate so that each half can span 60m. The proposed bridge is cable-stayed with a steel deck to minimise weight and reduce the requirements of the opening mechanisms. In the open position both moving parts would end parallel to each other and perpendicular to the original axis of the bridge.

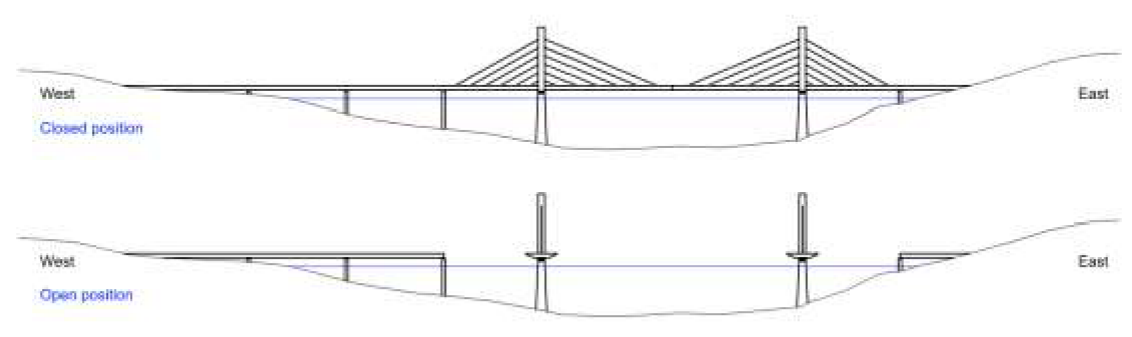


Figure 3-20: Swing Bridge Option

3.3.3 The Clyde swing bridge in Glasgow, which is a cable-stayed swing bridge, is currently being designed with a pivot-to-pivot distance of 130m. Multiple other swing bridges exist worldwide, including El Ferdan swing bridge with a span of 340m.

Figure 3-21: Clyde Swing Bridge (Glasgow)

3.3.4 The advantages and disadvantages of this type of bridge are:

Table 3-7: Advantages and Disadvantages of Swing Bridge Option

Advantages	Disadvantages
Infinite air draught: The opening mechanism allows for an infinite air draught, meaning that there would not be any clearance limitations on the vessels.	**Those listed in risks for moving bridges in this location, including:** need for construction of foundations in deep water, high operational and maintenance costs and traffic disruptions during the bridge opening times.
Efficient opening mechanism: Swing bridges tend to be more efficient than other opening bridges, such as bascule bridges.	**Greater risk** of ship impact on bridge piers.
	Opening mechanisms close to water level: Given the nature of the opening mechanism, it is located close to the water level, especially when tidal ranges are considered. The need for protecting these mechanisms from a marine environment could result in the need for lifting the bridge alignment further.

Lifting Bridge

3.3.5 A lifting bridge would allow the main span to be lifted when vessels are required to transit the channel.

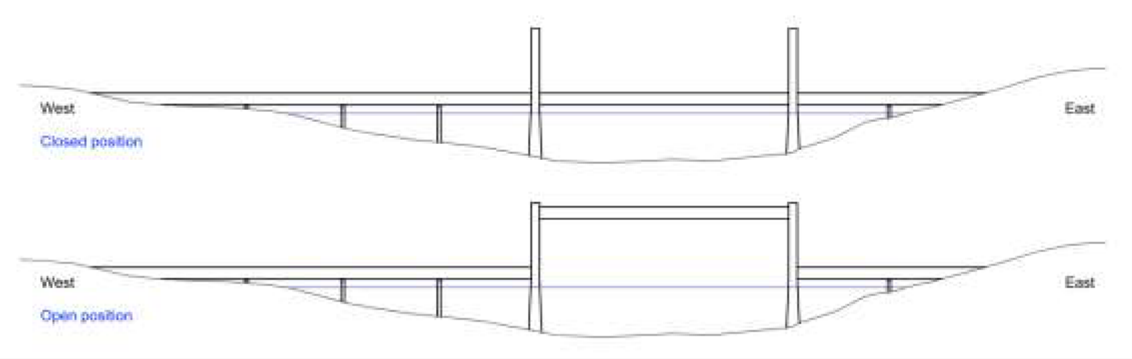


Figure 3-22: Lifting Bridge Option

3.3.6 Examples include, the Gustave Flaubert Bridge, a lifting bridge with a main span of 100m and clearance of 55m when open, located in Rouen (France) and completed in 2008.

Figure 3-23: Gustave Flaubert Bridge (France)

3.3.7 The advantages and disadvantages of a lifting bridge include:

Table 3-8: Advantages and Disadvantages of Lifting Bridge Option

Advantages	Disadvantages
Construction: Lifting bridges tend to be easier to build and operate than other types of moving bridges.	**Those listed in risks for moving bridges in this location, including:** need for construction of foundations in deep water, high operational and maintenance costs and traffic disruptions during the bridge opening times.
	Deck depth: Given the deck portion between the lifting towers is simply-supported, the resulting span is considerable and has a significant impact on the road alignment.
	Greater risk of ship impact on bridge piers.
	Inefficient opening mechanism: Given that weight of the deck needs to be lifted by several metres, the opening mechanism is less efficient than other options.
	Limited air draught: Whilst having the disadvantages of an opening bridge, it still provides limitations on air draughts (when compared with a swing bridge).
	Visual impact: The two towers would reach a height of over 40m above water level, which would result in a significant visual impact given that the towers are not slender.

3.4 Risk and Uncertainties

3.4.1 The current bridge-related constraints and assumptions present some risks and opportunities, which are listed in this section.

High-Level Bridge

- **Navigation channel:** A notional navigation channel that is 100m wide and allows for an air draught of 26m and seabed depth of 12m has been employed as a constraint. These requirements might need to be reviewed based on the expected and allowed cruise vessels in the channel, as well as deeper tide dynamic analyses by accounting for climate change effects. Modifications of these requirements might influence the alignment, the span lengths and the preferred bridge solution.
- **Ship impact:** Although a notional navigation channel has been defined, as per the previous point, accidental situations where erratic ships could fall outside the navigation channel should be considered. This could result in the need for designing the bridge supports within the channel against ship collisions (as usually done in major bridge schemes) with the associated increase in costs, or the provision of protection for these supports in the form of bollards or fenders. In addition, some of the bridge schemes presented in the options below might not be feasible if ship impacts on the superstructure are to be considered.
- **Supports outside the channel:** Although the current assumption is that pier supports might be located within the channel, there is an opportunity to provide supports exclusively outside the channel. With the ground profile and the maximum tide level of +2.5mCD (with the minimum tide at -2.5mCD, resulting in a 5m range), this would result in a span length of approximately 350m. This span would invalidate some of the proposed solutions, such as the girder, truss and extradosed options, but the cable-stayed and suspensions bridge would still be feasible.
- **Optimum position for bridge supports:** Site specific ground investigations and constructability requirements might lead to the need for placing the main bridge supports (i.e. piers or pylons) away from the current position. Similar to the previous point, this would invalidate some of the proposed solutions.
- **Consenting process and visual considerations:** Some of the bridge solutions proposed reach levels that are over 100m above the water level, with the associated visual impact on a naturally beautiful environment. This type of bridge crossing tends to shape the environment around them, so a significant amount of stakeholder consultation will be essential. Moreover, the standard consenting process could also lead to visual requirements that could invalidate the use of some of the proposed bridge solutions.
- **Alignment:** As reviewed in the optioneering exercise, many of the bridge options could be feasible for the crossing if the road alignment is raised sufficiently. These alignment changes would lead to environmental and cost implications by requiring taller and more voluminous approach embankments but can allow for choosing from a wider range of bridge options with completely different visual and cost considerations.
- **Approach embankments:** The current alignment leads to a bridge that is approximately 500m long (with a main span of 250m). There is an opportunity of increasing this length on the Western side to reduce the volume of earthworks required. This opportunity will be governed by: the need for modifying the alignment, fill material availability, cost implications, constructability preferences, carbon footprint implications and environmental requirements.

Low-Level Bridge

- **Navigation channel:** A notional navigation channel that is 100m wide and allows for an air draught of 26m and seabed depth of 12m has been employed as a constraint. These requirements might need a review based on the expected and allowed cruise vessels in the channel, as well as deeper tide dynamic analyses by accounting for climate change effects. Modifications of these requirements might influence the alignment, the span lengths and the preferred bridge solution.

- **Ship impact:** Although a notional navigation channel has been defined, as per the previous point, accidental situations where erratic ships could fall outside the navigation channel should be considered. This could result in the need for designing the bridge supports within the channel against ship collisions (as usually done in major bridge schemes) with the associated increase in costs, or in the need for providing protection to these supports in the form of bollards or fenders. In addition, some of the bridge schemes presented might not be feasible if ship impacts on the superstructure are to be considered.
- **Supports outside the channel:** Although the current assumption is that pier supports might be located within the channel, there is an opportunity to provide supports exclusively outside the channel. With the ground profile and the maximum tide level of +2.5mCD (with the minimum tide at -2.5mCD, resulting in a 5m range), this would result in a span length of approximately 350m. This span would invalidate some of the proposed solutions, such as the girder, truss and extradosed options, but the cable-stayed and suspension bridge would still be feasible. An increase in span would also increase the cost of a bridge solution.
- **Optimum position for bridge supports:** Site specific ground investigations and constructability requirements might lead to the need for placing the main bridge supports (i.e., piers or pylons) away from the current position. Similar to the previous point, this would invalidate some of the proposed solutions.
- **Consenting process and visual considerations:** Some of the bridge solutions proposed reach levels that are over 50m above the water level, with the associated visual impact on a naturally beautiful environment. This type of bridge crossing tends to shape the environment around them, so a significant amount of stakeholder consultation would be essential. Moreover, the standard consenting process could also lead to visual requirements that could invalidate the use of some of the proposed bridge solutions.
- **Alignment:** As reviewed in the optioneering exercise, many of the bridge options could be feasible for the crossing if the road alignment is raised sufficiently. These alignment changes would lead to environmental and cost implications by requiring taller and more voluminous approach embankments but could allow for choosing from a wider range of bridge options with completely different visual and cost considerations.
- **Approach embankments:** The current alignment would lead to a bridge that is approximately 350m long (with a main span of 120m). There is an opportunity of increasing this length on the western side to reduce the volume of earthworks required. This opportunity would be governed by; the need for modifying the alignment, fill material availability, cost implications, constructability preferences, carbon footprint implications and environmental requirements.

Foundations

3.4.2 As part of the geological review described in Geological Review for the tunnel options, the key risks for bridge foundations have also been considered and are outlined below. These apply to a greater or lesser extent to either high-level or low-level bridge options.

- **Glacial and periglacial deposits and landforms** present a risk of rapid change in ground conditions over short distances which presents a high degree of risk of an adverse impact on bridge abutments or pier foundations.
- **Potential variability in rockhead profile** creates a medium risk on the excavation depths to reach suitable formation.
- **Steeply dipping geology** presents a high risk of variability over the extent of a bridge footing, potentially requiring more complex foundation solutions.

- **Presence of peat**, potentially to depth, presents a medium risk to the bridge solutions especially during the construction phase where peat would be excavated and stored on site. Risks include greater volume of excavations to ensure they remain stable, and the potential for negative environmental impacts.
- There is also a risk of **impacting clash with directionally drilled services**, which would be confirmed through GI surveys.

3.5 Outline Costings

3.5.1 The estimated cost of the bridge options is calculated by following a top-down approach where other comparable built bridges have been used as reference. Bridge costs are mainly governed by the typology chosen, the length and width, the maximum span and multiple site-specific parameters (e.g., access; ground conditions (including working in or on water); loading requirements; labour cost; material costs; method-related works; and temporary works etc). As such, the cost figures reported below are high-level estimates to support the identification of a potential fixed link solution and would need to be subject to significant further work to be costed to a level comparable to that of the ferry option and supporting infrastructure.

3.5.2 For the cost estimates, a reference deck width must be assumed on the basis that costs are directly proportional to this geometrical parameter. Figure 3-24 presents the functional cross-section considered for this assessment: two lanes of 3.70m each; two hard shoulders of 1.0m each; a pair of vehicle barriers on each side of 0.5m each; two walkways of 1.5m each (one could potentially be used only for cyclists); and space proofing for two handrails of 0.3m each. The resulting deck is 14m wide. Depending on the bridge solution chosen, the functional cross section might be required to be modified to allow space for the provision of cables (i.e., where a single plane of stays is adopted along the bridge centreline), hangers and their anchorages. However, at this stage, the same cross-sectional width is considered for all the bridge types.

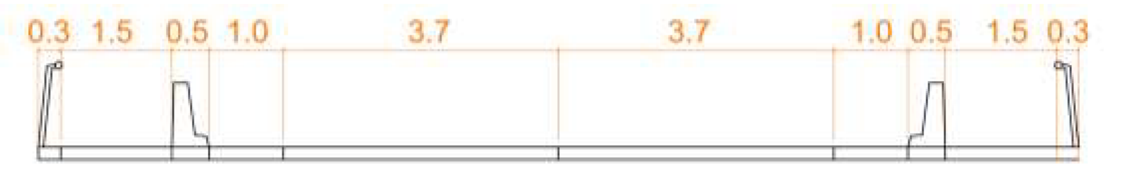


Figure 3-24: Assumed functional cross-section

3.5.3 Based on the analysis of the bridge options in the previous sections, a total bridge length of **500m** for the **high-level bridge** is assumed whilst for the **low-level bridge**, an overall bridge length of approximately **350m** is assumed. It should be recognised that the overall bridge lengths for the high-level and low-level options may vary due to detailed decisions on bridge layout that would be taken during a more detailed study.

3.5.4 Thus, the total bridge functional area adopted in the costing exercise is:

- **High-level** = 500m x 14m = **7,000m^2**
- **Low-level** = 350m x 14m = **4,900m^2**

Cost Estimation

3.5.5 A reasonable starting point is to adopt a 'rule-of-thumb' estimation for what the bridge construction cost would be. Based on experience, this is currently **between £4,000/m² and £5,000/m²**, which is independent of bridge form or typology. This would provide costs of:

Table 3-9: Cost comparison (£m) for high and low-level bridge (excluding Highways)

	£4000/m²	£5000/m²
High-level	£28.0	£35.0
Low-level	£19.6	£24.5

3.5.6 This estimated approach is supported by readily available reference material such as the technical note within the January 2015 edition of *The Structural Engineer*. This technical note provides that for short 'typical' span lengths between 100 and 150m, the construction cost per m² is approximately 1,000+15L, where 'L' is the typical span in metres. Beyond this length, the cost may be approximated by 2,000+7L.

3.5.7 However, it should be noted that **costs are dependent on local conditions**.

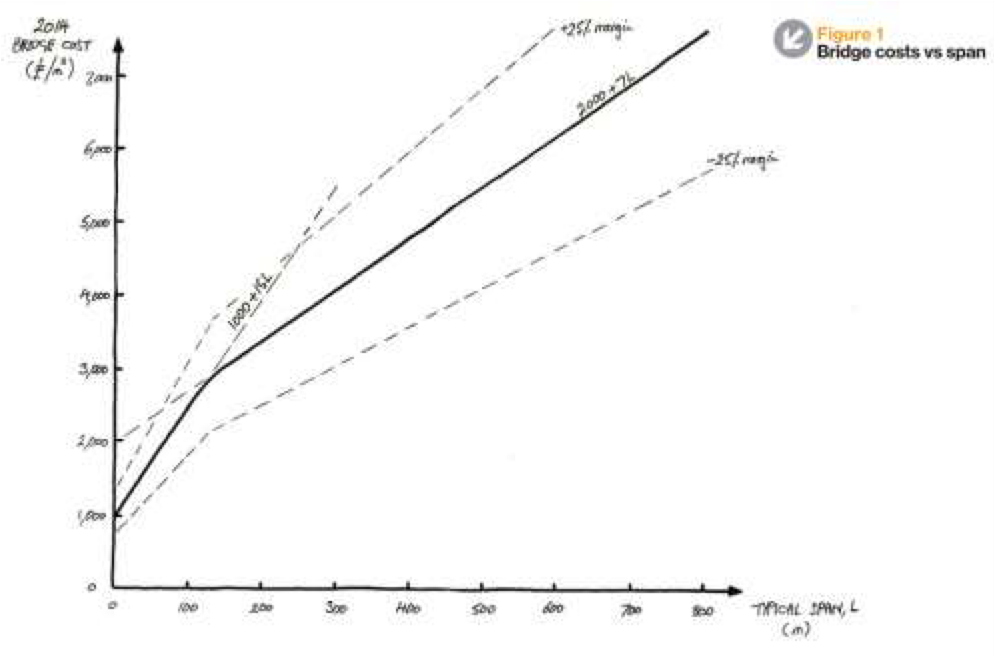


Figure 3-25: Bridge costs vs span (The Structural Engineer, January 2015)

3.5.8 Using this approach to costing for a main span of 250m (i.e., that assumed for the Corran Fixed Link) this would provide:

- 2015[6] prices = 2000 + (7x250) = **3,750 £/m²**

3.5.9 Adjusting to reflect 2023 prices, this would provide:

- 2023 prices = 1.33 * 3750 = **4,988 £/m²** (or approx. **£5,000/m²)**

3.5.10 For comparison, the Mersey Gateway Bridge, constructed between 2014 and 2017, is a 1km long, 3-pylon, 4-span cable stayed bridge, with approach viaducts on either side. The total bridge length is approximately 2.2km, with an average bridge deck width of approximately 33.5m. As such, the total deck area is approximately 73,700m². The estimated construction

[6] Inflation from 2014 prices in graph to 2015 is 0.1%.

cost of the main bridge (cable stayed bridge plus approach viaducts) was approximately **£450m**[7], meaning that the estimated cost per m² of the bridge was **£6,105/m²**[8]**.**

3.5.11 Assuming that the above was at 2015 prices, this would mean that at today's prices, the expected out-turn cost would be in the region of **£8,000/m²**, which is **60%** above that at the upper 'rule-of-thumb' level.

3.5.12 It should be noted that this cost includes the optimism bias factor and reflects certain aspects of complexity of this structure (varies by form adopted), for example construction of bridge foundations in a major estuary, construction of foundations in contaminated ground, and method related works associated with significant temporary works requirements, namely a mobile scaffold system (MSS) needed to construct approach spans of 70m. As such, it is considered reasonable to adopt the 'rule-of-thumb' approach described above as a starting point for costing the bridge options at the Corran Narrows.

3.5.13 Taking a cable-stayed bridge[9] as an example solution for the Corran Narrows, considering its suitability for this site, the estimated costs are provided in the table below. This assessment considers a number of key construction factors such as speed and complexity of construction, as well as bridge length, in addition to appraising the relative operational costs, at a high-level, of each option.

[7] Cost of full scheme was £600m

[8] Mersey Gateway Bridge ➔ £450,000,000 / 73,700 = £6,105/m²

[9] Bridge used as a baseline to inform other costs.

Table 3-10: Qualitative cost assessment of relative options (£m)

	Construction Cost		**Construction differentiators[10]**				**Adjusted Construction Cost (*)[11]**			
	Lower (based on £4,000/m²) (£M)	***Upper (based on £5,000/m²) £M***	***Speed of construction***	***Complexity of construction***	***Overall length***	***Factor on Option (Construction)***	***Adjusted Cost Lower (£M)***	***Adjusted Cost Upper (£M)***	***Lower + OB[12](60%)***	***Upper + OB[7] (60%)***
Cable Stayed Bridge (Baseline)	£28	£35	-	-	-				**£44.8**	**£56.0**
Truss (steel only)	-	-	*1*	*1*	*1*	***1.00***	**£28**	**£35**	**£44.8**	**£56.0**
Girder	-	-	*1*	*1*	*1.15*	***1.15***	**£32**	**£40**	**£51.5**	**£64.4**
Arch	-	-	*1.15*	*1.15*	*1*	***1.32***	**£37**	**£46**	**£59.2**	**£74.1**
Extradosed	-	-	*1*	*1*	*1.15*	***1.15***	**£32**	**£40**	**£51.5**	**£64.4**
Suspension	-	-	*1.15*	*1.25*	*1*	***1.44***	**£40**	**£50**	**£64.4**	**£80.5**
Swing Bridge			*1.25*	*1.25*	*0.65*	***1.02***	**£28**	**£36**	**£45.5**	**£56.9**
Lifting bridge			*1.25*	*1.25*	*0.65*	***1.02***	**£28**	**£36**	**£45.5**	**£56.9**
Highway Costs (RC3)	Extracted from previous 2019 study ➔ Western + Eastern approach 2020 prices = £3,609,511.00 2023 prices = 1.25 x £3,609,511.00 = **£4,511,888.75m**									

3.5.14 As can be seen from Table 3-10 above, the construction costs are expected to vary reasonably significantly between the various options, albeit this is based on a qualitative assessment to differentiate the cost effect due to various key factors. These costs should not be treated as absolute but rather an estimate based on the relative differences in complexity between the options.

3.5.15 Furthermore, the whole life cost, including operation and maintenance, will vary significantly between the different options. The low-level bridge options are likely to have significantly higher maintenance costs of the order of a third higher than the baseline Cable Stayed option. The steel truss and suspension options would be expected to be slightly higher than the baseline while the Girder will be slightly lower. Other options are comparable with the baseline.

3.5.16 For the maximum main span in question, a deep girder option, similar to that adopted on the Skye Bridge, would be expected to deliver the most efficient whole life solution, particularly where replaceable components, such as bearings, could be minimised (e.g., by adopting

[10] Identified cost differentiators are based on a relative, qualitative assessment of whether the alternative option would have a negative (low/medium/high = 1.15/1.25/1.35) or positive (low/medium/high= 0.85/0.75/0.65) effect on the out-turn cost

[11] (*) - Abutment to abutment cost only. Excludes highways costs etc at either end of the bridge.

[12] Optimism Bias of 55% plus allowance for Project Management, Design costs, consents and approvals etc

integral piers). However, this option is very much at the upper end of the feasibility scale when it comes to main span length and therefore does not provide the greatest flexibility.

3.5.17 It is expected that a bridge at Corran could be delivered for a construction cost of between approximately **£51m** and **£87m** for either a low-level or a high-level bridge (structure only, and inclusive of OB). Highway construction costs in the region of **£5m** are expected and would be in addition to the aforementioned figures, so circa **£56m-£92m**[13] in total.

3.6 Timescales

3.6.1 The below timescales provide an outline indication of possible durations for pre-planning, consenting, detailed design and construction. They are indicative only based on experience of similar scale projects of this nature. As with the tunnel option, procurement activities are assumed to run alongside the consenting and / or process and will not therefore form be on the critical path. It is important to note here that the timescales presented assume all **activities are end-on and proceed without delays related to approvals, funding, consents etc**.

3.6.2 The next immediate step for a project of this nature would be to undertake an Outline Business Case (OBC) for a fixed link, including identifying potential funding mechanisms. The OBC would take approximately **10 months** to complete due to the work already completed to date on fixed links across the Narrows. A further period of approximately **6-12 months** should then be provided to secure funding and obtain planning to support the transition towards construction.

Pre-Planning

3.6.3 On the basis that the OBC for a bridge is established, in addition to developing and defining procurement and funding strategies, a pre-planning phase of between **18-24 months** would be anticipated for a project of this scale.

3.6.4 Site investigations (e.g., ground investigation), site surveys and environmental impact assessments would be carried out during this phase to assist in informing the development of the business case options further, leading to the identification of a preferred design solution and eventual detailed design.

3.6.5 Akin to a RIBA Stage 3 design or similar, this stage should include pre-application dialogue, which would be crucial in engaging all project stakeholders, both statutory and non-statutory, with the developing design. This process would significantly de-risk the formal consenting period for the design.

3.6.6 The business case process would then proceed to the next stage Final or Full Business Case (FBC).

Consenting

3.6.7 Consenting periods vary by local authority and are wholly dependent on the consenting approach required by both regional and national guidelines. On the assumption that THC would support the project and with the pre-application demonstrating stakeholder engagement and feedback, a local planning consent could be provided within a **3-6 month** timescale.

[13] Including design, consenting and ground investigation

3.6.8 Other consents, such as highway consents, environmental consents, utilities consents and local landowner consents may be required. With sufficient pre-planning and engagement, receipt of all formal consents should be achievable within the proposed **6-month** timescale.

Design

3.6.9 On the assumption that robust preliminary design has been undertaken and received planning consent, a detailed design phase of between **15-18 months** could be assumed. This would include independent ‘Category 3’ checking, and technical approval authority sign-off.

Construction

3.6.10 For a project of this scale, a construction period of between **24-36 months** could be expected. However, this would depend heavily on the adopted bridge design and the method-related works adopted by the Main Contractor. By way of reference, the Cross Tay Link Road is programmed for **38 months** from commencement of site clearance to opening to traffic. This scheme has is a shorter span main crossing but with secondary bridges, greater earthworks and longer approach roads.

Conclusion

3.6.11 Based on the above estimates, the overall time from a decision to progress with a fixed link, to the link being open to traffic, could be **6-7 years**. This is a realistic scenario, although the duration of the project is ultimately subject to emerging environmental factors, land acquisition discussions, funding and affordability challenges as the scheme is developed and progressed.

3.7 Embodied Carbon

3.7.1 A high-level assessment of the embodied carbon of the two bridge solutions has been undertaken by benchmarking against a database of other known bridge case studies. Limited benchmarking data are available for the carbon assessment of bridges with the span length expected at Corran, so carbon figures should be considered carefully at this stage and there is considerable error margin in the values.

3.7.2 In both the high and low-level options, the carbon associated with the construction corresponding to life cycle modules A1 to A5 of PAS 2080 has been considered, and the carbon of the operation and maintenance is excluded. In addition, construction methods and temporary work requirements, and most importantly the material specifications used, have a significant impact on carbon calculations; and all these parameters are unknown at this stage.

3.7.3 The average carbon intensity for a bridge with a main span of 250m can be around 3,200kgCO2e/m² of deck area, which would lead to a total carbon estimate of 3,200*7,000 = **22,400tCO2e** for the high-level crossing; this figure excludes the approach embankments and all of the ancillary works related.

3.7.4 For the low-level crossing, the average carbon intensity would be around 2,400kgCO2e/m² of deck area, which would lead to a total carbon estimate of 2,400*4,900=**11,800tCO2e**. However, operational and maintenance costs of the moving bridge are excluded from this value and would therefore add significantly to this option. As this is unquantifiable, for the purpose of this assessment, the value associated with the high-level option would be considered a reasonable estimation at this stage.

3.8 Fixed Link Costs

3.8.1 The tables below outline the various high-level cost envelopes of different fixed link options for the Corran Narrows. These have also been compared to the original high-level costs developed in 2019/20. Where a '-' is present, reflects structures that have been added or removed between this study and the previous study to reflect suitability for the crossing.

Table 3-11: 2023 Fixed Link Costs

2023 Fixed Link Costs								
Fixed Link Options	**Indicative Capital cost (£m)**		**Capital Cost + OB (£m)**		**Operational and Maintenance (£m)**		**Total Indicative Costs (£m)**	
	Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
A - Cable Stayed Bridge	£32	£39	£51	£62	£10	£13	£62	£75
B - Suspension Bridge	£44	£54	£71	£87	£12	£14	£82	£101
C - Arch Bridge	£41	£50	£66	£80	£6	£8	£71	£89
D - Lifting Bridge	£32	£40	£52	£63	£17	£23	£69	£86
E- Cantilever Bridge	-	-	-	-	-	-	-	-
F - Truss Bridge	£32	£39	£51	£62	£12	£15	£63	£77
G - Tunnel	£70	£88	£110	£134	£23	£38	£133	£172
H - Girder Bridge	£36	£44	£58	£71	£9	£11	£67	£82
I - Swing Bridge	£32	£40	£52	£63	£17	£23	£69	£86
J - Extradosed Bridge	£36	£44	£58	£71	£10	£13	£68	£83

Table 3-12: 2023-2019 Fixed Link Cost Differences

2019-2023 Fixed Link Cost Differences								
Fixed Link Options	**Indicative Capital cost (£m)**		**Capital Cost + OB (£m)**		**Operational and Maintenance (£m)**		**Total Indicative Costs (£m)**	
	Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
A - Cable Stayed Bridge	-£3	-£6	-£7	-£13	£1	£2	-£5	-£11
B - Suspension Bridge	£7	£7	£10	£9	£2	£2	£11	£11
C - Arch Bridge	£11	£10	£16	£14	£1	£1	£16	£16
D - Lifting Bridge	£7	£10	£10	£13	£2	£3	£12	£16
E- Cantilever Bridge	-	-	-	-	-	-	-	-
F - Truss Bridge	-£3	-£6	-£7	-£13	£2	£3	-£5	-£10
G - Tunnel	£30	£23	£44	£26	£3	£5	£47	£31
H - Girder Bridge	-	-	-	-	-	-	-	-
I - Swing Bridge	-	-	-	-	-	-	-	-
J - Extradosed Bridge	-	-	-	-	-	-	-	-

3.8.2 As can be seen in the tables, the capital cost of both a Cable-Stayed bridge and Truss bridge have been calculated at a lower rate than previously costed in 2019/20. This is due to more recent cost profiles of similar structures in the UK in the time since the 2019/20 report providing more reliable data to underpin the costing exercise.

4 Wider Context

4.1 Overview

4.1.1 Whilst this study is primarily focused on further developing the costs for tunnel and bridge options for crossing the Corran Narrows, there is some value in setting this within the context of wider developments at Corran, including the Scottish Government policy position in relation to fixed links, the current status of the Corran Ferry OBC and the potential for introducing tolling on any fixed link.

4.2 Fixed links – national policy

4.2.1 The initial purpose of undertaking the Corran Narrows Fixed Link Feasibility Study in 2019 was to make the case for such a connection in the context of Transport Scotland's Strategic Transport Projects Review 2 (STPR2). STPR2 is a national investment programme covering a period of circa 20-years and defines measures which will contribute to delivering the National Transport Strategy 2 (NTS2), which was published in February 2020.

4.2.2 However, subsequent to the completion of the fixed link study, Transport Scotland confirmed that STPR2 would not include the local authority road network. This effectively placed the case for a fixed link back within the remit of THC and rendered it unaffordable in the immediate term, particularly in light of the long-term challenge of funding the proposed Stromeferry Bypass.

4.2.3 Whilst this position has not changed, the recent reliability issues with the Corran Ferry have starkly highlighted the dependence of peninsular communities on the crossing and the lack of resilience associated with it. Indeed, on 26th June 2023, the Scottish Parliament Net Zero, Energy and Transport Committee published its report on *A Modern and Sustainable Ferry Service for Scotland* and noted that: *"The situation with the Corran Ferry is deeply regrettable having been predicted by [The] Highland Council when they gave evidence earlier this year"*. One the Committee's recommendations was that:

- *"…the Scottish Government [should] commission a comprehensive study into the viability, cost and potential savings of fixed links in appropriate locations across Scotland. It should work with local authorities to build on the experience they have developed in initial scoping exercises to identify sites."*

4.2.4 The recent events at Corran combined with the Committee's report therefore suggest that this is an opportune time to reopen the discussion around a fixed link at the Corran Narrows, particularly given the work undertaken to date.

4.3 Corran Ferry OBC

4.3.1 Whilst the community preference is for the construction of a fixed link, and this remains a long-term priority of the Council, it is also **recognised from an operational perspective that a more immediate ferry solution is required**. A specific opportunity presented itself in this respect, with the Council being invited to join the Caledonian Maritime Assets Ltd (CMAL) Small Vessel Replacement Programme (SVRP), thus allowing THC to benefit from significant in-kind design work. To this end, the Council progressed an Outline Business Case (OBC) considering the preferred option for the ferry service only, completed in Autumn 2022.

Corran Ferry OBC - preferred option

4.3.2 THC has confirmed that its preferred option is **Option 2c: One larger 32 PCU straight through fully electric vessel / MV Corran as relief**. The primary driver of this decision is to ensure the continued operation of a resilient ferry service which is fundamental to the economic viability and future sustainability of the Ardgour peninsula, Lochaber and neighbouring Mull communities. The preferred option will provide the following benefits:

- **Common slipways and aligning structures** will remove the key constraint from the route once and for all. The structures will be flexible enough to accommodate the existing MV Corran and provide interchangeability with Roll on Roll Off vessels (either second hand or new) from CalMac routes in the West of Scotland.
- **Increased marshalling area and a new junction** at Nether Lochaber will address the consequential road safety issues of traffic backing up onto the A82(T).
- **Overnight berthing arrangements** at Ardgour will result in ceasing the current practice of high-risk ship-to-ship crew transfers, providing safer working operations for the ferry crew.
- **Reliability and resilience** having a new vessel with MV Corran as backup will reduce the reliability and resilience risks associated with maintaining the 49-year-old Maid of Glencoul.
- **Electric propulsion** offers (close to) zero emissions operation which will deliver the early decarbonisation of the route (in line with the Scottish Government and Highland Council's climate change commitments – net zero by 2045) with further benefits in terms of energy demand and overall fleet costs.
- **Increased capacity on the new vessel** (28 car to 32 car) will help reduce shuttling.

4.3.3 The use of the existing 23-year-old MV Corran (28 car) will provide service resilience as a relief vessel, until such time that the Council can undertake to deliver a second electric ferry, or the longer-term crossing options are reviewed again.

4.3.4 Finally, the SVRP provides an opportunity to realise economies of scale in design and procurement. The project has significant momentum behind it at present and represents a major opportunity for THC.

4.3.5 An important consideration in the OBC was **future-proofing the solution in the event that a fixed link is ultimately realised**. By participating in the SVRP, the design of the vessels will be consistent with those being developed for their wider CMAL fleet. They could therefore be sold / cascaded into the CMAL fleet if a fixed link is ultimately delivered. Any investment in harbour infrastructure would though be a sunk cost unless otherwise mitigated through future alternative use of the infrastructure.

4.4 Comparing ferry and fixed link costs

4.4.1 For completeness, the table below provides a simplistic comparison of the financial costs of the preferred ferry option with the tunnel and bridge options set out in Chapters 2 and 3. The following points should be noted in relation to the table:

- The costs for the preferred ferry solution are presented in Q1 2024 prices, whereas the cost for the fixed link are in Q2 2023 prices, so the fixed link costs will be understated relative to those for a ferry.

- Costs are capital only and do not take account of maintenance and any fares or tolling revenue.
- For both the ferry and fixed links options, the figures presented are a single lump sum accrued in a single year. In an appraisal or business case, costs would need to be apportioned across construction years and would be subject to inflation.
- Ferry costs include professional fees, site supervision and contingency.
- Despite the work set out in Chapters 2 and 3, the ferry costs remain much more fully developed than the comparator fixed link costs.

Table 4-1: Ferry and fixed link costs

	Capital Cost
Preferred ferry solution (Option 2c)	£55m
Tunnel	£115m - £139m
Low-level bridge	£57m - £68m
High-level bridge	£56m - £92m

4.4.2 It should be noted that if the business case for a fixed link is progressed (either in isolation or together with the ferry solution), a full economic costing analysis would need to be undertaken to highlight the value for money of the respective options.

4.5 Tolling

4.5.1 As set out in Chapters 2 and 3, the construction of a bridge or tunnel across the Corran Narrows would come at a significant capital cost. It is common practice when developing the business case for such structures to incorporate tolling within the financial model, often for a fixed period to recoup some or all of the costs. For example, the Mersey Gateway Bridge between Runcorn and Widnes which opened in 2017 includes a £2 toll for unregistered cars (with a 10% discount for registered cars) and a fixed fee of £10 per annum for residents of the Halton Borough Council area. Tolling was also adopted on several of the major estuarial and sea loch crossings in Scotland, including the Skye Bridge.

4.5.2 Whilst tolling is common across much of the world, there is a predisposition against it in current national policy in Scotland. Since the mid-2000s, the Scottish Government progressively removed tolls from bridges on the trunk road network, starting with the Skye Bridge in 2004. However, given the policy commitment to reduce vehicle kilometres nationally, it is possible that the concept of tolling could again become an acceptable proposition, especially when there is already a ferry fare for crossing the Narrows. In addition, with the vehicle fleet transitioning towards electric vehicles, there is an increasing consensus that some form of road user charging will be required in the medium-term to replace the fuel duty and VAT levied on petrol and diesel vehicles. Such a system would be able to incorporate a higher tariff on bridge / tunnel crossings. Moreover, any fixed link would likely be the responsibility of THC which would not be bound by the policy position of central government either way (depending on funding arrangements and any conditions attached).

4.5.3 Fully assessing the potential impact of tolling on traffic volumes and revenue in line with appraisal guidance is significantly beyond the scope of this study, and would require primary research and, potentially, application of a transport model. However, a very high-level ‘sketch’ analysis of indicative tolling revenues has been developed based on experience from the Skye Bridge.

Illustrative Example

4.5.4 This section considers the issue of potential tolls for any new bridge or tunnel across the Corran Narrows and the associated revenue.

4.5.5 The best recent 'case study' is the Skye Bridge which opened in October 1995. Initially the tolls levied were set at the same rate as the outgoing ferry fares. A discount scheme for Skye residents was then introduced in 1997 and tolls were abolished completely at the end of 2004. The period between 1995 and 2004 therefore provides some guide as to what could happen at Corran if a tolled fixed link was constructed.

4.5.6 The chart below shows:

- The 1994 ferry vehicle carryings.
- The actual Skye Bridge traffic flows as reported by Transport Scotland traffic counts at Kyle, and for context the projected Skye crossings had the trend from 1994 followed (i) the growth in general traffic in Scotland; and (ii) the growth in vehicular ferry traffic in Scotland[14].

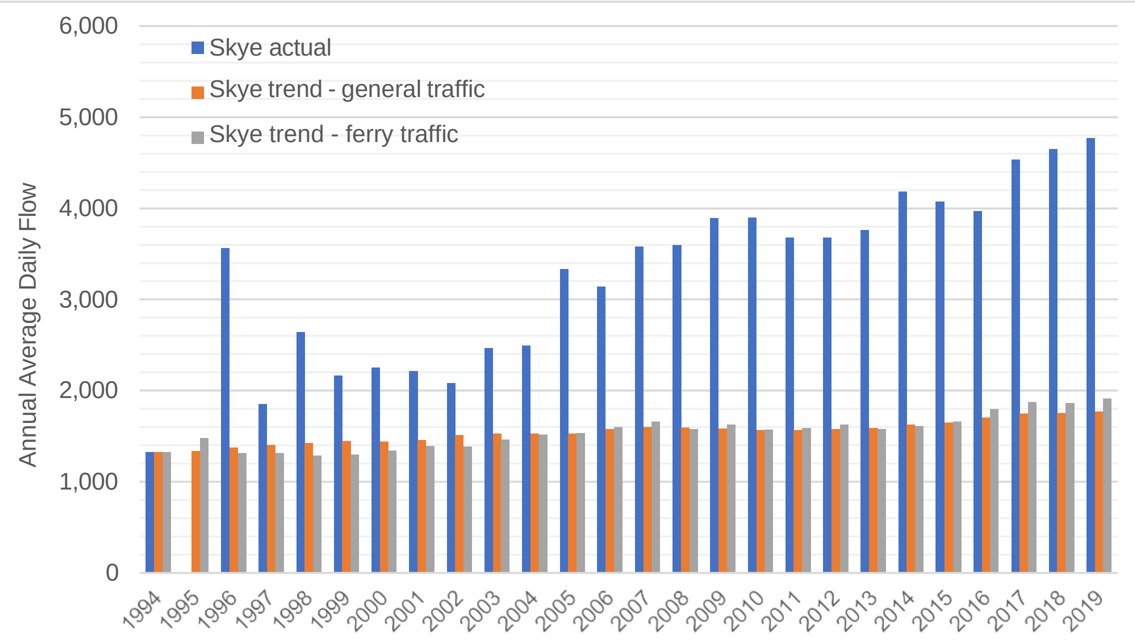


Figure 4-1: Skye Ferries / Bridge – Actual Flows and National Trends

4.5.7 The graphic illustrates that the opening of the bridge caused a very large increase in vehicular traffic to / from Skye. Assuming the traffic count data are accurate (there is no data for 1995), it can be seen that:

- In the period between 1997 and 2004 (where tolls were in operation):

[14] Calculating a similar trend CAGR for both Skye General Traffic and Skye Ferry over the same period as reported in the 2019 study for the Corran Ferry (2013-2019), produces a rate of 1.8% and 3.2% for road and ferry traffic respectively

  - Vehicular traffic was **56%** higher than it would have been had it followed the pattern of general road traffic in Scotland and around **70%** higher than vehicle-based ferry traffic.
- In the five years following the removal of tolls:
  - Vehicular traffic was **129%** higher than it would have been had it followed the pattern of general road traffic in Scotland and around **125%** higher than vehicle-based ferry traffic.
- In the five years prior to the pandemic:
  - Vehicular traffic was **155%** higher than it would have been had it followed the pattern of general road traffic in Scotland and around **141%** higher than vehicle-based ferry traffic – reflecting the boom in tourism in Skye in the last decade or so.

4.5.8 From these figures, if we benchmark against general road traffic:

- Corran volumes could increase by around **56%** if the level of tolls matched current ferry fares.
- Corran volumes could increase by around **130%** if the bridge / tunnel was free.

4.5.9 In 2019, THC reported that 276,856 vehicles used the Corran ferry, generating £1.38m. This implies an average of £2.50 per vehicle carried which is around the per journey cost of the 30-journey car discounted ticket.

4.5.10 As a simple assumption, if tolls were set at half the current fares, we might expect an increase in the region of **90%** (i.e., roughly halfway between no tolls (130%) and ferry equivalent tolls (56%)) across the first five years of opening. This has been used as a central assumption here.

4.5.11 If tolls were therefore applied which implied an average fare per vehicle of £1.25, (i.e., half the current rate), and volumes increased by 90%, then an annual toll revenue stream of around **£1.43m** would be generated, less the cost of collecting these tolls. Automatic toll collection systems could be implemented and staffed toll booths could be avoided. Arrangements at the Mersey Gateway bridge would be a good model, where tolls are paid by app, phone or by account using an ANPR system.

Wider Considerations

4.5.12 It is also important to recognise that road and other infrastructure on the peninsula is very limited. A toll-free crossing could induce significant traffic, potentially overwhelming that infrastructure, as has happened in some parts of Skye and also on some islands where Road Equivalent Tariff ferry fares have significantly reduced the cost barrier to taking a car to some islands. A tolling mechanism where cheaper tolls are available to residents in nominated postcodes, with tolls rising for visitors to offset this would protect local travel needs and therefore may be more acceptable and indeed popular locally. Visitor tolls could therefore be used to ‘manage’ tourism volumes in the peninsula.

4.5.13 A fixed link (tolled or otherwise) would represent a major change for the peninsula and also Mull. The full range of potential social and economic impacts would have to be analysed and clearly set out in advance of any fixed link decision, to ensure that all the benefits and potential downsides / unintended consequences are fully understood by peninsular residents, businesses and stakeholders.

5 Conclusions and Next Steps

5.1 Conclusions

5.1.1 This paper has provided a set of updated and further developed costs for a tunnel or bridge across the Corran Narrows, building on the work undertaken in the 2019 Corran Narrows Fixed Link Feasibility Study.

5.1.2 While we have been able to look more deeply into some of the key risks and opportunity there remains considerable uncertainty for fixed link options which can only be reduced further with more development of the preferred option(s). In principle however, whilst the figures are high-level at this stage, the cost of a bridge is competitive with that of ferry replacement and evidently delivers a wider range of benefits. A full economic costing exercise would be required to understand the comparative net present value and benefit-cost ratio of each option, which would naturally find its home in the business case process.

5.2 Next Steps

5.2.1 Should THC wish to further develop the case for a fixed link, either independently or in comparison to a ferry solution, it would be necessary to do this within the context of an H.M. Treasury *Green Book* business case using the ‘Five Case Model' or the Transport Scotland derivative, *Guidance on the development of business cases*.

5.2.2 Given, the work done to-date, it is possible that this process could commence at OBC stage, although a full **Strategic Business Case** may be required. That said, whilst the Strategic Business Case has not been written specifically in the context of a fixed link, this could be easily adapted from the compendium of studies undertaken since 2018.

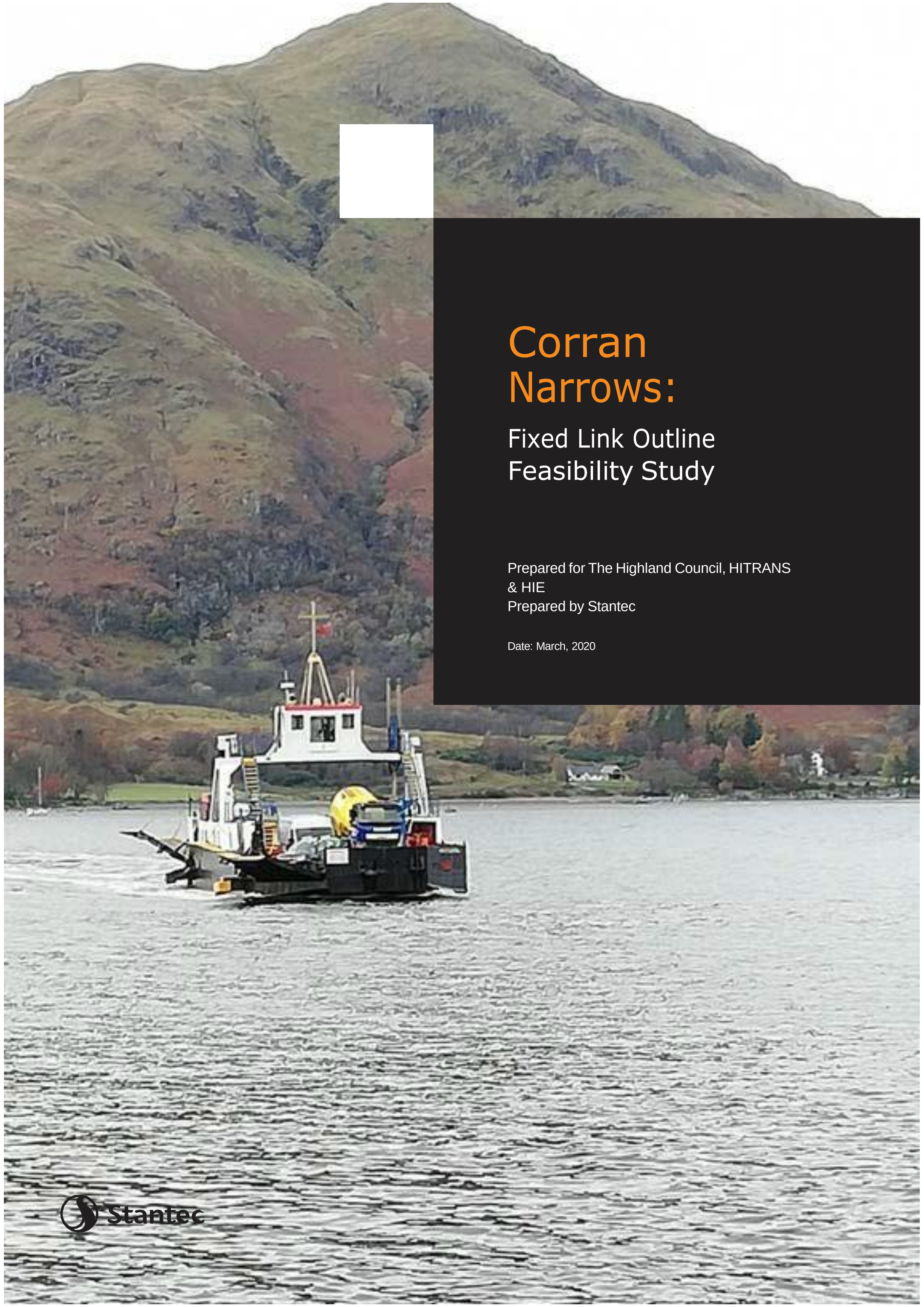
5.2.3 At OBC stage, the key task would be the detailed development of the **(Socio)-Economic Case** which would need to quantitatively consider the value for money of different fixed link and ferry options. THC would also need to develop the three ‘delivery cases' – the **Financial, Commercial and Management Cases** – in some detail, outlining how they would propose to fund, procure, deliver and manage any fixed link, included within which would be the consideration of tolling.

5.2.4 Further technical development at OBC stage would include undertaking further geotechnical studies and boreholes to build on the preliminary work presented in this report. It would also require technical constraints mapping, for example to confirm the design basis for clearances (air draught and pylon height limits, if applicable) and whether supports can be placed within the channel. An element of preliminary design work would be required to baseline the configuration, reduce uncertainty in cost estimates and improve confidence in outturn costs. This would include setting the number and size of lanes and provision for non-motorised users as well as the span configuration.

Option Development

5.2.5 It is important to recognise here that an OBC would not be an insignificant exercise. It would require further technical development of the options, community and stakeholder engagement and, potentially, the application of a transport model.

Appendix A Corran Narrows Fixed Link Feasibility Study



Corran Narrows:

Fixed Link Outline Feasibility Study

Prepared for The Highland Council, HITRANS & HIE
Prepared by Stantec

Date: March, 2020

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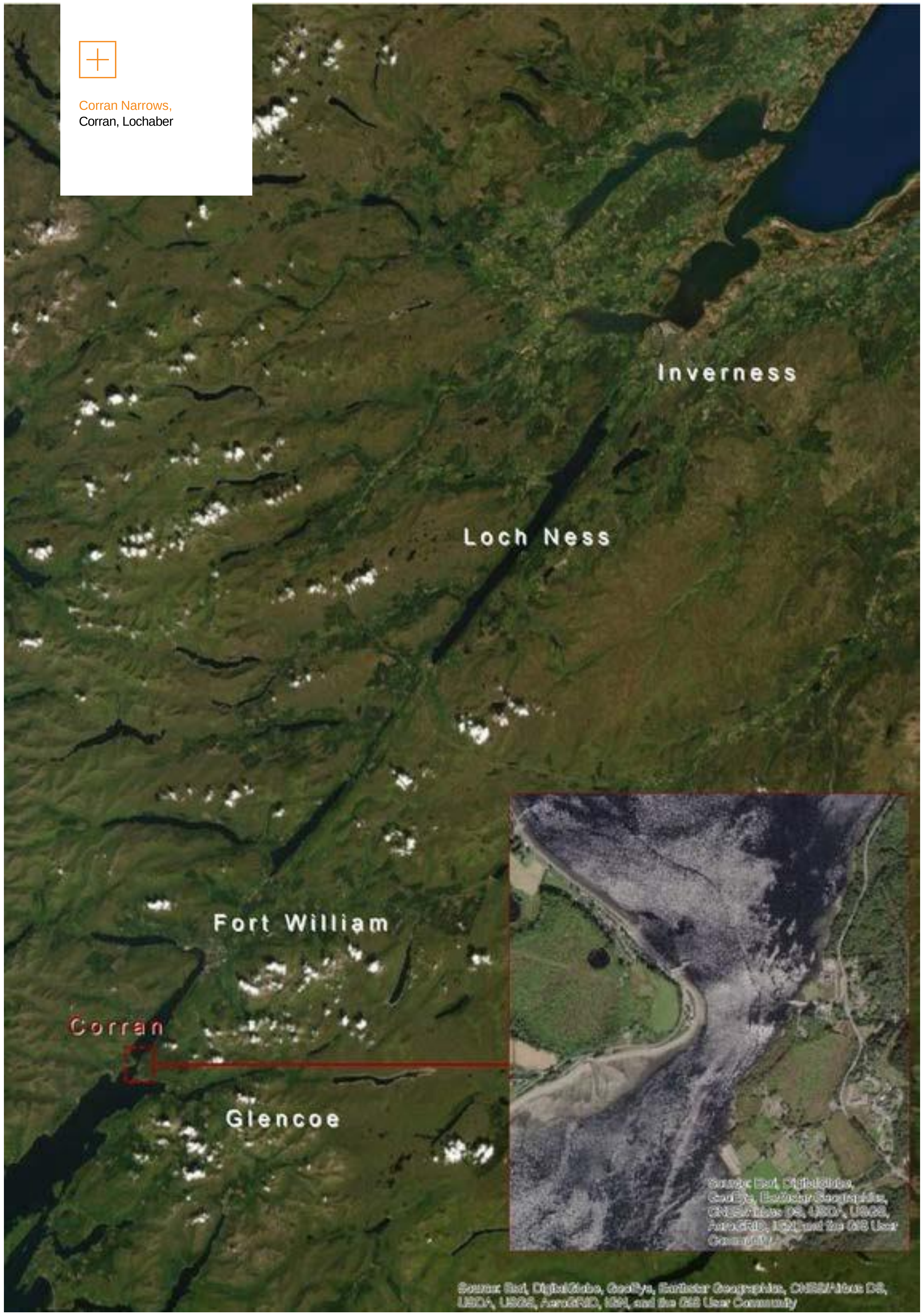
Corran Narrows,
Corran, Lochaber



1.0 Executive Summary

Overview

The Corran Narrows marks the dividing line between the upper and lower section of Loch Linnhe, a circa 30-mile long sea loch which runs along the Great Glen Fault. The loch separates Nether Lochaber from Ardgour and the areas beyond, albeit it is possible to drive around the loch (with some restrictions for larger vehicles). As the name suggests, Loch Linnhe is at its narrowest at Corran, circa 300 metres wide at its narrowest point.

The Corran Ferry service operates the short passenger and vehicle crossing of the Corran Narrows between Nether Lochaber and Ardgour. The service provides a **lifeline connection** linking the communities of Ardgour, Sunart, Ardnamurchan, Moidart, Morar, Morvern and, to a lesser degree, the Isle of Mull to Lochaber. The ferry serves a wide variety of purposes including: providing access to employment and other key services for residents; acting as a gateway for tourists visiting the peninsula; and meeting the supply-chain needs of the above communities. **It is understood to be the busiest single-vessel ferry crossing in Europe**.

Whilst the ferry has served communities on both sides of the crossing for many years, there is a longstanding aspiration amongst peninsular communities for a fixed link across the Corran Narrows. Recognising the aspirations of these communities, a partnership of The Highland Council (THC), Highlands and Islands Transport Partnership (HITRANS) and Highlands and Islands Enterprise (HIE) commissioned Stantec to develop a high-level feasibility study for a fixed link across the Corran Narrows.

Why commission this study now?

Whilst the desire for a fixed link at Corran has been a long-held aspiration, two factors have combined to create increased urgency and need for this study:

- The future of the ferry service: Significant investment in new vessels, infrastructure and human resource is required in the near future, prompting the question as to whether a ferry or a fixed link represents the best long-term value for money when considered in the widest sense (i.e. social and economic in addition to financial outcomes).
- Strategic Transport Projects Review 2 (STPR2): STPR2 is a Transport Scotland-led study which will inform transport investment in Scotland for the next 20 years, ensuring that such investment is in line with the vision, priorities and outcomes of the National Transport Strategy 2 (NTS2). Whilst this study may identify a fixed link as a feasible option, there is an affordability question, particularly within the context of limited local authority budgets. Recognising this, the funding partners are seeking to potentially submit the case for a fixed link into the ongoing STPR2, thus progressing it into the national context.

What is the scope of this study?

As alluded to above, this piece of work is a high-level feasibility study. The outcomes emerging from it will require further development, either within the context of STPR2 or as part of a standalone business case comparing ferry and fixed link options. In terms of outcomes, this study:

- reviews case-study evidence on the cost, procurement and socio-economic impact of equivalent fixed links;
- identifies potential route corridors for a fixed link, within which alignments are developed;
- considers the options in relation to the structural form of any fixed link;
- provides a commentary on the required supporting road infrastructure and tie-ins to the existing network on both sides of the crossing;
- provides high-level capital and maintenance cost-banded estimates for each fixed link option;
- identifies the scale of potential Transport Economic Efficiency (TEE) benefits of a generic fixed link, providing a quantified estimate of benefit ranges;
- compares the whole life costs of a fixed link with a continuing ferry service; and
- qualitatively explores the potential societal and economic impacts of a fixed on both sides of the crossing.

At this stage, the study does not:

- firmly define a preferred option in terms of alignment or fixed link structural form;
- recommend whether a ferry or fixed link is the most appropriate long-term option for the Corran crossing; or
- engage with communities and stakeholders.

The study findings help to determine whether there is merit in considering fixed link options for the Corran Narrows further, either within the context of STPR2 or more generally.

What can be learned from previous Scottish fixed links?

Case study evidence from fixed links constructed in the Highlands & Islands between the late 1970s and early 2000s has been considered and the following broad conclusions can be drawn:

- It is reasonable to conclude that a Corran Narrows fixed link will lead to significant traffic generation. This is likely to be due to a combination of: (i) latent demand for journeys which are currently suppressed by the limitations associated with the ferry service - this would include peninsular residents making more frequent trips to Fort William and elsewhere to access services; (ii) increased visitor numbers, particularly in terms of ‘unplanned’ or spontaneous trips; and (iii) additional journeys generated by 24-hour connectivity.

- The evidence suggests that the provision of a fixed link across the Corran Narrows would make a positive contribution to population retention and growth, although any effects would be long-term in nature and difficult to attribute directly to the crossing given that many factors impact on population numbers and structure.

- A fixed link across the Corran Narrows would provide residents of the peninsula with improved access to employment (and vice versa, although the effect in the other direction is likely to be weaker). There is a risk that it creates a ‘dormitory’ effect with an increase in commuting to Fort William or elsewhere, but this would nonetheless bring a range of benefits to the peninsula in terms of increased local spending power and the potential in-migration of working-age families.

- Anecdotal evidence suggests that the construction of a fixed link improves the business confidence of an area, but the issues of time-lag and causality make it challenging to isolate specific new business investments emerging directly as a result of a fixed link. The one exception is in the tourism sector where it is the growth in visitor numbers which acts as a direct stimulus to investment.

- Fixed links can fundamentally alter the economic and social fabric of an area. The extent to which this is the case depends on the specific local circumstances. On balance, the evaluation evidence suggests that fixed links have improved the quality of life where they have been built, but they do bring challenges, particularly in terms of any reduction in local services brought about by centralisation and pressure on local infrastructure associated with increased visitor numbers. These issues are likely to be less significant in the context of a peninsula compared to an island.

What are the key environmental, planning and construction considerations at Corran?

Environmental considerations

- The following environmental issues would need to be considered further at detailed design stage:

- the high likelihood of coastal flooding, especially on the eastern bank of Loch Linnhe between Nether Lochaber and Inchree, which can influence design and construction of any fixed link.

- statutory ecological designations, particularly, the Onich to Ballachulish Woods and Shore Special Area of Conservation and the Site of Special Scientific Interest south-west of Inchree; and

- landscape designations and heritage assets, particularly, the Ardgour Special Landscape Area along the west side of Loch Linnhe.

- The above considerations will contribute towards informing the potential alignments for a fixed link.

- It is though important to note that no ‘**showstopper**’ issues have been identified here from an environmental perspective which would preclude the construction of a fixed link across the Corran Narrows.

- Potential environmental impacts will however have to be fully scoped and appropriate mitigation identified through the appropriate assessments if the fixed link proposition is to proceed to detailed design in the future.

Planning considerations

- The proposal for a fixed link across the Corran Narrows is supported within the local planning context. Inclusion of the scheme as an STPR2 priority may also secure its recognition within the emerging National Planning Framework 4 (NPF4).

- However, any planning application will likely need to be accompanied by an Environmental Impact Assessment Report given the scale of the project and potential environmental impacts.

Construction considerations

- The depth of the Corran Narrows together with the main shipping channel being on the eastern side will have implications for the alignment, size and gradients of any fixed link option.

- The Corran Narrows has tidal characteristics which impact on the air draught requirement of vessels. There are also aspirations to develop tidal energy schemes at Corran and thus any fixed link should not prevent the future realisation of these projects.

- The requirement to maintain an appropriate air draught for the transit of vessels along Loch Linnhe, accounting for the tidal range at the Corran Narrows, will be an important consideration.

- The ferry currently provides the main dangerous goods route onto the peninsula (and currently Mull), including for the transport of e.g. fuel and heating oil, agricultural products etc. which is an important aspect in the context of Corran and the subsequent identification of potential fixed link options (i.e. transport of dangerous / hazardous goods through a tunnel)

What route corridors and alignments have been considered?

Five route corridors within which a fixed link could be located have been identified, comprising of **four** bridge corridor options and **one** tunnel corridor option. These are shown in the figure below:

These route corridors can be broadly categorised as follows:

- RC1 would be broadly on the alignment of the current ferry service

- RC2-RC4 would be to the north or south of the existing ferry service

- RC5 would be potentially suitable for a tunnel option..

The table below summarises the performance of each of these identified route corridors against a variety of criteria. The level of impact is registered using a 7-point scale similar to that defined in the Scottish Transport Appraisal Guidance (STAG) as indicated below:

✔ ✔ ✔ - Highly Positive Impact

✔ ✔ - Moderate Positive Impact

✔ - Slightly Positive Impact

O - No Impact

✕ - Slightly Negative Impact

✕ ✕ - Moderate Negative Impact

✕ ✕ ✕ - Highly Negative Impact

Criterion	RC1: Existing Corridor	RC2: Northern Corridor	RC3: Central Corridor	RC4: Southern Corridor	RC5: Tunnel Corridor
Ability to retain ferry service during construction	✕ ✕ ✕	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔
Long-list of structural options available	✕ ✕ ✕	✕ ✕ ✕	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔
Ability to retain Narrows as a shipping lane	✔	✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔
Ability to provide satisfactory air draught	✔	✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔
Ability to retain future potential for tidal energy generation	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔
Visual impact of a fixed link	✕	✕ ✕	✕	✕ ✕ ✕	✔ ✔ ✔
Environmental impact of a fixed link	✕	✕ ✕	✕	✕	✕ ✕
Conflict with land ownership	O	✕	O	✕	O
Routing of traffic away from settlements	✕ ✕	✕ ✕ ✕	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔
Reduction in quantity of required works (earthworks)	✕	✕ ✕	✕	✕ ✕	✕ ✕ ✕
Impact of construction	✕ ✕ ✕	✕	✕	✕ ✕	✕ ✕
Impact on costs of project	✕	✕ ✕	✕	✕ ✕	✕ ✕ ✕

Table 1 1: Route Corridor Impact Summary

Based on the scoring in the table above, the five Route Corridors have been narrowed down to **three** at this feasibility stage. These corridors are as follows:

- Route Corridor 3: Central Corridor, provides the greatest positive impact and the fewest negative impacts across all potential bridge corridors.

- Due to the benefits of the Tunnel Corridor: Route Corridor 5, this option has been retained. It should though be noted that the capital and ongoing costs of a tunnel are likely to be comparatively high and there are significant risks relating to the technical complexity of the work and the procurement of competent UK contractors to deliver it.

- It is also recommended that Route Corridor 1: Existing Corridor is considered further due its location in the current crossing corridor and therefore the more limited roadside works required, and its minimal disruption to surrounding property owners. However, it should be acknowledged that any future consideration of this corridor would be predicated on developing a solution to maintain the ferry service and the identification a deliverable and reliable bridge option which maintains the shipping corridor. Route Corridors 2 and 4, have been sifted at this stage as they offer no further benefits above Route Corridor 3.

Broad fixed link alignments have therefore been worked-up for each route corridor, although these would be subject to significant refinement if the project is taken forward.

Fixed Link Structure Options

A range of fixed link structure options has been developed, building on the STAG principle that all options should be considered and progressively sifted to a working shortlist. These options include both high and low-level bridge options for consideration for Route Corridors 1 and 3, and a tunnel option for route corridor 5.

Each option has been considered on its own merits as a structure and its suitability for this location. The shortlist of fixed link structure options to be considered in any subsequent study are as follows:

- Cable-stayed bridge
- Suspension bridge
- Tied-arch bridge
- Vertical lift-bridge
- Cantilever bridge
- Truss bridge
- Tunnel

A causeway, bascule bridge and swing bridge have been ruled out for a range of reasons, including cost, deliverability and the impact on the shipping channel.

The table below shows estimated undiscounted low and high capital cost ranges for the different options, with risk-adjusted costs also presented (i.e. the inclusion of 66% optimism bias). 60-year operating and maintenance costs are also included, based on a varying percentage of the overall capital cost.

Option	Indicative Capital Cost		Capital Cost + OB		Operational and Maintenance	
	Low	**High**	**Low**	**High**	**Low**	**High**
A - Cable Stayed Bridge	£35m	£45m	*£58m*	*£75m*	*£9m*	*£11m*
B - Suspension Bridge	£37m	£47m	*£61m*	*£78m*	*£10m*	*£12m*
C - Tied-arch Bridge	£30m	£40m	*£50m*	*£66m*	*£5m*	*£7m*
D - Vertical Lift Bridge	£25m	£30m	*£42m*	*£50m*	*£15m*	*£20m*
E - Cantilever Bridge	£40m	£45m	*£66m*	*£75m*	*£5m*	*£8m*
F – Truss Bridge	£35m	£45m	*£58m*	*£75m*	*£10m*	*£12m*
G - Tunnel	£40m	£65m	*£66m*	*£108m*	*£20m*	*£33m*

Table 1 2: Risk Adjusted Capital Cost Ranges of Fixed Link Structures

The cost of the connecting road infrastructure varies depending on the route corridor and alignment chosen, but generally it represents only a small proportion of the total cost of the crossing. It should however be noted that any requirement for rock blasting would significantly increase the cost of the road connections.

An illustrative example of a cable-stayed bridge in Route Corridor 3 (Alignment 1) is shown below:

Figure E1: RC3, Alignment A, Cable Stayed Bridge

Figure E2: RC3, Alignment A, Cable Stayed Bridge, Road Connectivity

What are the potential scale of benefits of a fixed link?

Wider Economic and Social Benefits

It is difficult to quantify the wider economic benefits of these types of schemes in such a sparse rural context. While the economic appraisal in the main focuses on a Benefit Cost Ratio (BCR) figure, it is important to consider the importance of **connectivity and resilience** in the region and the benefits it brings to society.

The recently published National Transport Strategy 2 (NTS2) outlines the importance of taking cognisance of social inclusion and reducing the levels of inequality and deprivation.

As such it is important to consider the following challenges and policies within NTS2, and their application within the context of the communities that depend on the Corran Narrows crossing, as for some it is a lifeline service.

NTS2 The Challenges facing society		
Poverty and child poverty	Social isolation	Gender inequalities
Disabled people	Scotland's regional differences	Global climate emergency
Decline in bus use	Productivity	Fair work and skilled workforce
Tourism	Digital and energy	Spatial planning
Health and active travel	Information & integration	Resilience
Ageing population	The changing transport needs of young people	Reliability and demand management
Technological advances	Air quality	Safety and security
Trade and connectivity	Freight	

Table 1 3: NTS2 Challenges, Transport Scotland 2020

NTS2 Vision

We will have a sustainable, inclusive and accessible transport system, helping deliver a healthier, fairer and more prosperous Scotland for communities, businesses and visitors.

PRIORITIES	OUTCOMES
Promotes equality	Will provide fair access to services we need
	Will be easy to use for all
	Will be affordable for all
Takes climate action	Will adapt to the effects of climate change
	Will help deliver our net-zero target
	Will promote greener, cleaner choices
Helps our economy prosper	Will get us where we need to get to
	Will be reliable, efficient and high quality
	Will use beneficial innovation
Improves our health and wellbeing	Will be safe and secure for all
	Will enable us to make healthy travel choices
	Will help make our communities great places to live

Table 1 4: NTS2 Vision, Transport Scotland 2020

NTS2 Policy

Policy	Enabler
	Increase safety of the transport system and meet casualty reduction targets
A. Continue to improve the reliability, safety and resilience of our transport system	**Increase resilience of Scotland's transport system from disruption and promote a culture of shared responsibility**
	Implement measures that will improve perceived and actual security of Scotland's transport system
	Increase the use of asset management across the transport system
B. Embed the implications for transport in spatial planning and land use decision making	Ensure greater integration between transport, spatial planning, and how land is used
	Ensure that transport assets and services adopt the Place Principle
	Ensure the transport system is embedded in regional decision making
C. Integrate policies and infrastructure investment across the transport, energy and digital system	Ensure that local, national and regional policies offer an integrated approach across all aspects of infrastructure investment including the transport, digital, and energy system
D. Provide a transport system which enables businesses to be competitive domestically, within the UK and internationally	Optimise accessibility and connectivity within business and business-consumer markets by all modes of transport
	Ensure gateways to and from domestic and international markets are resilient and integrated into the wider transport networks to encourage people to live, study, visit and invest in Scotland
	Support measures to improve sustainable surface access to Scotland's airports and sea ports
E. Provide a high-quality transport system that integrates Scotland and recognises our different geographic needs	Ensure that infrastructure hubs and links form an accessible integrated system that improves the end-to-end journey for people and freight
	Minimise the connectivity and cost disadvantages faced by island communities and those in remote and rural areas
	Safeguard the provision of lifeline transport services and connections
F. Improve the quality and availability of information to enable better transport choices	Support improvements and innovations that enable all to make informed travel choices
	Support seamless journeys providing the necessary infrastructure, information and interchange facilities to connect all modes of transport
	Ensure that appropriate real-time information is provided to allow all transport users to respond to extreme weather and incidents
G. Embrace transport innovation that positively impacts on our society, environment and economy	Support Scotland to become a market leader in the development and early adoption of beneficial transport innovations
H. Improve and enable the efficient movement of people and goods on our transport system	**Ensure the Scottish transport system efficiently manages needs of people and freight**
	Promote the use of space-efficient transport
I. Provide a transport system that is equally accessible for all	Ensure transport in Scotland is accessible for all
	Identify and remove barriers to public transport connectivity and accessibility within Scotland
	Reduce the negative impacts which transport has on the safety, health and wellbeing of people
	Continue to support the implementation of the recommendations from, and the development of, Scotland's Accessible Travel Framework
J. Improve access to healthcare, employment, education and training opportunities to generate inclusive sustainable economic growth	**Ensure sustainable labour market accessibility to employment locations**
	Ensure sustainable access to education and training facilities
	Improve sustainable access to healthcare facilities for staff, patients and visitors
K. Support the transport industry in meeting current and future employment and skills needs	To meet the changing employment and skills demands of the transport industry and upskill workers
	Support initiatives that promote the attraction and retention of an appropriately skilled workforce across the transport sector
L. Provide a transport system which promotes and facilitates travel choices which help to improve people's health and wellbeing	**Promote and facilitate active travel choices across mainland Scotland and islands**
	Integrate active travel options with public transport services
	Support transport's role in improving people's health and wellbeing
M. Reduce the transport sector's emissions to support our national objectives on air quality and climate change	Facilitate a shift to more sustainable modes of transport for people and commercial transport
	Reduce emissions generated by the transport system to improve air quality
	Reduce emissions generated by the transport system to mitigate climate change
	Support management of demand to encourage more sustainable transport choices
N. Plan our transport system to cope with the effects of climate change	Increase resilience of Scotland's transport system to climate change related disruption
	Ensure the transport system adapts to the projected climate change impacts

Economic Benefits

A fixed link would provide benefits to the user through reductions in journey times and no longer having to pay a toll. These would be offset slightly by the increased vehicle operating costs resulting from taking a longer driving route compared to being on a ferry.

Note that a 'Do Nothing' scenario is not considered here. The Corran transport connection is lifeline in nature and as such investment in either ferry services or a fixed link in essential in the short / medium term.

Two main scenarios have been considered here:

- Reference Case: In the Reference case, it is assumed that:
  - No fixed link is constructed, with the ferry service providing the long-term solution for the crossing of the Narrows.
  - New ferries and associated infrastructure are provided on life expiry of the current assets. There are a number of variants of the Reference Case, reflecting the range of costs of the different ferry options, and these are set out in more detail below
- Do-Something: In the Do-Something, it is assumed that:
  - A new fixed link will be provided, opening in 2027. This is a conceptual fixed link between Nether Lochaber and Ardgour as the structural form and alignment would not significantly impact on the scale of the benefits.

Within the modelling, as a core assumption, it is assumed that there would be a 50% uplift in trips associated with the introduction of a fixed link, accounting for people in the area making more trips and an increase in tourist-based trips.

Given the uncertainties surrounding the main appraisal parameters at this early feasibility stage, we developed **72 different scenarios (4*6*3)** to represent the potential costs and benefits of a fixed link compared to an ongoing ferry operation, comprising:

- **4 Ferry Cost Scenarios:**
  - Quarter Point Ferry Low Cost
  - Quarter Point Ferry High Cost
  - Straight Through Ferry Low Cost
  - Straight Through Ferry High Cost
- **6 Fixed Link Cost Scenarios:**
  - Cable Bridge Low Cost
  - Cable Bridge High Cost
  - Vertical Lift Bridge Low Cost
  - Vertical Bridge High Cost
  - Tunnel Low Cost
  - Tunnel High Cost
- **3 Benefits Scenarios:**
  - 5 Minute Wait for Ferry
  - 10 Minute Wait for Ferry
  - 15 Minute Wait Ferry

The four ferry options were derived from the preferred options identified through the Corran Ferry STAG Part 2 Appraisal and encompass the variety of costs represented by these options.

The three core fixed link options provide an envelope of costs comprising the seven options (A-G) providing a representative cost range.

costs associated with the options A-G described above. These three core fixed link options provide an envelope of costs comprising the seven options (A-G) providing a representative cost range.

We have estimated a range of PVBs (Present Value of Benefits) based on 5, 10 and 15-minute average ferry wait times (indicated by the 3 benefits scenarios), ranging from **£25.8m to £60.0m.**

Of all the scenarios considered, over **80% generated an implied Benefit Cost Ratio of greater than 1.**

Other notable results from the analysis include:

- 5 Min Wait Scenario: With the exception of the high cost tunnel options, the majority of the scenarios provide a BCR greater than 1. Only seven scenarios fail to deliver a BCR greater than 1.
- 10 Min Wait Scenario: Only 4 scenarios fail to deliver a BCR greater than 1, with these comprising the high cost tunnel scenarios.
- 15 Min Wait Scenario: All scenarios provide a BCR greater than 1.

This implies that, based on this initial analysis and the core assumptions made here, the fixed link could be a 'feasible' proposition from this perspective.

How might a fixed link impact on the economy and society of the area?

Outwith the estimated quantified economic benefits, a key question is how the construction of a fixed link would impact on the social and economic structure of both the peninsula and Lochaber communities. It should be noted that, as this is a high-level feasibility study only, no primary research or stakeholder & public engagement has been undertaken, with the type and potential scale of benefits drawn from the case study evidence and some initial consultation undertaken during the Corran Ferry STAG Appraisal work. Should the proposal be progressed further, supporting research (potentially including an Economic Impact Assessment) and a full programme of engagement would be required to more fully establish existence and scale of the anticipated benefits.

When considering the potential impacts, it is important to bear in mind that the peninsula is an expansive land mass, connected throughout much of that area by single track roads. Impacts are therefore likely to be most strongly felt in Ardgour, Morvern and Sunart, but perhaps less so in Ardnamurchan and Moidart.

The 'logic map' shown in Figure E3 below provides a systematic means of considering and presenting the potential benefits of a fixed link. The **Strategic Need** sets out the rationale for intervention, with the evidence showing the current issues and problems. If there is investment of X (**Inputs**) this will then generate **Outputs** which result in certain **Outcomes** and then, ultimately, **Impacts**.

When considering how a fixed link may affect the economy and society of the study area, the key column in the logic map is the

Table 6 3: NTS2 Policy, Transport Scotland 2020

Items in Orange are especially applicable to the Corran Narrows.

The six fixed link scenarios were derived from the range of anticipated '**impacts**':

Figure E3: Corran Narrows Fixed Link – Logic Map

Strategic Need

- Nether Lochaber – Ardgour busiest single vessel route in Europe
- Capacity constraints on the ferry service at peak times or when MV *Maid of Glencoul* is operating on its own
- Requirement for major capital investment in ferry service
- Human resource challenges associated with the ferry service – front line and back office
- Limitations on the size of commercial vehicles which can access the peninsula when ferry is off or MV *Maid of Glencoul* is operating on its own
- Social & economic development – supporting development of a fragile community

Inputs

- Corran Narrows Fixed Link Feasibility Study
- Development of Outline and Final Business Cases – these would include detailed option development and established funding, procurement and management arrangements
- Placing of contract following procurement process

Outputs

- Bridge or tunnel across / under the Corran Narrows
- Connecting road infrastructure to the A82 and A861
- Management, operation and maintenance contract in place
- Sale or disposal of the MV *Corran* and MV *Maid of Glencoul*

Outcomes

- Additional trips across the Corran Narrows
- 24-hour access between the peninsula and Lochaber (and vice versa)
- Creation of unrestricted large HGV route onto peninsula
- Reduced journey times
- Overall improved journey time reliability
- Improved resilience for the peninsula and, to a lesser extent, the A82
- Supports active travel corridor along west side of Loch Linnhe (although reliance on Camusnagaul Ferry for 'short' connection to Fort William)
- Increased emissions from more trips
- Reduced emissions from not operating ferries

Impacts

- Population retention / growth
- Expanded labour market catchment & job opportunities
- Increased local / regional productivity
- New business formation
- Increased tourism in peninsula
- Improved access to services – health, education, social & leisure opportunities
- Improved supply-chain efficiency
- Efficiencies in service delivery from the perspective of the public sector
- Quality of life benefits

What are the key conclusions?

This high-level feasibility study has demonstrated that, subject to more detailed option development and costing, a fixed link across the Corran Narrows appears a potentially viable proposition from an engineering, planning and financial perspective. In particular, it should be noted that:

- There are no 'showstopper' issues preventing the construction of a fixed link, albeit there are environmental, planning and construction issues which would need to be taken into consideration. The fixed link is therefore technically feasible.
- The costs of a fixed link are not significantly out of step with a continued ferry service, particularly when set against the range of benefits of a fixed link.
- Under the majority of the scenarios developed here, the fixed link proposal generates a benefit-cost ratio of greater than 1.

The analysis and evidence presented in this report therefore suggests that **there is a case for further exploring the comparative merits of a fixed link, either within the context of STPR2 or as a standalone business case**.

What are the next steps?

Whilst this study has demonstrated that a fixed link is a potentially viable option for the Corran Narrows, it is essential to bear in mind that it is an early feasibility study, drawing together high-level option development, costing and economic narrative. It is clear that further development work will be needed to take the project to the next stage.

The project partners should consider **submitting this report to Transport Scotland for consideration within the STPR2 options appraisal process**. Whilst STPR2 represents an important opportunity to realise a fixed link at Corran, it should not be considered the only avenue for realising this aspiration as there are a number of uncertainties attached to it, not least whether a fixed link across the Narrows would be prioritised.

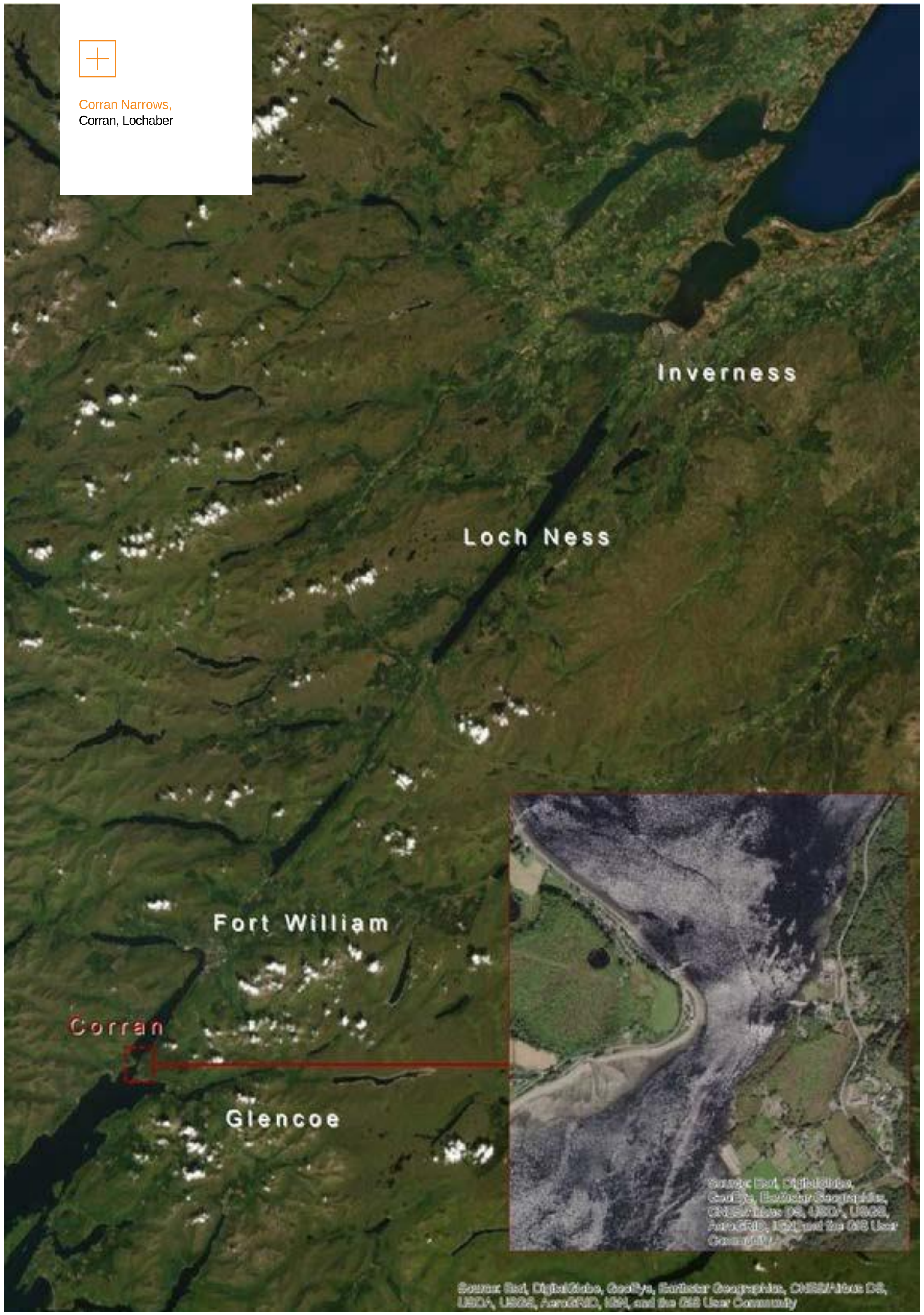
Corran Transport Link – Outline Business Case

There are now two recent studies exploring future transport provision across the Corran Narrows:

- Corran Ferry STAG Appraisal: This report was published in 2018 and considered the different options for the future of ferry services at Corran, mainly form a technical and financial perspective. This study did not cover fixed links and thus was focussed on ferry-based options only.
- Corran Narrows Fixed Link Feasibility Study (i.e. this report): This report develops the fixed link options to a level equivalent with ferry options in the Corran Ferry STAG Appraisal.

To comply with best practice, in devising a long-term solution for the Corran Narrows, there would be significant benefit in developing single, umbrella Strategic and Outline Business Cases considering the comparative merits of ferry and fixed link-based solution in the round. This would involve:

- Combining the Corran Ferry STAG Appraisal and the Fixed Link Feasibility Study into a single Strategic Business Case within the STAG format.
- Infilling material to comply with STAG including public and stakeholder engagement
- Undertaking bespoke analysis of the economic and social impacts of a fixed link on the peninsula
- The SBC should then be progressed to an Outline Business Case (OBC) which would select a preferred option for the long-term future of transport across the Narrows.



2.0 Introduction

2.1 Overview

The Corran Narrows marks the dividing line between the upper and lower section of Loch Linnhe, a circa 30-mile long sea loch which runs along the Great Glen Fault. The section of the loch upstream of Corran separates Lochaber from Ardgour and the areas beyond, albeit it is possible to drive around the loch, although with some restrictions for larger vehicles. As the name suggests, Loch Linnhe is at its narrowest at Corran, circa 300 metres wide at its narrowest point. The map left shows the location of the Corran Narrows.

The Corran Ferry service operates the short passenger and vehicle crossing of the Corran Narrows between Nether Lochaber and Ardgour. The service provides a lifeline connection linking the communities of Ardgour, Sunart, Ardnamurchan, Moidart, Morar, Morvern and, to a lesser degree, the Isle of Mull to Lochaber. The ferry serves a wide variety of purposes including: providing access to employment and other key services for residents; acting as a gateway for tourists visiting the peninsula; and meeting the supply-chain needs of the above communities. **It is understood to be the busiest single-vessel ferry crossing in Europe.**

Whilst the ferry service has met the needs of communities on both sides of the crossing for many years, it is at present facing significant challenges associated with:

- the requirement for capital investment to replace life-expired assets, particularly the back-up ferry, MV *Maid of Glencoul*, which entered service in 1971; and
- the development of a sustainable human resources solution, both in terms of front-line and back office staff, to operate the service.

In parallel to this, there is a long-held aspiration amongst the peninsular communities, and those living in Mull, for a fixed link to replace the ferry service, as reflected in the adopted 2019 WestPlan, safeguarding the crossing for future option appraisal. Recognising the aspirations of both these communities, a partnership of The Highland Council (THC), Highlands and Islands Transport Partnership (HITRANS) and Highlands and Islands Enterprise (HIE) has commissioned Stantec to develop a high-level feasibility study for a fixed link across the Corran Narrows.

2.2 Why Commission This Study Now?

Whilst the desire for a fixed link at Corran has been prominent for many years, two factors have combined to prompt the requirement for this study.

2.2.1 The future of the ferry service

Whilst THC is addressing some of the immediate issues with the ferry service through a business case process, there is a much longer-term consideration as to whether a ferry or fixed link would provide the best value for money when considered in the widest sense (i.e. social and economic as well as financial outcomes). With capital expenditure in the region of £23m-£40m required on the ferry service in the medium term, it is essential to contrast the comparative merits of an ongoing ferry service against a fixed link before committing to any new investment. This high-level feasibility study will identify and compare the costs and benefits of a fixed link relative to a ferry, providing an initial steer with respect to future investment priorities.

2.2.2 Strategic Transport Projects Review 2 (STPR2)

Whilst the study may identify a fixed link as providing value for money over the long-term, the up-front investment cost is likely to significantly exceed that of a ferry replacement programme. There is therefore an affordability question, particularly within the context of reductions in local authority budgets.

Recognising the affordability challenge, THC is seeking to submit the case for a fixed link into the ongoing Strategic Transport Projects Review 2 (STPR2), thus progressing it for consideration in the national context. STPR2 is an ongoing Transport Scotland study which will inform transport investment in Scotland for the next 20 years, ensuring that investment is in line with the vision, priorities and outcomes set out in the National Transport Strategy 2 (NTS2). This study will, at a high-level, frame the costs and benefits of a fixed link, providing a basis for further development and appraisal within the context of STPR2.

2.3 Study Scope

As alluded to above, this piece of work is a high-level feasibility study. The outcomes emerging from it will require further development, either within the context of STPR2 and / or as part of a standalone business case comparing ferry and fixed link options. In terms of outcomes, the study will:

- review case study evidence on the cost, procurement and impacts of equivalent fixed links;
- identify potential alignments for a fixed link, defined on a corridor basis;
- consider the types of fixed link which could be progressed in each corridor;
- set out the most appropriate fixed link options within each corridor;
- provide a commentary on supporting road infrastructure and tie-ins to the existing network on both sides of the crossing;
- provide high level capital and maintenance cost bands for each fixed link option;
- identify the Transport Economic Efficiency (TEE) benefits of a generic fixed link;
- qualitatively explore the potential societal outcomes and impacts of a fixed link on both sides of the crossing; and
- compare the whole life costs of a fixed link to continuing with a ferry service.

The output of this process **will** determine:

- whether a fixed link can feasibly be delivered at the Corran Narrows;
- if so, identify options in relation to the alignment and structural form;
- lifetime costs of the fixed link;
- the benefits of a fixed link; and
- the comparative costs of a fixed link and continued ferry service over a 60-year appraisal horizon.

At this stage, the study **will not**:

- firmly define a preferred option in terms of alignment or structural form;
- recommend whether a ferry or fixed link is the most appropriate long-term option for the Corran crossing; or
- engage with communities, which is outwith the scope of work at this stage.

2.4 Corran Ferry Stag Appraisal

It should be noted that THC commissioned Stantec (formerly Peter Brett Associates LLP), Mott MacDonald and WSMD Associates to prepare a Scottish Transport Appraisal Guidance (STAG) study of future options for the Corran Ferry in February 2018. The findings of this study were published in November 2018. To avoid confusion, it is worthwhile explaining the purpose and broad outcomes of this piece of work, and how they relate to this feasibility study.

The Corran Ferry STAG Appraisal was prompted by a desire to secure the short to medium-term future of the ferry service (circa 5-10 years), addressing the issues associated with ageing capital assets and human resource pressures. The study sought to answer two discrete questions within the overall context of the STAG framework:

- What level of service should be provided in the future? (the 'what'); and
- How should the service be funded and delivered? (the 'how').

The study did not compare a ferry service and fixed link given the shorter-term focus of the work, but it highlighted that there was a longer-term question surrounding the most appropriate solution for the Corran Narrows.

The key point in relation to this feasibility study is that the STAG study identified and costed three vessel and marine infrastructure solutions, thus allowing for a comparison with the cost of a fixed link.

2.5 Report Structure

This report consists of five further chapters, as follows:

- Chapter 3 provides case study evidence considering the form, cost and outcomes & impacts of other fixed links from within the United Kingdom (UK).
- Chapter 4 sets out the land-use, planning and environmental constraints in the vicinity of the Corran Narrows, which must be considered when developing fixed link proposals.
- Chapter 5 sets out the detailed option development, with respect to the alignment, structural form, connecting road infrastructure and indicative cost of different fixed link options.
- Chapter 6 establishes the TEE and wider economic impacts of a fixed link and compares the whole life costs and benefits of such a structure to the equivalent for a continued ferry service.
- Chapter 7 provides conclusions, recommendations and next steps.

MV Corran,
Corran Narrows.

3.0 Case Studies

3.1 Overview

In order to place the proposed fixed link at Corran in context, it is beneficial to review case study evidence and experience related to other fixed link schemes, which have been delivered in the UK. This chapter consists of three sections, as follows:

- The **appraisal context** (Section 3.2): this section considers how the case for a fixed link at Corran would be made.
- The **deliverability context** (Section 3.3): This section sets out other fixed link schemes which have been delivered in the UK in recent decades and explores the cost, design and procurement challenges associated with different types of fixed link.
- The **socio-economic context** (Section 3.4): Using case study evidence, this final section explores the societal outcomes and impacts which have emerged from recent fixed link projects.

3.2 The Case For Fixed Links

3.2.1 Appraisal and the Business Case Process

The case for any major new piece of transport infrastructure in Scotland is initially made in the context of a STAG study and a subsequent business case. The appraisal process allows for an objective-led and multi-modal approach to identifying a preferred option which addresses an evidenced set of transport problems and opportunities.

Whilst the STAG process involves a multi-criteria appraisal, the key output in most studies is the benefit-cost ratio (BCR), which compares the social welfare benefits of a scheme against its financial cost.

3.2.1.1 Transport Economic Efficiency

The ‘benefit’ side of the cost-benefit ledger is principally determined by the TEE benefits of a scheme - this typically involves:

- calculation and monetisation of the travel time savings associated with a scheme for existing users;
- where a fixed link is new / replacing a ferry service (rather than replacing a life-expired fixed link), monetisation of the frequency benefits; and
- benefits for ‘new’ demand, where these new users are assigned half of the benefits of existing users (the ‘rule of a

On large scale fixed link projects, such as the Queensferry Crossing and Mersey Gateway, the TEE benefit accounts for the bulk of the benefits generated, reflecting the high volumes making movements between e.g. Edinburgh & Fife and Cheshire & Merseyside.

The Corran Ferry is understood to be the busiest single vessel ferry route in Europe and thus a fixed link across the Narrows would similarly generate TEE benefits associated with:

- the ability to travel without waiting on a timetabled ferry and travelling at times when the ferry does not operate (or when it is suspended due to weather or a breakdown);
- reduced crossing times between Nether Lochaber and Ardgour from not having to queue for, board, travel on and disembark the ferry; and
- year-round 24-hour access to the peninsula.

Whilst a Narrows fixed link would generate TEE benefits (which will be estimated as part of this study), it is possible that the costs of such a connection would exceed the TEE benefits. Despite being the busiest single vessel route in Europe, absolute traffic numbers remain relatively low, circa 700-750 Annual Average Daily Traffic (AADT) currently. The long-term case for a fixed link across the Narrows therefore has to be much wider than would perhaps be required for a link connecting two major centres of population or adjoining banks of a river in a major urban area.

3.2.1.2 Wider Economic Impacts

In recent years, transport appraisal guidance has evolved to account for 'wider economic impacts' (WEI), which are non-transport benefits which emerge in addition to the TEE. WEI take the form of:

- increases in **productivity**, associated with improved transport connections effectively bringing places, businesses and employment & labour markets closer together (known as **agglomeration**); and
- enhancements to the functionality of **labour markets**, in terms of:
  - those currently out of work moving into employment;
  - people in work moving to more productive employment; and
  - people working more hours.

The guidance suggests that WEI, and in particular agglomeration benefits, only typically occur in the largest schemes, and in any case are treated as a sensitivity on the BCR rather than a core component. They have nonetheless been integral in several business cases making the case for investment where the conventional BCR does not suggest that the project is economically beneficial. For example, WEIs have been an important part of the business case for the dualling of the A9 and A96. Whilst not expressed as WEI specifically, the productivity, land-use and labour market benefits were also integral to making the case for the committed new River Clyde crossing between Renfrew and Yoker as part of the Glasgow and Clyde Valley City Deal.

As alluded to above, the guidance would suggest that WEIs are unlikely to be material with respect to a fixed link at Corran given relatively low traffic flows, low population and limited economic activity on either side of the crossing – it will therefore not be possible to monetise the WEIs. There is nonetheless a strong qualitative case that a fixed link in this context would support the delivery of a range of socio-economic benefits beyond the pure TEE – this report will therefore include an 'economic narrative' explaining the potential of a Corran Narrows fixed link to generate wider economic and distributional benefits, including:

- Facilitating improved **access to employment** in Fort William and beyond – the Corran Ferry operating day currently permits a standard working day in Lochaber, but shift work is more difficult.
- Improving access to all other **services** in Lochaber, including Belford Hospital (particularly in emergencies) and higher education.
- Improving the **resilience** of the peninsula and, to a lesser degree, the Isle of Mull (providing an alternative route to the mainland in the event that the Oban - Craignure route is out of service).
- Promoting scope for **business investment** through improving access to Lochaber and beyond (although note that given the size of the labour market, on-peninsula infrastructure etc, the scale of new business investment is likely to be limited).
- Promoting increased **tourism**, in effect addressing the 'psychological barrier' associated with having to take a ferry. Those unfamiliar with the arrangements at Corran may be interested in visiting the peninsula but could drive past due to lack of awareness of the fares, length of operating day, timetable etc. It should though be noted that increased tourism can be a double-edged sword in areas with limited road and public infrastructure provision.
- Assuming any fixed link is not tolled, increasing the **disposable income** of residents in the peninsula, which generally lags regional and Scottish averages due to limited employment opportunities.
- Improved **supply-chain efficiency** and public transport reliability.

The extent to which such benefits have emerged in other recent fixed link schemes in the Highlands & Islands (e.g. Skye Bridge, Scalpay Bridge etc) will be explored in Section 2.4.

3.2.2 What are the implications for the Corran Narrows?

The purpose of this feasibility study is to calculate the TEE benefits associated with a fixed link across the Corran Narrows and compare them to:

- the costs associated with a shortlist of bridge and tunnel options, deriving a benefit-cost ratio; and
- the costs and benefits of continued operation of a ferry between Nether Lochaber and Ardgour.

This technical exercise will act as a 'gateway' process to enable the joint agencies to submit the study information for consideration in Transport Scotland's STPR2 or if required to be considered more widely beyond STPR2. If the decision is made to promote the scheme, a much more detailed piece of research will be required to expand on the social and economic 'outcomes' and 'impacts' of a fixed link.

3.3 Recent Experience, Standards And Procurement

3.3.1 Overview

The 'optioneering' task of this appraisal will explore the different types of fixed link which could be constructed across the Narrows. Whilst the full range of fixed link options will be considered, it is highly likely that the solution would either be a bridge or a tunnel (the requirement to maintain a shipping lane and the depth of water would likely prevent a causeway).

To provide context, this section firstly reviews recent new build bridges and tunnels in the UK, before exploring technical design standards and the procurement environment within which any fixed link would be constructed.

3.3.2 Recent New Build Bridges & Tunnels in the UK

3.3.2.1 Bridges

In setting the context for a potential bridge across the Corran Narrows, it is worth reflecting on other bridges recently built in the UK. A selection of such bridges is shown in the table below, setting out their length, the number of lanes, opening year and cost, both at the time of construction and in 2018 prices. It should be noted that:

- Only road bridges crossing river estuaries / firths / sea lochs have been included, with a focus on crossings in Scotland and in particular the Highlands & Islands.
- With the exception of the recently constructed Queensferry Crossing and Mersey Gateway bridges, the focus is predominantly on smaller and lower cost bridges akin to what would be anticipated at Corran.
- The table is only intended to provide an indication of recent history in terms of cross-water bridge construction in the UK. Every project has its own unique characteristics and cannot readily be compared to what is proposed at Corran.
- The uprating of build costs to 2018 prices is based on the Bank of England inflation calculator, which uses the Retail Price Index. These costs therefore do not specifically reflect construction indices and any location related cost inflations.
- In many cases, it is unclear whether the bridge costs we have found through our research are for the structure only or include the connecting road infrastructure.

Bridge	Length (m)	Total Lanes	Year Opened	Cost (£m)	Cost (£m, 2018 prices)[1]
Clyde Arc	96	2	2006	£20.30	£28.90
Jubilee Bridge, Stockton-on-Tees	150	4	2002	£14.30	£22.90
Surtees Bridge, Teesside	150	6	2008	£14.30	£18.70
Creagan Bridge	150	2	1999	£4.00	£6.80
Scalpay	170	1	1997	£6.40	£11.40
Kylesku	276	2	1984	£4.00	£12.60
Flintshire	294	4	1998	£55.00	£95.10
Skye	500	2	1995	£27.00	£51.00
Cleddau, Pembrokeshire	820	2	1975	£11.80	£97.20
Dornoch	892	2	1991	£13.50	£28.50
Kessock	1,056	4	1982	£17.50	£60.70
Clackmannanshire	1,200	3	2008	£120.00	£157.30
Sheppey Crossing, Kent	1,250	4	2006	£30.00	£42.60
Cromarty	1,464	2	1979	£5.0[2]	£17.30
Mersey Gateway	2,200	6	2017	£600	£620.00
Queensferry	2,700	4	2017	£1,350	£1,395.00

Table 3 1: Recent Cross-Water Bridges Constructed in the UK

The key points of note from the above table are as follows:

- There is a strong and recent UK track record in building new bridges spanning rivers, estuaries / firths and major sea lochs, with the above providing only some examples from a much longer list. This is an important point as it demonstrates that there is current procurement and contractor experience in the UK.
- There was a concerted programme of bridge building in the Highlands over the period 1982 to 1995. It is notable that there was an established road route available prior to the construction of the Kessock, Cromarty and Dornoch Bridges. The focus of these connections was therefore on reducing journey times and promoting improved accessibility along what is now the A9 corridor (and in particular from Caithness and Sutherland to Inverness).

3.3.2.2 Tunnels

An equivalent table showing recent UK experience in tunnelling is provided below. Given the context at Corran, the focus is again on road crossings under major bodies of water.

1 | 2018 costs calculated on basis of Bank of England inflation calculator.

2 | This was the only published figure which could be found for the Cromarty Bridge, but it appears very low and out of keeping with other bridges of a similar length, so it is possible that there is an error in the figure.

Bridge	Length (m)	Total Lanes	Year Opened	Cost (£m)	Cost (£m, 2018 prices)[3]
Medway Tunnel	240	4	1996	£80.00	£147.50
Queensgate Tunnel, Cardiff	715	4	1995	£60.0[4]	£113.30
Conwy Tunnel, North Wales	1,080	4	1991	£146.00	£307.90
Tyne Tunnel 2	1,500	4	2011	£139.00	£166.40
Limehouse Link, London	1,800	6	1993	£293.00	£586.30

Table 3 2: Recent Underwater Tunnels Constructed in the UK

The key points of note from the above table are as follows:

- There have been comparatively few major underwater road tunnels built in the UK in recent years, although there have been several tunnels built under hills and for railways, canals and utilities. The most recent underwater road tunnel built in Scotland was the Clyde Tunnel, which opened in 1963. This suggests that procurement and contractor expertise is much more limited than is the case with bridges.

- It is also notable from the above list that, with the exception of the Conwy Tunnel, the others are in major city centres where presumably land availability / value and, to a lesser degree, visual amenity are the key driving factors in choosing a tunnel over a bridge.

- In the context of Conwy, a tunnel was chosen over a bridge for environmental reasons and to preserve views of Conwy Castle[5]. This tunnel is an immersed tube rather than a bored tunnel, as would be required at Corran to avoid compromising the navigation channel and future potential for developing tidal energy in the Narrows.

3.3.3 Design Standards

3.3.3.1 Bridges

Roads in Scotland are designed to the requirements set out in the Design Manual for Roads and Bridges (DMRB). These requirements include desirable minimum requirements and absolute requirements. In certain circumstances, at the discretion of the designer, designs can incorporate elements which do not meet the desirable minimum requirements, road gradients for example. These are known as **'Relaxations'**.

If a design does not meet the absolute requirements, a **'Departure from Standard'** is required and this must be approved by the Overseeing Organisation, which in this case is likely to be one of the road authorities, The Highland Council or Transport Scotland[6].

3.3.3.2 Tunnel

THC has recently published a range of STAG and DMRB reports in relation to options for addressing rock falls on the A890 at Stromeferry in Wester Ross. The options considered in that report included a range of fixed link types for crossing Loch Carron. Of particular relevance with respect to this piece of work is the review of tunnel options, which sets out the design considerations for a tunnel in an area broadly similar to Corran. There is benefit in replicating this section of the Stromeferry report almost in its entirety, as it provides useful design considerations and a benchmark for Corran.

Design Standards

Tunnel options were considered as part of the Stromeferry STAG Appraisal, which identified that Transport Scotland would be the Technical Approval Authority (TAA) for the options presented in that appraisal. Given that any fixed link at Corran would be on the THC road network and also tie into the A82(T), it is highly likely that Transport Scotland would be the TAA in this instance also. As such, the applicable design standard for road tunnels constructed as part of the scheme would be DMRB BD 78/99 'Design of Road Tunnels'.

Other Design References

Road tunnels which form part of the Trans-European Transport Network (TEN) and exceed 500m in length must be designed in accordance with the Road Tunnel Safety Regulations 2007, which is transposed into UK law Directive 2004/54/EC of the European Parliament and of the Council (although this is now, of course, potentially subject to change). Whilst neither the A82 or A861 are part of the TEN, the regulations do, however, exist as an example of best practice and provide relevant guidance intended to minimise risk in road tunnels. It is, therefore, considered that the design of any new tunnel under the Corran Narrows should be in accordance with relevant requirements of the regulations as referenced below:

- Directive 2004/54/EC of the European Parliament and of the Council of 29 April 2004 on minimum safety requirements for tunnels in the Trans-European Road Network.

- Statutory Instruments, 2007 No. 1520, Highways, Tunnels, The Road Tunnel Safety Regulations 2007.

Risk Evaluation & Management

Risk evaluation and management are key components in road tunnel design and several sources provide guidance. The British Tunnelling Society has published a code of practice that sets out guidance on the identification, minimisation and management of risks associated with tunnelling works[7]. The World Road Association (PIARC) also provides guidance on the management of operational risks for road tunnels. This guidance is published online as the PIARC Road Tunnels Manual.

Interpreted Design Requirements and Guidance

The references cited above provide important requirements and guidance for the design of new road tunnels and these should be considered at the option selection and design stages – i.e. the stages subsequent to this study if a tunnel is selected as the most appropriate form of fixed link. Relevant guidance and requirements are summarised below:

- The Road Tunnel Safety Regulations suggest the following should be considered for any tunnel across the Narrows:
  - Duties of the Tunnel Manager.
  - Appointment of a Safety Officer.
  - Appointment of an Inspection Entity.
  - Appointment of a Technical Approval Authority (anticipated to be Transport Scotland).
  - Use of Risk Analysis to assess operating risks prior to design.

- Suitable signage should be provided as indicated within the 2007 Regulations, Annex I.

- Emergency equipment and exits and the provision of information to tunnel users in an emergency should be in accordance with the 2007 Regulations, Annex I.

- Planning and design of the tunnel and ground investigation for tunnelling should be in accordance with the 'Codes of Practice' referenced above.

- Pedestrians and animals are generally not permitted to use road tunnels under the requirements of BD 78/99. The majority usage at Corran would be vehicles (as per the ferry) but the requirement for pedestrian and animal usage would need to be consulted on in any future business case. Specific design requirements must be considered if pedestrians and animals are to be permitted to use the tunnel. This may require the use of a dividing wall within the tunnel to provide a separate structural cell for these user classes.

- BD 78/99 requires classification of the tunnel by length and traffic volume to determine safety measures and requirements. Based on an annual average traffic flow (AADT) of 700-1,000[8] vehicles per day and tunnel lengths of between 1km and 3km, the tunnel would be classified as Tunnel Category B[9]. This classification would lead to the following principal safety and fire protection requirements:
  - emergency telephones;
  - fire extinguishers;
  - pressurised fire hydrants;
  - emergency exit signs;
  - lane control and tunnel closure signs / signals;
  - emergency stopping lane;
  - emergency walkway; and
  - ventilation for smoke control.

- In addition, the following equipment or measures may be required:
  - radio rebroadcasting system;
  - traffic Loops;
  - CCTV;
  - fire hose reels; and
  - escape doors.

Transport of Dangerous Goods

BD 78/99 requires assessment of the risks associated with the carriage of dangerous goods through road tunnels and the adoption of suitable safeguards. Dangerous Goods are defined as explosives, flammables, radioactives and toxins. Assessment of the risks involved would include consideration of the types of materials that are likely to be carried, patterns of traffic flow and the risks associated with passage through the tunnel compared to alternative routes.

Research has been carried out by the World Road Association (PIARC) regarding the assessment of risks associated with the passage of dangerous goods through tunnels. This research has resulted in the development of a Quantitative Risk Assessment Model (QRAM) for Dangerous Goods Transport through Road Tunnels. The software model allows parameters for the tunnel and alternative routes to be entered and permits evaluation of tunnel facilities and safety measures.

Where there is no suitable alternative route for hazardous goods or the alternative routes give rise to significant risks, it is usual to provide specific safety measures, such as isolation of vehicles carrying hazardous goods from other tunnel users. This is an important issue in the context of Corran, as the ferry currently provides the main dangerous goods route onto the peninsula, including for the transport of e.g. fuel and heating oil, agricultural products etc. Whilst there are alternative routes, they are predominantly single track and also have height restrictions which limit the types of vehicle which can use them. Moreover, the Corran Ferry also currently provides the dangerous goods access for Mull and Iona via the Lochaline – Fishnish ferry. This is because the current vessel on the primary Oban – Craignure route is closed deck and cannot accommodate certain categories of dangerous goods

3 | 2018 costs calculated on basis of Bank of England inflation calculator.
4 | Note – this project was developed as part of the wider Butetown Link Road and there is no readily available data on the outturn cost of the project overall or the tunnel component of it.
5 | http://www.engineering-timelines.com/scripts/engineeringItem.asp?id=381
6 | Stromeferry Options Appraisal STAG Part 1 / DMRB Stage 1 Report (URS, 2013), pp. 89-92.
7 | The Joint Code of Practice for Risk Management of Tunnel Works in the UK, prepared jointly by The Association of British Insurers and The British Tunnelling Society, published by The British Tunnelling Society, 2003

8 | Scottish Transport Statistics notes that, in 2018, the Corran Ferry carried 257,500 cars, meaning Average Annual Daily Traffic (AADT) is 705 cars (and 35 com- mercial vehicles and coaches). It is though assumed that any fixed link would generate traffic, so for the purposes of this comparison, it can be assumed that AADT would be in the region of 700-1,000 vehicles per day.

9 | See BD 78/79, Figure 3.1.

10 | Stromeferry: Review of Tunnel Options (URS, 2014), pp. 6-8.

(although it should be noted that proposed vessel deployment on the Oban – Craignure route from 2022/2023 would eliminate this issue and would actually provide an alternative dangerous goods route onto the peninsula).

Nonetheless, given the relatively low traffic flows expected to use a Corran Narrows tunnel, it is likely that controlled entry of vehicles carrying dangerous goods could be implemented with adequate mitigation methods in place to reduce any significant delays to other road users, with specific cognisance of the risks of traffic backing up onto the A82(T). Consideration could therefore be given to limiting access to other traffic during passage of vehicles carrying hazardous goods by use of stop lights or barriers[10].

3.3.4 Procurement

As previously noted, work on a business case subsequent to this study would progressively take-forward and define a 'preferred option'. As part of the business case process, the preferred approach to the procurement and management of the delivery of the selected option would be identified in the 'Commercial' and 'Management' Cases. It is however worthwhile to initially consider procurement in the context of a bridge or tunnel in terms of how this may influence the appraisal of options.

The purpose of this study is to explore whether a Corran Narrows fixed link has any merit and, if so, to initially make a case for its inclusion in the STPR2. If the scheme was to be included in STPR2, its delivery would likely fall upon Transport Scotland (although this would remain to be confirmed in the business case).

In the context of a bridge, it is important to note that:

- Both Transport Scotland and various local authorities have experience of designing, procuring and managing a bridge construction project. The most obvious example is of course the highly successful build and delivery of the Queensferry Crossing, but other recent examples include the Clackmannanshire and Skye Bridges.
- There is also an established pool of consultants, contractors and project managers with recent experience of delivering bridge construction projects in the Scottish market, and thus they are familiar with the institutional, legal and procurement frameworks used.

The same cannot however be said of an underwater road tunnel. As can be seen from Table 3.2, there have been very few underwater road tunnels built in the UK in the last 30 years, and none in Scotland. In the event that a tunnel was identified as the preferred option for Corran, this would present a challenge to overcome, in terms of:

- The procurement authority putting in place a sufficiently large and experienced team to procure and deliver the structure.
- The absence of local consultants and contractors with experience of delivering underwater road tunnels in Scotland or indeed the UK. It is likely that the risks associated with this inexperience would be priced into the bid (or may later materialise as a cost over-run if not priced appropriately).

3.3.4.1 Could best-practice approach from elsewhere be adopted?

Whilst tunnelling is not particularly common in the UK, it is a widely adopted approach amongst our European neighbours, particularly the Norwegians, who have decades of experience in delivering estuarial and cross-fjord tunnels at comparatively low costs. The question is whether procurement and construction approaches from Norway could be readily adopted to deliver a low-cost tunnel solution for the Corran Narrows.

The potential adoption of Norwegian tunnelling expertise in the Scottish context has been explored across several studies, most notably in Shetland where there are long-standing aspirations for tunnels to Bressay, Unst, Whalsay and Yell. Indeed, in 2010, Shetland Islands Council facilitated a workshop with Norwegian and UK tunnelling experts to compare approaches and determine whether Norwegian tunnel costs could be achieved in the Shetland / Scottish context. The key findings of this workshop in relation to Norwegian tunneling were as follows:

- Contractors
  - There tend to be fewer but highly skilled and experienced personnel on Norwegian tunnelling projects who work very efficiently.
  - 'Active design' at the face during construction means decisions are taken in 'real time' enabling quick and efficient progress.
  - Competition is high.
  - Low profit margin of circa 2%-3% acceptable.
  - Dedicated and modern equipment.
- Technical standards
  - Norwegian tunnels are generally based on quite a minimal design.
  - Tunnel Linings: The Norwegian highway tunnels are typically constructed in relatively high-quality rock masses and utilise structural linings only where necessary to provide additional support. Tunnels generally include local shotcrete support and rock-bolting, but do not include a continuous concrete lining as would likely be required by UK standards.
  - Water Ingress: Norwegian tunnels, including sub-sea tunnels, do not typically provide a water-tight lining, but instead allow some degree of water ingress which is dealt with by tunnel drainage. There is potential for increased operational cost associated with pumping water ingress to the surface. Water ingress is typically limited by providing relatively large depths of cover and by grouting the rock mass during construction.
  - Cross-section: Norwegian tunnel cross-sections reflect reduced lining requirements, as described above, and relatively low traffic volumes. Tunnel cross-sections are typically in the region of 50 to 60m2, which allows for two lanes of traffic, but does not provide provision for a segregated escape route or dedicated stopping lane. Locally widened sections of tunnel are typically provided to allow emergency lay-bys containing safety stations (fire extinguishers and emergency telephones).
  - Tunnel Lengths: Norway has the longest road tunnel in the world with a length in excess of 24km (Laerdal Tunnel). Typical road tunnel length is in the order of 1km. Norwegian standards place more emphasis on traffic volume and less emphasis on length when determining safety requirements, compared to the BD78/99 regulations.
  - Escape Routes / Refuges: Segregated escape routes or refuges are not generally provided in single bore tunnels[11].
- Procurement
  - There is significant tunnel procurement and contract management expertise within the Norwegian public sector.
  - The contractual system in Norway helps, with the public sector sharing the risks attached to tunnel projects to keep costs down.
  - The Government 'self-insures' and has a dedicated budget for this.
  - Insurers also share the risk in Norway (up to 30%). In contrast, the cost of tunnelling insurance tends to be much higher in the UK.
  - The Contractor provides insurance for machinery, labour, and tunnel collapse (under certain circumstances only).
  - Taxes are applied to waste (excavated rock) in the UK if taken 'off-site', sold as aggregate or put in landfill whereas waste can be disposed of in land around the tunnel in Norway with no disposal cost, without planning permission or Environmental Impact Assessment (EIA), if placed to a thickness of less than 0.5m[12].

In their considerations surrounding the proposed Stromeferry tunnel options, URS noted that, whilst Norwegian tunnelling approaches provide potential cost savings and are suitable for lightly trafficked areas with good quality rock, there are several disadvantages when compared to typical UK road tunnel specifications:

- Reduced cross-sectional area precludes some safety measures, such as a segregated emergency exit or service corridor. Therefore, it is only suitable where risks are low, such as tunnels with very low traffic intensity.
- Reduced cross-sectional area also means that there is no provision for pedestrian access or other non-motorised users.
- Absence of full lining increases tunnel lighting requirements and may reduce aesthetic appeal. It also makes cleaning more difficult. Exposed rock areas may require increased inspection and maintenance compared to lined tunnels.
- The absence of a water-tight lining requires that all infiltration is pumped to the surface unless the geometry of the tunnel allows gravity drainage. Infiltration is likely to be more widespread and measures such as internal water management may be necessary to control seepage water. Grouting requirements may be increased to avoid excessive infiltration.
- Depending on the chosen contract, an increased allocation of risk to the client would add to the uncertainty of overall capital cost[13].

Whilst the evidence suggests that there is much to learn from the Norwegian approach, it is important to note that it is not easily transferable to Scotland in the short-term. Indeed, in the Shetland workshop, it was recorded that:

- Norwegian contractor costs would most likely rise if they were working outside the Norwegian market.
- Norwegian contractors are giving up on working outside of Norway, e.g. when working in Sweden, the Norwegian contractors find that they face much slower progress because of issues with contracts, regulations, culture, etc and the costs become higher with reduced profits as a result[14].

3.4 Case Studies – Outcomes & Impacts Of Fixed Links

3.4.1 Overview

This final section explores the potential impacts of a fixed link across the Corran Narrows through the application of case study evidence. The evidence presented in this section will form the basis of the 'economic narrative' of benefits set out in Chapter 5.

3.4.2 Selection of Case Studies

The first step in this task was selecting the case studies to be used in supporting the analysis for Corran. Following a review of available case study material, the decision was taken to focus predominantly on Scottish examples (although wider examples will be drawn in where appropriate), particularly in the

11 | Stromeferry: Review of Tunnel Options (URS, 2014), p. 9.

12 | Shetland Inter-Island Transport Study: Fixed Links Review Supplement (Donaldson Associates, 2016), pp. 10-11.

13 | Stromeferry: Review of Tunnel Options (URS, 2014), pp. 9-10.

14 | Shetland Inter-Island Transport Study: Fixed Links Review Supplement (Donaldson Associates, 2016), pp. 10-11.

Highlands & Islands because:

- There are several recent comparable examples, most notably the Skye Bridge.
- Whilst there are many rural areas across the UK, the Highlands & Islands is unique in its scale, economic structure and population density. Almost all major transport schemes in the area – going back as far as the Caledonian Canal – have been justified on the dual basis of improving transport connectivity and overtly promoting socio-economic development. This compares to most other schemes where the focus is predominantly on improving transport connectivity between conurbations (e.g. the Severn Bridges) or major areas of economic activity (e.g. the Dartford Bridge between Essex and Kent, or the Cleddau Bridge which links settlements on either side of the strategically important Haven Waterway in Wales).
- International experience is useful (and incorporated where appropriate) but differences in spatial development, economies, history and culture makes these limited comparisons at best.

The relevant case studies which will be drawn on in this analysis are therefore (in chronological order of construction):

- Burra and Trondra, Shetland, 1970
- Cromarty Bridge, 1979
- Kessock Bridge, 1982
- Kylesku Bridge, 1984
- Dornoch Bridge, 1991
- Skye Bridge, 1995
- Scalpay Bridge, 1997
- Berneray Causeway, 1999
- Eriskay Causeway, 2001

Having reviewed a range of recent studies in relation to the above and other fixed links, case study evidence is generally presented on a scheme-by-scheme basis. However, our approach in this review is to focus on themes in terms of what a fixed link has meant for different components of societies or economies, drawing on all of the case study material as appropriate. This narrative is set out in Section 2.4.4, but firstly the challenges associated with using case study evidence are explored.

3.4.3 Challenges with Case Study Evidence

Case study evidence and benchmarking is a valuable means of understanding the type and scale of impacts which may emerge from a transport investment. However, it is important to note that there are several challenges and limitations associated with such evidence, each of which are set out below.

3.4.3.1 Monitoring and Evaluation Data

Whilst several fixed links have been constructed in the last three decades, there is a paucity of robust ex post evaluations. This is a UK-wide issue applying as much to major schemes as to smaller local fixed links – whilst the uplift in traffic as a result of fixed link is widely reported (or can be calculated), holistic evaluations considering how the 'output' of a fixed link translates into transport 'outcomes' and societal 'impacts' are comparatively rare.

The Highlands & Islands is somewhat better off than most areas in this respect, as evaluations have been undertaken in relation to the Skye Bridge, the Scalpay Bridge and the causeways to Eriskay and Berneray. However, even in these cases, the analysis is limited and has generally been undertaken relatively quickly after the completion of the fixed link.

3.4.3.2 Impacts Time-Lag

Where evaluations of fixed links have been carried out, this has typically been a short-time after the new connection was opened. For example, there were several studies assessing the impact of the Skye Bridge on different aspects of the island in the late-1990s, whilst the evaluation of the Berneray and Eriskay causeways was published in 2004. Early evaluations of this nature are essential as they pick-up immediate travel and other changes (e.g. increased tourism) following the opening of the fixed link.

However, impacts in terms of business investment, changes in the level and structure of population, migration rates etc will generally emerge over a much longer period – i.e. the supply-side takes longer to respond to new investment than the demand-side. Therefore, whilst the traffic generation and some of the shorter-term tourism impacts of the various fixed links in the Highlands & Islands are understood, the long-term implications are less well understood.

3.4.3.3 Causality

A further challenge with available case study evidence is demonstrating causality between a fixed link and the outcomes and impacts which emerge as a result. This is particularly the case with longer-term impacts (e.g. business investment) and intangible outcomes (e.g. community confidence).

In particular, a number of case studies reviewed as part of this research suggest that population has grown as a result of a fixed link being introduced. Whilst fixed links will have been a contributor in most cases, a range of other factors will also have been at play, not all of which are easily identifiable or measurable.

3.4.3.4 Local Applicability

Finally, it is important to bear in mind that every area has its own local circumstances, and the impact of a fixed link will differ to reflect these circumstances. Indeed, the evidence on the impact of fixed links is mixed - the background economic conditions appear to have a strong bearing on the success of fixed links in stimulating economic growth – a point also referred to later in this summary.

3.4.4 What have been the main impacts of fixed links?

Using the case studies previously cited, the following sections set out a thematic commentary on the evidence of the impact of fixed links.

3.4.4.1 Rationale for Intervention

The rationale for progressing a fixed link has generally either been:

- reducing the long journey times associated with looping around estuaries / firths or major sea lochs; or
- replacing ferry services which are either:
  - life-expired and where there is thus a case for capital investment in new tonnage and supporting marine infrastructure (which is set against the cost of a fixed link); or
  - incapable of providing the required capacity to meet the needs of the island or peninsular community.

The progressive bridging of the major Firths (**Moray, Cromarty and Dornoch**) between Inverness and Thurso is the most obvious example of the first bullet above. The opening of the Kessock Bridge in 1982 dispensed with the need for either travelling on a capacity constrained ferry or making a long inland loop to Beauly. The Cromarty Bridge did likewise, removing the need to route via Dingwall. The Dornoch Bridge was opened in 1991 providing a direct route across the Dornoch Firth linking south-east Sutherland and Easter Ross. Previously these trips had to be made by travelling inland to cross the Firth at Bonar Bridge, and thus the new crossing provided a 20-mile reduction in the journey between Golspie and the area immediately south of the Dornoch Firth[15].

When completed, the combination of the Kessock, Cromarty and Dornoch bridges provided a direct route from Inverness to Sutherland and ultimately Caithness, linking Wick, Thurso and other settlements to the Highland capital. Moreover, these three fixed links provided a much higher quality route for residents of the Orkney Islands travelling to e.g. Raigmore Hospital for appointments or Inverness for shopping.

The effect of these improvements can be seen in the comparative road and rail journey times between Inverness and Thurso. The road journey time is around 2h:30m, whilst the equivalent journey time by rail is 3h:45m as the train continues to loop around the major water bodies (albeit line speeds are also low).

The concept of bridging major firths / estuaries, sea lochs and rivers is common across Europe. As previously alluded to, the practice of tunnelling under fjords is very common in Norway, whilst in the Faroe Islands, tolled tunnels have been constructed as alternatives to long land journeys on poor quality roads.

The situation in **Skye** was broadly similar to that at Corran. Despite a frequent and high capacity two vessel service running 24-hours per day in its latter years, ferry capacity was simply incapable of keeping pace with peak demand, with queues often extending to several hours in peak season[16]. As well as this observed excess demand, there was significant latent demand, particularly in the peak summer daytripper / short-break market, as the ferry acted as a barrier to accessing the island.

Whilst a more extreme situation than that currently experienced at Corran, the 'case for change' was broadly one of demand exceeding supply. The Skye Bridge opened in 1995, with tolls set at a level slightly cheaper than previous ferry fares, although high by comparison to other fixed links. It nonetheless alleviated the capacity constraints associated with crossing Loch Alsh, with the removal of tolls in 2004 accelerating the increase in demand for trips to Skye.

In the Outer Hebrides, the case for fixed links to **Scalpay, Berneray and Eriskay** were made in part due to the inadequacy of the previous ferry services. In each case, the islands were served by very small car ferries, with comparatively short operating days (it is understood the vessels were single crewed and thus the operating day restricted to what one crew could deliver). The situation at Eriskay was even more challenging, where tidal (and likely daylight) restrictions meant that the ferry could only be operated during limited tidal windows, a more extreme version of what is currently experienced on the Sound of Harris in the present day[17].

The rationale for constructing the bridge to Scalpay and the causeways to Berneray and Eriskay was essentially social and economic . It was identified that the restrictions associated with the then transport connections were of such a level that they were negatively impacting various elements of island life (e.g. personal travel, supply-chain, employer's business etc) and thus contributing to population decline.

In the case of the Berneray and Eriskay causeways, there was a wider objective than just linking these two islands to Uist. Both islands became the Uist terminals for the inter-island ferry services to Harris and Barra, thus becoming part of the Outer Hebrides Spinal Route, and significantly strengthening links along the island chain. For the first time, it became possible to travel from the Butt of Lewis to Vatersay over land and sea in a single day.

It is our understanding that the replacement of a ferry with the **Kylesku Bridge** in 1984 was related to reducing journey times for fish lorries travelling from Kinlochbervie.

15 | Argyll & Bute Transport Connectivity and Research Report (HIE, 2016), p.85.

16 | Argyll & Bute Transport Connectivity and Research Report (HIE, 2016), p.72.

17 | Argyll & Bute Transport Connectivity and Research Report (HIE, 2016), p.85.

18 | Shetland Fixed Links Strategy: Socio-Economic Study (Reference Economic Consultants, 2007), p.43.

What are the implications for Corran?:

The rationale for intervention in the context of Corran is a combination of addressing the capacity constraints and improving connectivity and resilience between Lochaber and the peninsula, partly with a view to supporting the social and economic development of the area.

3.4.4.2 Traffic Generation

When a fixed link is introduced, the demand-side response is generally very swift, with an immediate increase in traffic. This is generally caused by a combination of (i) people already travelling making more journeys (e.g. island / peninsular residents); (ii) induced journeys (e.g. additional tourist visits); and (iii) substitution effects (e.g. on Skye, travellers switching from the Armadale – Mallaig ferry to the new bridge).

In a 2007 study for Shetland Islands Council, Reference Economic Consultants tabulated traffic generation factors for a range of fixed links - the Scottish examples are reproduced in the table below:

Fixed Link	Before Date	After Date	Years of Growth	Factor from before to after traffic
Skye Bridge (Tolled)	1995	1996	1	1.20
Skye Bridge (Toll Free)	2004	2005	1	1.46
Scalpay Bridge	1996	2006	10	12.86
Berneray Causeway	1999	2006	7	5.70
Eriskay Causeway	1998	2003/04	5/6	22.40

Table 3 3: Fixed Link Traffic Generation Factors[18]

Before considering the specifics of some of the above fixed links, it is worth noting some general trends identified in relation to their traffic generation impacts. It was noted in the Reference study that improvements in quality are the main driver behind the increase in traffic growth, and it is the variations in quality (and where appropriate, the tolling regime) that contribute to the variations in demand uplift. Reference note that the quality improvements depend on the following factors.

- The quality of the previous ferry service in terms of journey time, frequency and hours of operation. The poorer the quality of the previous ferry service the larger the uplift in demand.
- The proximity of the crossing to centres of population. Crossings that mainly serve short distance trips usually provide a larger percentage step-change improvement and therefore generate the largest uplifts in demand.
- The availability of services and employment on the island or peninsular community connected by the fixed link. A lack of on-island services and employment opportunities will increase the propensity to travel off the island once the fixed link has been constructed (although, paradoxically, islands which are less well connected generally have more on-island services)[19].

The **Skye Bridge** provided a transformational change in accessibility from the island to the Scottish mainland. Research by Reference found that the large uplift in demand from the removal of the Skye Bridge tolls was primarily driven by local trips between two settlements quite close to the bridge (Kyle of Lochalsh and Broadford)[20]. However, the bridge fundamentally altered perceptions of the accessibility of Skye, providing a stimulus to the tourism industry which has continued largely unabated ever since. It also provided improved connectivity to Harris and North Uist via Uig, growing the tourist and resident travel market for those two islands.

The significant increase in traffic generated as a result of the **Berneray and Eriskay** causeways reflected both the replacement of the limited ferry services and, perhaps more significantly, the growth in travel along the Outer Hebrides chain. As with the Skye Bridge, the growth generated by the causeways has been sustained, and indeed has been further stimulated by successive improvements in the connecting Sounds of Barra and Harris ferry services (e.g. the introduction of the larger capacity vessels MV Loch Portain (Sound of Harris) and MV Loch Alainn (Sound of Barra); timetable improvements; and the introduction of Road Equivalent Tariff)[21]. The continued growth in traffic with each incremental improvement on and adjacent to the Sounds highlights the potential traffic generation impacts of fixed links (and improved ferry connections).

Whilst built in part to support the logistics needs of the fishing industry, the **Kylesku Bridge** has become an integral part of the highly popular North Coast 500 route. It can be argued that the construction of this bridge has, in the long-term, enhanced the attractiveness / viability of that route and has thus assisted in growing overall traffic levels.

What are the implications for Corran?:

It is reasonable to conclude that a Corran Narrows fixed link will lead to significant traffic generation. This is likely to be due to a combination of: (i) peninsular residents making more frequent trips to Fort William and elsewhere to access services; (ii) increased visitor numbers, particularly in terms of 'unplanned' trips; and (iii) additional journeys generated by 24-hour accessibility.

3.4.5 Population

Whilst the demand-side impacts of a fixed link become apparent relatively quickly, the supply-side changes only become manifest over a much longer period and are often very subtle in nature. One of the principal reasons cited for pursuing a fixed link in a number of the case studies presented is to reverse population decline. In advance of considering the case study evidence, it is worth laying out the 'transmission mechanisms' by which this may happen:

- Improved accessibility to employment and services may encourage **existing residents** of an island or peninsular community to remain when they would otherwise leave.
- The removal of a barrier to travel may encourage **new residents to move into an island or peninsular community from a neighbouring area** to take advantage of e.g. lower land-values or lifestyle benefits.
- Improved accessibility may also attract **lifestyle in-migrants** to an area, who are seeking a rural / island way of life, but with the ability to travel with minimum hindrance when they so wish to do so. The growth of remote working is making this an increasingly strong effect across north-west Scotland.

In general, there is deemed to be a positive relationship between the construction of a fixed link and population. The previously cited Reference study found that fixed links have helped to contribute towards increasing, or in some cases slowing the decline in, the number of residents[22]. Similarly, international research by Peak Economics reviewed recent ex post Norwegian work, which found that, on average, populations increase after the introduction of a fixed link. The study found that over 11 fixed links, average population growth was 2% after 5 years and 6 % after 15 years (when compared against the 'counterfactual' – i.e. what would have happened without a fixed link having been built). It is however noted that this disguises substantial variation with some islands experiencing large population growth and others experiencing a static or declining population. In general, islands close to urban areas experience large growth but elsewhere results are more mixed. Importantly, it was noted that traffic flows on the fixed links are not good indicators of population change (possibly due to the 'two way road' effect) and land-use change in the main exhibits a lot of inertia with few impacts in the first few years after opening but with effects still being experienced some 15 years after construction, highlighting the lag effect described previously[23].

22 | Shetland Fixed Links Strategy: Socio-Economic Study (Reference Economic Consultants, 2007), p.54.
23 | The Value of Transport (Peak Economics, 2017), p.34.

In terms of specific case studies, research undertaken by Derek Halden Consultancy (DHC) on the impacts of the **Skye Bridge** noted that, whilst the population of Skye increased following the opening of the bridge, the extent to which this can be directly attributed to the new link is "not clear" (highlighting the issue of causality previously raised). Nonetheless, a 1999 evaluation of the Skye Bridge found that 6% of the island residents surveyed indicated that they had moved to Skye from elsewhere because of the bridge, which enhanced the attractiveness of the island as a place to live. Similarly, it was noted that follow-up surveys undertaken once the tolls were removed found that 8% of respondents had moved, or would consider moving, to Skye as a result of the toll-free crossing[24]. Whilst the above evidence cannot directly link the construction of the bridge to an increase in population, there is at least some evidence that it has contributed to the overall growth in those living in Skye.

In the context of the Outer Hebrides, evaluations of the fixed links connecting **Scalpay, Berneray and Eriskay** found that construction of fixed links has helped to stabilise and / or reduce the rate of long-term population decline. The research indicated that the fixed links had attracted people to the isles who would not have moved there otherwise. They also encouraged existing residents to remain - some 28 residents of Scalpay and five on Berneray reported that they or a member of their household would have left if the fixed link had not been built[25]. Whilst the absolute numbers are relatively small, it is important to note that in fragile communities like those listed above, the retention or otherwise of even a single family can impact on the sustainability of an island through its implications for e.g. the school role or voluntary work on the island etc.

What are the implications for Corran?:

The evidence suggests that the provision of a fixed link across the Corran Narrows would make a positive contribution to population retention and growth, although any effects would be long-term in nature and difficult to attribute directly to the crossing given the plethora of other factors which impact on population numbers and structure.

3.4.6 Employment

There are two considerations from an employment perspective:

- Access to the **employment / jobs market** - i.e. connecting people with areas of employment; and
- Access to the **labour market** - i.e. providing employers with a larger labour market catchment from which to recruit.

3.4.6.1 Employment Market

An integral component of any case for a fixed link across the Corran Narrows would be improving access to employment. The current ferry is heavily used by commuters travelling to Fort William and other surrounding settlements. Whilst the ferry operating day comfortably permits a standard day's work in Lochaber (and limited shift work), a fixed link would fundamentally transform labour market access, which could provide new opportunities if the proposed developments at the Fort William smelter are realised to the scale originally envisaged. Access to employment is a strong determinant of population retention in island and peninsular communities, and thus this would be a key benefit of a fixed link at Corran given the proximity of Fort William[26].

The **Skye Bridge** improved labour market catchment areas in South Skye and Lochalsh. It was noted that this facilitated greater access to employment, allowing individuals to access a range of new jobs as well as lower paid and / or part-time jobs which may not otherwise have been possible. This was particularly significant in Skye given the importance of seasonal and part-time work in the area, reflecting the significance of the tourism sector[27]. It could likewise be important in the Lochaber and peninsula study areas given the strong but generally seasonal tourism demand, particularly in and around Fort William.

In common with much of the preceding analysis, the long-term labour market and employment impacts are not fully understood, as much of the evaluation work was undertaken soon after the bridge opened or the tolls were removed. Nonetheless, it is evident from the evidence that has been

24 | Argyll & Bute Transport Connectivity and Research Report (HIE, 2016), p.72-74.

25 | Argyll & Bute Transport Connectivity and Research Report (HIE, 2016), p.85.
26 | The Value of Transport (Peak Economics, 2017), p.15.
27 | Argyll & Bute Transport Connectivity and Research Report (HIE, 2016), p.72-74.

collected, and wider anecdotal evidence, that the Skye Bridge has more tightly bound together the Skye and Lochalsh economies from an employment and labour market perspective.

Whilst there are no formal evaluations for the **Kessock, Cromarty and Dornoch** bridges, it is evident from peak traffic flows alone that these fixed links (and in particular the Kessock Bridge) have significantly expanded opportunities to enjoy the rural lifestyle of Ross and Sutherland whilst being able to readily access Inverness and surrounding areas for employment. This effect can be seen in the below travel-to-work graphic, which shows the origin points of all travel-to-work journeys to Inverness.

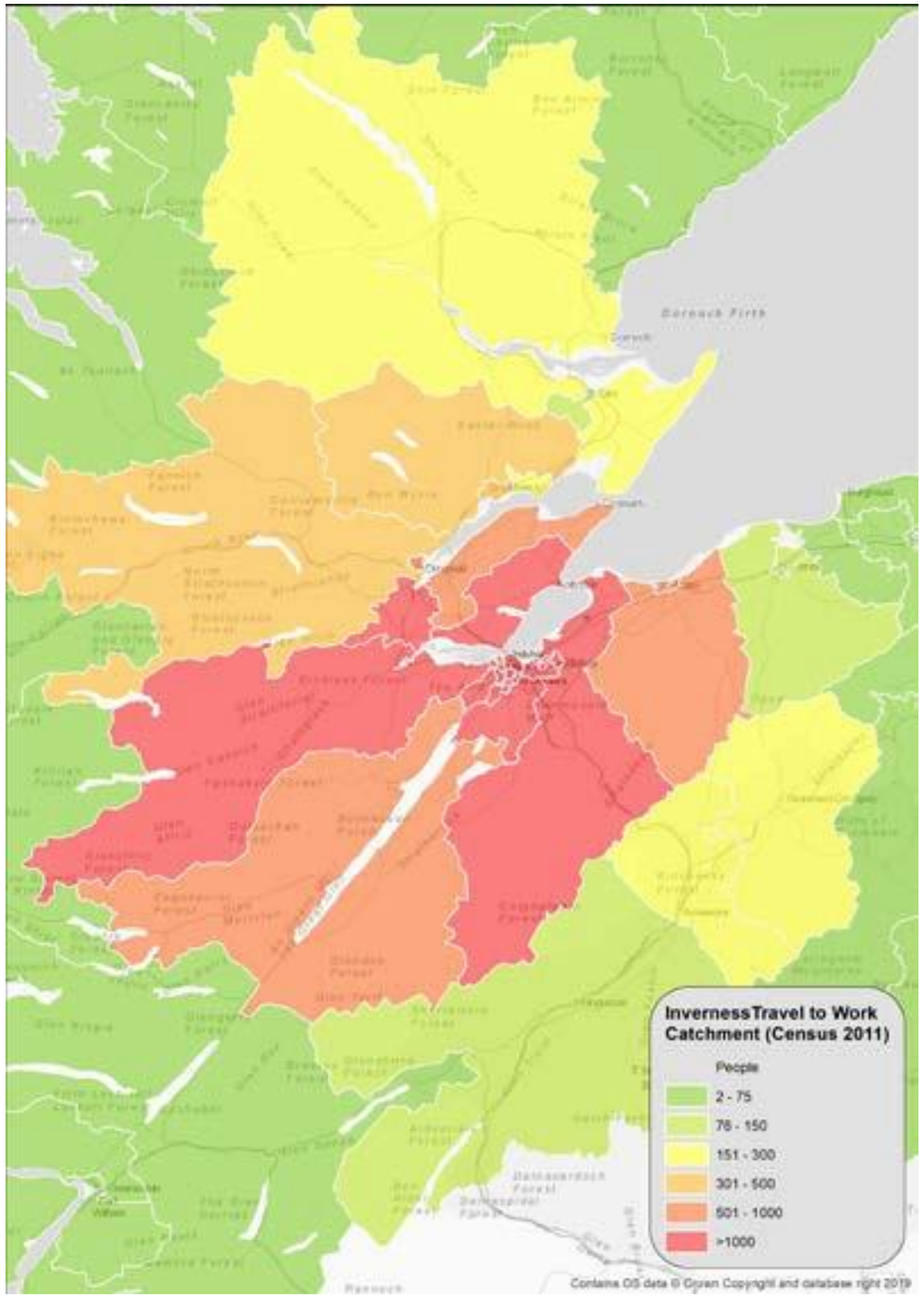


Figure 5: Inverness Travel-to-Work Catchment

Evidence from the fixed links in the Outer Hebrides also highlights their role in improving access to employment, both in Uist and, as a result of the improved Sound ferries, along the entire Outer Hebrides chain (although typically non-daily commuting in the context of the wider island chain). One specific finding from the evaluation is that the **Berneray** causeway has led to a significant increase in employment among women due to improved access to jobs off of the island[28].

Whilst the evidence does suggest that fixed links generate new employment opportunities, it is essential to bear in mind the 'two-way street' effect of transport improvements. There is an extensive body of evidence from across the UK and elsewhere which suggests that where transport connections between a rural area and a larger settlement(s) are improved, the dominant flow will be to the larger settlement(s). Specific fixed link examples of this effect include:

- In the islands of **Burra and Trondra** in Shetland, the construction of fixed links provided a quick and high-quality connection to Scalloway, Lerwick and Sullom Voe, fundamentally altering the travel-to-work market in the two communities. Whilst several benefits have been realised as a result of these new connections, consultees in a previous evaluation noted that the fixed links led to a leakage of economic activity from these islands. It was noted that there are now fewer shops, less fishing vessels based in the area and a general loss of amenities, with Burra in particular described as a "dormitory" community[29].

- In a number of the smaller islands which have been connected by fixed links (e.g. **Scalpay**), there has been a growth in off-island commuting, although this mirrors wider developments in mainland rural areas, where centralisation of employment and services is common[30].

- The case of **Bressay** in Shetland is also illustrative. Whilst the island does not have a fixed link, the frequency of the ferry service and the length of operating day has been improved over several years, whilst the fares are low by most comparable benchmarks. These improvements have stimulated significant daily commuting to Lerwick. As more people commute to Lerwick, they now take their children to school there and go to the shops in the town. In many respects, Bressay has now become part of 'Greater Lerwick' – there are very few on-island services or amenities left, with the island now highly integrated into the Lerwick economy. Bressay contrasts to other islands close to major settlements (e.g. Shapinsay, Hoy, Cumbrae etc) where the more limited ferry service has acted as a barrier to such a strong dormitory effect emerging.

The benefits or otherwise of the dormitory effect are debatable – indeed, there is a whole body of research dedicated to this topic. Whilst a fixed link at Corran may make commuting to Fort William and elsewhere more common, it is important to note that:

- The communities which would be served by the fixed link are amongst the most fragile in Scotland. Improving access to employment would be positive, bringing additional income to the area, and potentially attracting families to move there.

- Whilst a dormitory effect is possible, and indeed even likely in areas closest to the proposed crossing, it is possible that those whose journey to work is prevented or made more difficult may leave anyway, increasing the fragility of the area.

- The growth in remote working may to some extent limit the 'dormitory effect'. Whilst a majority of people still physically travel to a workplace, remote working has been growing very strongly in the last two decades and is likely to continue doing so.

What are the implications for Corran?:

A fixed link across the Corran Narrows would provide residents of the peninsula with improved access to employment (and vice versa, although the effect in the other direction is likely to be weaker). There is a risk that it creates a 'dormitory' effect with an increase in commuting to Fort William or elsewhere, but this would nonetheless bring a range of benefits to the peninsula in terms of increased gross value added (GVA) and potential in-migration of working-age families.

3.4.6.2 Labour Market

A fixed link across the Corran Narrows would also improve labour availability for businesses in Lochaber and further afield by expanding the employment catchment. This outcome was particularly prominent in Skye when the bridge was completed. However, given the large land mass of the peninsula, the low population and long journey times between settlements, it is likely that this effect would be less significant in the context of the peninsula.

The more prominent issue for businesses is likely to be the **labour productivity improvements** associated with improvements in supply-chain efficiency, reduced dead time etc associated with not having to wait for a ferry, or being unable to travel when the ferry is out of hours / service.

3.4.7 Business Formation

A further question in relation to the impact of fixed links is the extent to which they support new business formation. As previously noted, the evidence on this issue is limited due to a combination of investment lagging new infrastructure by several years and the ability to demonstrate causality between a fixed link and specific business investments.

There is broad consensus across a range of evaluation studies that a fixed link (and indeed transport improvements generally) improves business confidence in an area through providing increased certainty.

The one potential exception to the above point is tourism,

28 | Shetland Fixed Links Strategy: Socio-Economic Study (Reference Economic Consultants, 2007), p.50.
29 | Shetland Fixed Links Strategy: Socio-Economic Study (Reference Economic Consultants, 2007), p.45.
30 | Shetland Fixed Links Strategy: Socio-Economic Study (Reference Economic Consultants, 2007), p.45.

where there is a strong linkage between increased visitor numbers and business investment. For example:

- It was found that the **Skye Bridge** has made a major contribution to the tourism product on the island, particularly once tolls were removed. Day and short-stay visitor numbers grew considerably and prompted investment in accommodation, campsite provision and retail / food businesses serving the tourism market[31].

- A substantial increase in tourist bus and coach travel was also recorded after the bridge opened. There were some early indications in the evaluation work undertaken that an increased proportion of trips appeared to be travelling through Skye to the Outer Hebrides, and there were also more circular trips to Skye making use of the bridge and the Armadale-Mallaig ferry – each of these trips generates spend and bed nights[32].

- The **Kylesku Bridge** is now an integral part of the North Coast 500, and indeed has become a tourist attraction in its own right. It is one of the most photographed bridges in the country and has featured in films, adverts and TV programmes.

- Primary research showed that 62% of visitors to **Berneray** would not have made the trip without the causeway and the ferry service that it enabled. In the case of **Scalpay**, almost half (49%) of the surveyed visitors would not have visited the island if the bridge had not been built[33]. Total visitor expenditure on Berneray was estimated to be just under £110,000 and £150,000 on Scalpay[34]. The additional spend on both islands will have stimulated new tourism businesses and a growth in employment in that sector – for example, six new B&Bs opened on Scalpay and two on Berneray shortly after the fixed links were completed[35].

What are the implications for Corran?:

The evidence suggests that the construction of a fixed link improves the business confidence of an area, but the issues of time-lag and causality make it challenging to isolate specific new business investments emerging directly as a result of a fixed link. The one exception is in the tourism sector where it is the growth in visitor numbers which acts as a direct stimulus to investment.

3.4.8 Quality of Life / Community

The final and much less tangible impact of a fixed link is how it impacts on the newly connected communities and the quality of life of their residents. This is a challenging area to evidence as it very much depends on local circumstances and is also often about how an area is perceived rather than actual outcomes.

The following bullets set out some of the potential impacts of a fixed link, drawing on evidence from case studies where available:

- Overall, the evidence suggests that fixed links will not in themselves reverse major social and economic changes on islands – e.g. declining populations. However, they are considered to improve general confidence in an area as a place to live, work and invest.

- The construction of a fixed link to a rural community has in many cases led to a centralisation of key services such as health, high school education and social care. Whilst this is often viewed as a negative as it reduces local facilities and requires travel for essential appointments (albeit this is not anticipated to be a major issue in this context (i.e. Corran)), it can also create benefits in terms of access to a wider range of services or better facilities than would be available locally (e.g. evening classes). This effect can also provide cost savings for local authorities which can be reinvested elsewhere.

- Evidence from Scalpay in particular suggests that a fixed link can significantly improve health, home care, day care and residential care services. However, this effect is likely to be less noticeable on the peninsula due to the high quality, reliability and frequency of the Corran Ferry service.

- Linked to the above is the loss of local retail, which can gradually become centralised when a new fixed link is realised. Whilst this loss of local services is again generally viewed negatively, the fact that residents do choose to shop, eat out etc in larger settlements suggests that they derive a benefit from doing so.

- Fixed links provide improved access to evening leisure (e.g. the cinema, events etc) and community / voluntary opportunities. This can be important in retaining young people, and thus families, in an island or rural community.

- Opportunities to visit friends and relatives can also improve – this is essential in rural communities where adult children will often live elsewhere and travel home or e.g. in-migrants may have elderly relatives elsewhere in the country that they wish to visit.

- Fixed links have almost universally been evidenced to grow visitor numbers in the Highlands and Islands. For example, the Skye Bridge has been an integral component in developing the Skye tourism market, and supporting secondary tourism growth in e.g. Harris, North Uist and Raasay. Tourists generate additional employment and income for local residents but can also prompt investment in e.g. cafes' restaurants and infrastructure from which tourists and residents alike benefit.

- Whilst increased visitor numbers are on the whole beneficial, they can generate their own issues in terms of overwhelming the local infrastructure, which could be a particular issue on the peninsula given the limited road network and facilities (e.g. public toilets, campsites, waste disposal etc).

- Other issues raised through the case study material include reduced need for two cars (i.e. an island and mainland car) and perceptions of reduced security through being unable to 'pull up the drawbridge'. These effects are though less relevant in the context of Corran.

What are the implications for Corran?:

Fixed links can fundamentally alter the economic and social fabric of an area. The extent to which this is the case depends on the specific local circumstances. On balance, the evaluation evidence suggests that fixed links have improved the quality of life where they have been built, but they do bring challenges, particularly in terms of the centralisation of services and pressure on limited local infrastructure associated with increased visitor numbers.

31 | Argyll & Bute Transport Connectivity and Research Report (HIE, 2016), p.72-74.
32 | McQuaid, R.W. and Greig, M., Socio-Economic Impact of Skye Bridge (HITRANS & HIE, 2007), p.7
33 | Argyll & Bute Transport Connectivity and Research Report (HIE, 2016), p.85.
34 | An evaluation of the social and economic impacts of fixed links to the islands of Scalpay and Berneray, (Western Isles Enterprise (Unpublished), 2004), p. 25
35 | Argyll & Bute Transport Connectivity and Research Report (HIE, 2016), p.85.

Figure 6: Study Area for Planning and Environmental Scoping

4.0 Planning & Environmental Context

4.0 Overview

This chapter provides sets out the environmental and planning position in the vicinity of the Corran Narrows, providing the context against which fixed link options can be developed. The analysis undertaken at this stage is proportionate and reflective of an initial feasibility study and, as such, any identified and highlighted constraints will be noted for further consideration and mitigation if the study progresses to the next stage in the process.

This chapter is divided into three distinct sections:

- Study Area: The definition of the geographic area for which planning and environmental data have been collated and assessed.
- Environmental Context: An outline of the pertinent environmental characteristics and features within the study area, including identification of issues for future consideration if the scheme progresses.
- Planning Context: An outline of the applicable planning policy framework and key planning issues likely to influence the consentability of any future fixed link.

4.2 Study Area

The study area considered in the context of the environmental and planning analysis comprises land on both the western and eastern banks of Loch Linnhe at the Corran Narrows, together with the stretch of water itself. This encompasses the villages of Ardgour, Corran, Nether Lochaber and Inchree, and their hinterlands (including Clouvillin and Keppach). The Corran Narrows lies below Mean High Water Springs (MHWS) and therefore falls within the Scottish Marine Area.

Looking southwards along Loch Linnhe from the Corran Ferry

4.3 Environmental Considerations

4.3.1 The Water Environment and Flood Risk

The SEPA Flood Map (http://map.sepa.org.uk/floodmap/map.htm) indicates that, in relation to Loch Linnhe:

- Western bank, all land east of the A861 carriageway has a high likelihood of coastal flooding. This includes Corran Point and the foreshore of Loch Linnhe. Additionally, land surrounding the confluence of Allt Cladh a'Mhuillin and Loch Linnhe (approximately 500m south-west of Corran) has a high likelihood of fluvial flooding. The area is generally free form identified surface water flood risks, with the exception of isolated parcels of land surrounding Lochan nan Luireach (immediately west of Corran) and in the south eastern extent of the Blar a Corran marshland (west of the Bruac nan Corran dwelling house);

- Eastern bank, all land south and west of Nether Lochaber has a high likelihood of coastal flooding. This includes an extensive area of the Blar Moine marshland but excludes Inchree and land immediately west of the A82. The area is generally free from identified surface and fluvial flood risks, with the exception of land either side of Abhainn Righ watercourse and at its confluence with Loch Linnhe south of Inchree (and the south eastern extent of the study area) which has a high likelihood of fluvial flooding.

Notwithstanding the presence of substantial areas with a high likelihood of coastal flooding, the study area is not located within any 'Potentially Vulnerable Areas' i.e. areas identified as being at significant flood risk as designated within the Highland and Argyll Local Flood Risk Management Strategy (2015).

The extent of high coastal flood risk on the banks of Loch Linnhe at the Corran Narrows means that, irrespective of the specific alignment and type of fixed link considered, the design process should be underpinned by detailed flood modelling. Any alignments, fixed link type options and indicative designs identified through this feasibility study **therefore need to be subject to further flood risk analysis**, taking account of SEPA's Climate change allowances for flood risk assessment in land use planning guidance (2019).

> **Key Point:**
> Further flood risk analysis, including detailed modelling, will be required if the fixed link concept progresses to detailed design.

4.3.2 Ecology

Figure 6: Study Area for Planning and Environmental Scoping

Figure 8: Areas of Ancient Woodland

As shown in the Figures 4 & 5, the key ecological constraints within the study area are:

- International Designations
- The Moidart and Ardgour Special Protection Area (SPA) is located approximately 2km to the north-west and west of Ardgour slipway.
- The Onich to North Ballachulish Wodds and Shore Special Area of Conservation (SAC), is situated approximately 1km to the south east of the Nether Lochaber slipway.
- National (Statutory) Designations:
- The Onich to North Ballachulish Woods and Shore Site of Special Scientific Interest (SSSI) is the constituent statutory designation of and co-located with the aforementioned SAC.
- Several areas of ancient woodland are present within the study area, the largest of which is located just over 250 metres to the north-east of the Nether Lochaber slipway, while two other parcels are located approximately 200 metres to the west of the Ardgour slipway.
- Local (Non-Statutory) Designations:
- At present no local nature conservation or wildlife sites are designated within THC's administrative area.
- The adopted West Highland and Islands Local Development Plan (2019) also did not designate any green network corridors within the study area.

> **Key Point:**
> Although the SAC, SSSI and SPA are not within the immediate proximity of the Corran Narrows, there is **potential for indirect disturbance** related to the effects from construction activities and increased vehicle movements associated with any potential fixed link project. The level of this disturbance would need to be **considered at the design stage**.

4.3.3 Landscape

The entirety of the study area falls within Landscape Character Type (LCT) 234 - Lochs with Settled Edges as identified on the SNH Landscape Character Assessment (2019). The following landscape designations and recreational routes are also present within the study area:

- National Designations:
- On the eastern side of Loch Linnhe, the Ben Nevis and Glen Coe National Scenic Area (NSA) encroaches on the south extent of the study area surrounding Onich, 1.5km south of the Lochaber slipway.
- On the western side, the Ardgour House Inventory Garden & Designated Landscape is situated inland west of Clouvillin and 1km from the Ardgour slipway.
- Further to the west, 2km, lies the Ardgour & Moidart Wild Land Area.
- Local Designations:
- With the exception of Corran Point itself, the western side of Loch Linnhe lies within the Ardgour Special Landscape Area (SLA).

It should also be noted that a network of Core Paths provides access to Ardgour House from the village on the western side, and on the eastern side to upland wooded areas north of Inchree. The Corran Ferry also acts as part of the National Cycle Network Route 78, which links Campbeltown to Inverness. Heading northbound towards Fort William, the route travels along the A82, before crossing Loch Linnhe via the Corran Ferry and then continuing northbound along the A861 on the western shore of Loch Linnhe, before once again crossing Loch Linnhe using the Camusnagual Ferry.

Irrespective of any specific alignment identified, the design of a fixed link will need to consider likely impacts on the setting of the LCT, each landscape designation and associated landscape features and sensitivities. Of particular relevance is the Ardgour SLA, as any potential alignment is likely to result in a western landfall and associated road infrastructure within or adjacent to this designation. Designated by THC, the SLA covers the Ardgour peninsula west of Loch Linnhe and is designated for contrasting rugged interior mountains and wooded and sheltered shorelines. Views across the open water of Loch Linnhe, swathes of woodland and a sense of remoteness are identified as key characteristics of the SLA. THC's SLA Citation (2011) also advises that sensitivities associated with development in or affecting the SLA specifically include:

- *"New structures or buildings on land or sea (or the enlargement of existing ones) which would obstruct or significantly detract from the quality of coastal vistas; and.*
- *Structures which would visually connect the peninsula to the mainland and diminish the formers sense of detachment and remoteness".*

Figure 9: NCN78, Core Paths & Listed Buildings in Study Area

Key Point:

The design of a fixed link should include consideration of likely impacts on the setting of the Landscape Character Type, each landscape designation and associated landscape features and sensitivities. A key consideration here is how any fixed link would interact with the Ardgour Special Landscape Area.

4.3.4 Cultural Heritage

There are eight listed structures or buildings and no other designated heritage assets present within the study area. Seven of these assets are situated on the west side of Loch Linnhe. This includes the Category C listed Corran Narrows lighthouse and adjacent former lighthouse keeper's dwelling, as well as the Ardgour Hotel to the north-west. As with the identified landscape constraints, impacts on the setting of these listed buildings would need to be considered in the selection of alignment options and in the design process.

4.3.5 Summary

To summarise, the key environmental considerations within the study area pertaining to any future fixed link are as follows:

- There is a high likelihood of coastal flooding, especially on the eastern bank of Loch Linnhe between Nether Lochaber and Inchree.
- Statutory ecological designations, particularly, the Onich to Ballachulish Woods and Shore SAC and SSSI south west of Inchree.
- Landscape designations and heritage assets, particularly, the Ardgour SLA along the west side of Loch Linnhe.

Key Point:

The above identified considerations will contribute towards informing the identification of potential alignments for a fixed link. It is though important to note that no 'showstopper' issues have been identified from and environmental perspective which would directly preclude the construction of a fixed link across the Corran Narrows. Potential environmental impacts will however have to be fully scoped and appropriate mitigation identified if the fixed link proposition is to proceed to detailed design in the future.

4.4 Planning Considerations

A Corran Narrows fixed link would require planning permission from:

- THC (or related consent) for terrestrial elements above Mean Low Water Springs (MLWS).
- The granting of a marine licence from Scottish Ministers for marine elements below Mean High Water Springs (MHWS).

4.4.1 Planning Policy Framework

Any planning or other consenting applications for a fixed link would be determined in accordance with the statutory Development Plan and other material considerations of relevance at the time of the application. The current statutory Development Plan applicable to the Study Area comprises the adopted Highland-wide Local Development Plan (HwLDP) (2012) and the West Highland and Islands Local Development Plan (WestPlan) (2019). In terms of how these two documents relate to each other, it should be noted that:

- The HwLDP provides the strategic planning context and a comprehensive suite of development management policies (including policies addressing the key environmental considerations identified above).
- WestPlan identifies local spatial priorities and development constraints for specific settlements. Key constraints noted for Ardgour and Clovullin include landscape designations, coastal flooding, cultural heritage assets, ancient woodland, carbon rich soils, core paths and green network requirements. Nether Lochaber and Inchreee are not identified as specific settlements but rather fall within the wider Fort William hinterland.

In relation to marine spatial planning, relevant general and subject policies from Scotland's National Marine Plan (and any future marine plan developed for the West Highlands marine region) would be applicable to the determination of any marine licence application for the project.

Figure 10: Past and Present Planning Applications

4.4.2 Key Planning Issues

Reflecting the nature of this feasibility study and the environmental characteristics of the study area, the two main determining issues for any future consenting application for a fixed link are likely to comprise the principle and need for the development and the acceptability and likely environmental & amenity impacts of the scheme. These are discussed in more detail below.

4.4.2.1 The Principle and need for the development

The project already benefits from strong policy support at the local level, as the recently adopted WestPlan (2019) and associated Action Programme prioritises 'the A82 to A861 Corran Narrows Crossing' as one of the key transport improvements needed in the plan area. **Of direct relevance to this feasibility study, the WestPlan Action Programme commits to the potential safeguarding of land either side of the Corran Narrows to facilitate any future fixed link**. However, it is noted that further transport appraisal work is required to demonstrate the benefits and inform the alignment and design of a fixed link between the A82 (T) and A861 (it should be noted that this report is the first step in undertaking that appraisal work).

A possible outcome of this study is consideration by the client group to submit the fixed link project for inclusion within the STPR2. In addition to securing funding support, inclusion within STPR2 would likely secure recognition of the project within the emerging National Planning Framework 4 (NPF4). This will:

- Form part of the statutory Development Plan and include a suite of high-level thematic policies to replace the current Scottish Planning Policy (2014).
- Define a suite of 'National Developments' for which the overarching principle of development is deemed to be established at the national level.
- Support the preparation of Regional Spatial Strategies (RSS), which under Section 6 of the Planning (Scotland) Act 2019 must identify priorities for and the proposed location of "strategic developments"[36]. Whist the main benefit (connecting the A82 and A861 across Loch Linnhe) would be contained within THC's administrative area, wider socio-economic impacts around Loch Linnhe may allow the project to be considered as a candidate strategic development in any RSS.

4.4.2.2 The acceptability of likely environmental and amenity impacts

The key environmental considerations identified earlier in this chapter should inform the final design of any fixed link (including alignment selection) and will need to be subject to detailed assessment to inform any consenting application.

The determination of any such application is likely to be influenced significantly by these issues through the application of related subject policies within the statutory Development Plan (in particular relevant policies within the HwLDP (2012)) and in guidance set out in other relevant material considerations. In general terms, the key tests which any consenting application (and thus finalised design) for the project should satisfy are:

- the avoidance of any likely significant effects during construction or operation on the qualifying and special features of the Onich to North Ballachulish Woods and Shore SAC and SSSI;
- the avoidance of any likely significant adverse effects during construction or operation on flood risk, ecological, heritage and other environmental interests; and,
- the avoidance of any unacceptable likely significant adverse effects during operation on landscape character, landscape designations and visual amenity. This acknowledges the likely occurrence of localised significant landscape and visual effects, taking account of the nature of the project and the characteristics of the Study Area.

Owing to the area required to develop the project it would constitute a Schedule 2 Development under the Environmental Impact Assessment (EIA) Regulations[37] and therefore require EIA screening. Subject to confirmation through formal EIA screening, the project is likely to constitute an EIA Development and any consenting application is therefore likely to require to be accompanied by a statutory EIA Report in order to assess all likely significant effects on the environment.

Key Point:

Any consenting application will likely need to be accompanied by an Environmental Impact Assessment Report.

4.4.3 Summary

As with the investigation of the environmental considerations, there are no planning related 'showstoppers' for a fixed link at Corran, indeed the scheme is recognised within the local development planning context. Of particular notes is the WestPlan Action Programme, which commits to safeguarding land on either side of the Narrows for a future fixed link. The policy framework, therefore, has been established to support and influence the identification of any alignment and design for a fixed link, around which a robust case must be made outlining the need for the fixed link from an economic societal perspective.

4.5 Conclusion

From this initial examination of the environmental and planning context in the proximity of the Corran Narrows, there exists no 'showstoppers' which would preclude the future determination of a fixed link across the Narrows. Constraints have been identified and would have to be more fully evidenced and, potentially, mitigation measures developed at detailed design stage where the scale of impacts is deemed to be unacceptable

Although these constraints would not preclude a fixed link, they can and would influence the identification of any particular alignment and the design of the structure itself. Additional mitigation would also need to be considered to address any other constraints identified through a more detailed review of planning policy in the context of a more developed design for a fixed link.

The proposal for a fixed link across the Corran Narrows is supported within the local planning context. Local promoters are keen to see this infrastructure as part of a long term national programme, ideally included as an STPR2 priority scheme, which may also secure its recognition within the emerging NPF4.

36 | Defined as developments "likely to have a significant impact on future development within the area of more than one planning authority".

37 | As the project would involve development above and below MHWS, both the Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2017 and the Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017 are likely to be engaged.

Corran Lighthouse,
Corran Narrows

5.0 Option Generation And Development

5.1 Overview

Having defined the environmental context within with which a fixed link would be constructed, this chapter sets out the process of option generation and development. There are six sections in this chapter covering:

- the key characteristics of the Narrows which will influence the type, design and scale of any fixed link;
- the identification of route corridors which any potential crossing could be developed within;
- definition of broad alignments within the identified route corridors;
- consideration of structural options for a fixed link within the identified route corridors;
- indicative costings for each fixed link solution; and
- consideration of route and junction options for connecting into the existing road network on both sides of the Narrows.

Whilst this is a feasibility study, the STAG principle that optioneering should be unconstrained is adopted, and thus a wide range of route corridors, alignments and structural forms have been considered in the analysis. The options developed reference DMRB requirements.

This chapter will conclude by:

- identifying whether a fixed link across the Corran Narrows is technically feasible;
- if so, the definition of a shortlist of options in relation to the most appropriate route corridor(s), alignment(s) and structural form(s); and
- the broad cost of each shortlisted option, feeding into the cost-benefit comparison in Chapter 5.

5.2 Key Characteristics Of The Corran Narrows

The Corran Narrows has a number of characteristics which will need to be accounted for if a fixed link is to be constructed across or indeed beneath it. These are set out in more detail below.

5.2.1 Bathymetry

Despite the short distance between Nether Lochaber and Ardgour, the Corran Narrows is a deceptively deep stretch of water. The bed drops off dramatically close to the shore on both sides to a maximum depth of circa -24m Chart Datum (CD). This is important in the context of a fixed link, and in particular tunnel options where the entrance and exit portals would need to be well inland to provide acceptable gradients for getting under this depth of water. Any bridge support tower located away from the shoreline would also need to extend a significant distance to reach the seabed.

It should also be noted that the channel is deepest on its eastern side and thus the shipping lane (see below) is to that side of the channel. From a bridge perspective, the maximum air draught (see below) will need to be provided over this part of the channel, rather than in the centre point, which has implications for the structural design of the bridge.

Key Point:

The depth of the Corran Narrows together with the main shipping channel being on the eastern side will have implications for the alignment, size and gradients of any fixed link option.

5.2.2 Tidal Conditions

The Narrows act as the confluence between the upper and lower sections of Loch Linnhe and are effectively a choke point in the Loch. This gives rise to very specific tidal conditions, namely:

- A 'tidal race' through the Narrows, which, according to Admiralty Chart 2380, can give rise to tidal streams as high as 5 knots, with local anecdotal evidence suggesting that a combination of weather and freshwater levels can lead to tidal streams of 6-7 knots at times[38].
- From historic levels recorded and data available from www.tidetimes.org.uk it is estimated that water levels in the Corran Narrows can vary by up 4-5 metres on spring tides. This is a significant tidal range and has implications for required air draught (see next section).

5.2.2.1 Tidal Energy Opportunities

The tidal race through the Corran Narrows means that it has long been identified as a potential source of tidal energy. This has been promoted through several studies and there has been commercial development interest in the site. At this stage incorporation of tidal energy generation options have not been included as part of any fixed link solution due to current research identifying that current designs are not cost effective.[39] As such this will require further exploration at a later detailed appraisal stage to understand changes in the market as renewable energy continues to play a key role in ongoing policy development and the possible introduction of hybrid ferries.

As such, any consideration of a fixed link should, as a minimum, not prevent the future realisation of these aspirations.

Key Point:

The Corran Narrows has very specific tidal characteristics. This impacts on the air draught requirement of vessels. There are also aspirations to develop tidal energy schemes at Corran and thus any fixed link should not prevent the future realisation of these aspirations.

5.2.3 Air Draught

As alluded to above, Loch Linnhe is a shipping channel connecting Fort William and the port facilities at Corpach with the Sound of Mull, Firth of Lorn and beyond to the open sea. Traffic through the Narrows is a combination of leisure craft, coasters & cargo vessels and small cruise ships. At present, there are no significant restrictions for vessels transiting the Narrows.

Clearly, the construction of a bridge could, depending on design, place a restriction on the movement of vessels through the Narrows. This could have negative impacts on the Lochaber economy and would give rise to public and stakeholder acceptability issues. The key design parameter from this perspective is air draught, which is the distance from the surface of the water to the highest point of the vessel, itself influenced by the tidal range at Corran.

A particular issue in this respect is cruise liners, which tend to have a larger air draught requirement than small coaster and cargo vessels (high masted yachts are also an issue but can be more readily de-masted) and relatively inflexible schedules. Cruise vessels therefore require a degree of certainty when planning schedules and the requirement to work around tidal windows is likely to be unattractive to them, such as only being able to transit under a fixed link during low tides.

Due to the success of marketing in recent years, Fort William has witnessed a steady increase in the number of cruise ships calls, with 19 vessels scheduled to arrive during 2020. There are aspirations from Fort William Marina & Shoreline Company Limited, local residents and Elected Members to increase this market to further support the economic development of the Lochaber region. It is therefore important that any potential route corridors or structural options do not within reason constrain these growth opportunities, and the option development therefore accounts for this. From data highlighting vessels that have previously called at Fort William, the maximum air draught indicated is 40 metres.

It is though important to bear in mind that there will be trade-off to some extent with the height of any bridge (and its associated air draught), its design and its cost. A fixed structure would also put a hard and permanent constraint on the height of vessels which could transit the Narrows to Fort William and Corpach. These issues will be explored in more detail in this chapter and, if a fixed link scheme progresses, in the business case and detailed design stage.

Key Point:

The requirement to maintain an appropriate air draught, accounting for the tidal range at the Corran Narrows, will be an important consideration in the option development process which follows.

5.3 Route Corridor Identification

Having determined the key planning & environmental considerations and the specific characteristics of the Corran Narrows, the next step in the option development process is to identify the corridors in which a fixed link could be built.

In line with DMRB guidance, and recognising the feasibility nature of this study, a variety of route corridor options have been identified. It was quickly identified that there are a limited number of corridors within which a fixed link could feasibly be constructed. Consequently, the number of locations was established as four potential route corridors for bridge crossings and one route corridor for a tunnel option.

5.3.1 Potential Route Corridors

The route corridors considered as part of this high-level feasibility study are illustrated in figure 11 below and can be broadly categorised as follows:

- RC1 would be broadly on the alignment of the current ferry service
- RC2-RC4 would be to the north or south of the existing ferry service
- RC5 would be the required road corridor for a tunnel option.

38 | Corran Ferry STAG Appraisal (Peter Brett Associates LLP, 2018), p. 26


Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

In more detail, the corridors, therefore, are:

- Route Corridor 1 - Existing Ferry Service Corridor: On the line of the existing ferry crossing, linking Nether Lochaber and Ardgour in the vicinity of the current slipways.
- Route Corridor 2 - Northern Corridor: This corridor would link into the A82 north of the existing access junction to the Corran Ferry on the eastern shore. On the west bank, the corridor would link into the existing junction of the A861 and James Carmichael Way, which is approximately 270 metres north of the Ardgour slipway.
- Route Corridor 3 - Central Corridor: This corridor would link into the A82, south of the existing access junction to the Corran Ferry on the eastern shore. On the western shore, the corridor would land on the hill above the Corran Lighthouse and link down onto the A861.
- Route Corridor 4 - Southern Corridor: This corridor would link into the A82, further south of the existing access junction to the Corran Ferry and just north of the Abhainn Righ watercourse. On the western shore, the landing point would be south of the junction of the A861 and the access road to Clovullin.
- Route Corridor 5 - Tunnel Corridor: Due to the physical constraints within the study area, the potential corridor options for a tunnel are limited. As such, the identified route for a tunnel is a hybrid of Route Corridors 3 and 4 above. On the eastern shore, the entry portal would be located slightly north of the location identified in RC4 above. The tunnel route would then need to curve along a similar alignment to RC3 due to the length required to minimise gradients, keeping them within the thresholds recommended by DMRB. On the western shore, the portal would then be located north of the access road to Clovullin.

Having defined broad route corridors, the pros and cons of each are explored in more detail below. These route corridors are indicative and by no means firmly define a preferred crossing point, rather they provide an envelope within which any crossing would be located. If this study was to progress beyond the feasibility stage, these route corridors would be fully assessed as part of a more detailed route option assessment stage to assist in identifying a preferred route alignment to take forward for detailed design and development. Public and stakeholder engagement would be a key element of this process, particularly for those directly affected by the route corridors.

5.3.2 Potential Route Corridors – Pros and Cons

5.3.2.1 Route Corridor 1: Existing Ferry Service Corridor

Pros

RC1 would follow the same broad alignment as the current ferry service. This would make best use of the current road access points from both the A82 and A861, reducing the amount of construction related works.

At 550 metres in length, this route corridor is also the shortest of those identified, which would reduce the overall cost of the fixed link.

RC1 would minimise impacts on the local environment - it would require minimal vegetation clearance, especially with respect to the plots of ancient woodland within the study area and thus may be more readily consentable.

This route corridor would also require minimal land-take and is unlikely to impact significantly on any property boundaries on both shores.

RC1 would not inhibit future tidal energy schemes in the Corran Narrows.

Cons

The primary disbenefit of this route corridor is the impact it would have on the ferry service during the construction period. The ferry could not operate its current route for a period of circa 24 months and thus a temporary ferry service and marshalling would need to be established at an alternative crossing point (which would be very challenging and be an additional cost to this option) or the service would need to be suspended. It is possible that a temporary ferry service could not be established given limited options to operate from elsewhere and this would thus give rise to major severance issues for the peninsular communities, severely restricting access to employment, services and onward travel opportunities. If a suspension of the ferry necessary, there would likely be major public acceptability issues with this route corridor.

Due to the levels of the road connector points on both the A82 and A861, any fixed crossing along this corridor could not achieve the required air draught and thus the shipping lane would be closed off to all but the smallest of vessels. It would therefore be necessary to construct a low-level bridge with an opening or lifting mechanism to maintain the shipping channel. This in itself would be challenging as:

- The location of the main channel means that the opening bridge would have to be asymmetric, with the difficulty of providing a support for the opening sections to rest on when the bridge is opened.
- A vertical lifting bridge would need to be of a considerable scale to provide the necessary clearance. As well as being expensive, the structure would have a significant visual impact and may have difficulties in securing the required planning and environmental consents.

A swing or lift bridge would also introduce a delay for users of the fixed link, particularly with the latter. These delays would erode the journey time savings benefits associated with the fixed link. In addition, there would be little predictability in terms of when the bridge would be opening, which would be a major issue for public transport operators given their requirement to maintain a timetable and for those trying to make an onward connection, the ferry at Lochaline for example.

A bridge with an opening or lifting mechanism would also have a higher level and cost of ongoing maintenance. Additionally, there may be a more frequent need to replace parts due to the saltwater environment, which hastens corrosion and rust to moving parts. This would diminish the reliability of the fixed link. Additionally, there would be an ongoing cost associated with running a control centre and operative to manage the structure.

The construction phase in itself would also give rise to several obstacles that would need to be mitigated, such as establishing a safe construction working zone due to the number of properties that would share the access with construction vehicles and staff (e.g. the Corran Inn and Corran Bunkhouse and several residential properties). The access road is narrow and could give rise to potential conflicts between pedestrians / general traffic and construction traffic. In addition to disruption to existing properties and businesses taking access from this route.

Summary of RC1:

There are many benefits to this route corridor, such as reduced requirements for roadside construction and the minimisation of impacts on both neighbouring properties and the environment as it uses an established corridor. However, this route corridor may require the suspension of the ferry service for the duration of the construction period (this remains to be determined), which would have major socio-economic impacts on the peninsula communities. Moreover, the requirement for a low-level structure with an opening / lifting mechanism would add to the capital and ongoing costs and would give rise to delays and, potentially, reliability issues.

5.3.2.2 Route Corridor 2: Northern Corridor

Pros

RC2 would permit the continued operation of the ferry service during construction.

This route would not inhibit future tidal energy schemes in the Corran Narrows.

Due to the location of this corridor, there is sufficient length to construct a new access road to the bridge structure running perpendicular to the current A82 to establish the height necessary to provide the required air draught. The structure would then need to reduce in height quickly to link into the existing A861 and John Carmichael Way junction. This is however possible as the navigation channel for the Narrows is in close proximity to the eastern shoreline and thus there is scope for the bridge to gently decrease in height as it approaches the western landing point.

RC2 would also have a limited impact on surrounding residential properties in terms of both the requirement for compulsory purchase and construction related disturbance.

Cons

RC2 is the second longest of the route corridors currently identified at approximately 1km in length. This length would increase the cost and ongoing maintenance of any fixed link compared to the other corridors. Additionally, there would be higher road based construction costs incurred at the eastern side to develop the connecting road from the A82 and to form an embankment of sufficient height to meet the bridge at a level which allows it to achieve the required headroom clearance over the shipping lane.

The structural options for a bridge would be limited given the required length of the span.

There would be a requirement for the felling of some parcels of ancient woodland to facilitate this corridor on the eastern shore, whilst there would also be potential conflicts with the Scottish Water Pumping Station and fish farms closer to the shoreline on the Ardgour side of the Narrows. Ongoing construction work at sub-sea level and on the banks of the loch could give rise to sedimentary disturbance and discharge which could impact the water quality and subsequently the aquatic ecology. Additionally, as the structure is likely to be situated in an undeveloped corridor, it will have a significant visual impact on residents on the Ardgour side who currently have an undisturbed view across Loch Linnhe.

Currently the main traffic movement of users of the Corran Ferry on the Ardgour side is to turn left towards Clovullin, bypassing the village at Ardgour. As this corridor would make landfall to the north of the village, the majority of traffic movements would be routed through the village which would impact on the local environment, in terms of both noise and air quality and could give rise to safety concerns, due to the increased likelihood of conflicts between vehicles, pedestrians and cyclists. There may be a minor benefit associated with an increase in passing trade.

Summary of RC2:

Whilst this route corridor would provide benefits in terms of the continuation of the existing ferry service during the construction period, the scale of the disbenefits is significant. These include higher capital costs than the other options, challenges in terms of obtaining environmental consents and limitations in terms of the number of bridge options available due to the length of span required.

5.3.2.3 Route Corridor 3: Central Corridor

Pros

The ability to continue to operate the existing ferry service during the construction period, limiting the impact on the residents and visitors.

RC3 is also one of the shortest crossings, which will minimises the cost and ongoing maintenance of any potential fixed link structure.

This route corridor also provides advantages over the other corridors with respect to its topographical characteristics. The natural height afforded by the bluff on the eastern side of the Narrows and the hill above Corran Lighthouse on the western side provide natural height and reduce the amount of land and earthworks required to provide this when compared to some of the other options.

The potential locations of the bridge piers would be close to the shoreline. This would ensure that future proposals to harvest tidal energy are not compromised, whilst construction would not impact upon the fish farm on the Ardgour side.

This route corridor would have minimal environmental impact on designated features.

There is potential to improve overall local access to the A82 from the local settlement of Inchree by rationalising the A82 junction connections in the area and providing an improved single junction connection onto the trunk road network.

Cons

A number of properties have recently been constructed on the bluff above the Narrows in the vicinity of the route corridor. To develop a sufficiently wide corridor, a 30 metre buffer was established around the route corridor to ensure that it does not infringe upon any land boundaries. Nonetheless, there are still likely to be significant visual impacts for these properties, particularly for those facing onto the Narrows.

The residents of neighbouring properties would potentially be subject to noise and air quality impacts during construction and there would be a need to consider mitigation measures to reduce these impacts.

The corridor is also in close proximity to Corran Lighthouse, which is a Category C-Listed Building, and there would also be an additional requirement to relocate the war memorial from the top of the hill behind the lighthouse. The final environmental consideration would be the requirement to fell a small parcel of ancient woodland that surrounds the hill where the western extent of a fixed link would land.

To provide the required air draught, the structure would be high and visible from a significant distance away. It would also have significant visual impact on residents of Inchree and Bunree on the Lochaber side who currently have an undisturbed view across the Narrows. The impacts on views from local properties and villages on the Ardgour side is anticipated to be less significant due to the presence of woodland planting. This route corridor will have very limited interaction with any residential property boundaries.

Summary of RC3:

This route corridor has more benefits than disbenefits, with many of the disbenefits similar to all other corridors under consideration, while the benefits for this corridor are more specific to it. Of particular importance is the natural height afforded on both sides, which would provide the required air draught to maintain the shipping lane.

5.3.2.4 Route Corridor 4: Southern Corridor

Pros

This route corridor would allow the ferry service to be maintained during construction and would not preclude tidal energy development in the Narrows.

There is land available on both sides of the Narrows to facilitate construction of embankments of sufficient height to tie into a structure with the clearance required to permit free transit of vessels along Loch Linnhe. However, it should be noted that the earthworks of an option along this route may encroach on residential properties.

The landing point on the western shore also provides a direct route for traffic to continue southbound without residual impact on the neighbouring village.

Environmental impacts are likely to be minimal, with only a small number of trees requiring to be felled and with limited impact to no impact on the fish farm further up the loch.

RC4 would not inhibit future tidal energy schemes in the Corran Narrows.

Cons

This corridor is the longest of those identified at approximately 1.5km. This length would increase the cost and ongoing maintenance of any fixed link compared to the other options. There also would likely be increased road construction costs on the eastern end due to the need to have a lengthened connecting road between the bridge and the A82. The bridge would also have a larger gradient (although still with standards) to ensure sufficient air draught – this will incur additional costs associated with earthworks to provide this height.

This corridor would also have conflicts with surrounding residential properties on both the eastern and western sides of the Narrows and may even require the compulsory purchase of land on the eastern side depending on the final alignment. It is also likely to have a significant visual impact on both residents and visitors due to the length and height required and its proximity to the Bunree Caravan and Motorhome site.

Summary of RC4:

This route corridor is likely to have significant costs associated with it, due to the span of the structure required and the associated subsequent road-based works to provide access to the structure. There are few obvious advantages over RC3.

5.3.2.5 Route Corridor 5: Tunnel Corridor

Pros

As well as providing continuity for the ferry service during construction, the main benefit of the tunnel corridor is that there would be little in the way of visual impact in comparison with an above ground fixed link.

A tunnel would also allow any future aspirations for harvesting tidal energy, and it will not impact on the shipping lane through the Narrows. Indeed, it future proofs the shipping the lane against growth in vessel size / height, removing any 'hard' constraints in this respect.

Environmental impacts would be minimal with both entry and exit portals located away from any designations and there would be no need for the felling of any trees. Sub-seabed activity is also unlikely to impact on aquatic ecology and seabed biodiversity.

Cons

The main disbenefits associated with this route corridor, as highlighted within the case studies section, is cost and the lack of tunnel procurement and construction experience in the UK.

There are several risks associated with this route, including unknows with regards to the geology below the seabed and ability to source the required experience and machinery to make this route viable.

Construction impact is also likely to be high with increased HGV trips in the area to remove excavated material during the boring process.

A tunnel option would also make it difficult to create an active travel route as part of a fixed link option.

Summary of RC5:

This route corridor is likely to be the most expensive option for a fixed link structure across the Narrows. The level of construction and removal of excavated materials is likely to increase the environmental impact associated with noise and emissions from significant numbers of HGV trips. Also, there is a significant degree of risk associated with tunneling due to the limited experience of procuring and delivering such projects in the UK.

5.3.2.6 Route Corridor Summary

The table below summarises the performance of each of these identified route corridors against a variety of criteria, effectively collating the above narrative into a single table. Level of impact is registered using a 7-point scale similar to that defined in the STAG guidance and indicated below:

✔ ✔ ✔	- Highly Positive Impact
✔ ✔	- Moderate Positive Impact
✔	- Slightly Positive Impact
O	- No Impact
✕	- Slightly Negative Impact
✕ ✕	- Moderate Negative Impact
✕ ✕ ✕	- Highly Negative Impact

Criterion	RC1: Existing Corridor	RC2: Northern Corridor	RC3: Central Corridor	RC4: Southern Corridor	RC5: Tunnel Corridor
Ability to retain ferry service during construction	✕ ✕ ✕	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔
Long-list of structural options available	✕ ✕ ✕	✕ ✕ ✕	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔
Ability to retain Narrows as a shipping lane	✔	✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔
Ability to provide satisfactory air draught	✔	✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔
Ability to retain future potential for tidal energy generation	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔
Visual impact of a fixed link	✕	✕ ✕	✕	✕ ✕ ✕	✔ ✔ ✔
Environmental impact of a fixed link	✕	✕ ✕	✕	✕	✕ ✕
Conflict with land ownership	O	✕	O	✕	O
Routing of traffic away from settlements	✕ ✕	✕ ✕ ✕	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔
Reduction in quantity of required works (earthworks)	✕	✕ ✕	✕	✕ ✕	✕ ✕ ✕
Impact of construction	✕ ✕ ✕	✕	✕	✕ ✕	✕ ✕
Impact on costs of project	✕	✕ ✕	✕	✕ ✕	✕ ✕ ✕

Table 5 1: Route Corridor Impact Summary

From the variety of benefits and disbenefits associated with each of the potential route corridors, the five corridors have been narrowed down to **three** at this stage, and these should form the basis of any subsequent engagement if the project were to proceed. These corridors are as follows:

- Of the high-level bridge options, **Route Corridor 3: Central Corridor**, provides a greater positive impact and the fewest negative impacts across all potential bridge corridors.
- Due to the benefits of the **Tunnel Corridor: Route Corridor 5**, this option has been retained. It should though be noted that the capital and ongoing costs of a tunnel are likely to be comparatively high and there are significant risks relating to the technical complexity of the work and the procurement of competent contractors to deliver it.
- It is also recommended that **Route Corridor 1: Existing Corridor** is considered further due to the more limited roadside works required at this site and its minimal disruption to surrounding property owners. However, it should be acknowledged that any future consideration of this corridor would be predicated on developing a solution to maintain the ferry service and the identification a deliverable and reliable structural option.

5.4 Route Corridors - Broad Alignments

Having identified three route corridors for further consideration, broad alignments were investigated identifying a possible location for a fixed link within each corridor. As stated previously, these alignments are wholly indicative at this stage and are intended to provide a broad basis for comparative purposes.

5.4.1 Route Corridor 1 - Alignment

As route corridor 1 is situated within the existing crossing corridor, the alignment of any structure would remain within this corridor to take the full advantage of the existing infrastructure and therefore, no other possible alignments have been considered further at this stage – i.e. it can effectively be thought of as approximately slipway to slipway or approximately 520m.

Figure 12: Route Corridor 1, Alignment A (Indicative)

Figure 13: Route Corridor 3, Alignment A (Indicative)

5.4.2 Route Corridor 3 – Alignment A

SPAN: 485M

EASTERN APPROACH: 265M
WESTERN APPROACH: 605M

VOLUMETRIC CUT: 114,170M^3
VOLUMETRIC FILL: 114,920M^3

Working from east to west, the alignment leaves the existing A82, using the natural height afforded by the bluff on this side of the Narrows, landing on the hill directly west of the Corran Lighthouse, before sweeping round to the south on a tight radius curve before tying into the A861 at a new priority junction. This alignment would require significant earthworks on the western side to tie into the elevated bridge and then would transition down through a large cutting to tie into the existing road network. This alignment minimises environmental impacts, with limited vegetation required to be removed, while at the same time providing a safe link into the existing road network.

5.4.3 Route Corridor 3 – Alignment B

SPAN: 485M

EASTERN APPROACH: 265M
WESTERN APPROACH: 257M

VOLUMETRIC CUT: 14,707M^3
VOLUMETRIC FILL: 10,760M^3

This alignment follows the previous alignment in much the same vein, with the only difference involving the link into the existing A861 on the western side of the Narrows. This alignment would also involve a deep cutting into the hillside to provide a transition into the existing road network. The height of the bridge crossing causes some issues for this option as the road would require a steep alignment to facilitate a connection into the existing road network, due to restricted available space.

This alignment is likely to require a 'Departure from Standards' to facilitate its development. Another limitation of this particular alignment is the link into the road network which would be, situated on the inside of a bend. This is not a recommended arrangement and would, therefore, increase the need for the removal of vegetation and potential earthworks adjustments to increase sightlines and visibility. This process may also identify a need to consider alternative junction types to mitigate against potential hazards at this intersection.

Figure 14: Route Corridor 3, Alignment B (Indicative)

Figure 15: Tunnel Alignment (Indicative)

5.4.4 Route Corridor 5 – Tunnel Alignment

SPAN: 1,555M **EASTERN APPROACH:** 192M **WESTERN APPROACH:** 84M **VOLUMETRIC CUT:** 35,959M³ (APPROACHES ONLY)

The alignment currently considered falls outwith the desirable maximum gradient for all-purpose single carriageways in DMRB guidance, with gradients of 8% required to ensure the structure could be accommodated within the route corridor and the subsequent tunnelling length minimised. This incline is not a 'showstopper' in its own right but would require a relaxation from the desirable minimum standard by the approving authority.

Additionally, the alignment has assumed relatively easy tunnelling and thus has a depth of 5 metres below seabed. This is a significant uncertainty and the position could change significantly based on any future geological reports that are sought if this option was to be pursued. The alignment design has currently followed the bare minimum required from a road geometry perspective. The curvature of the alignment may also raise issues with regards to drilling and the ability for heavy duty machinery to manoeuvre within these tight confines.

5.5 Fixed Link Structural Options

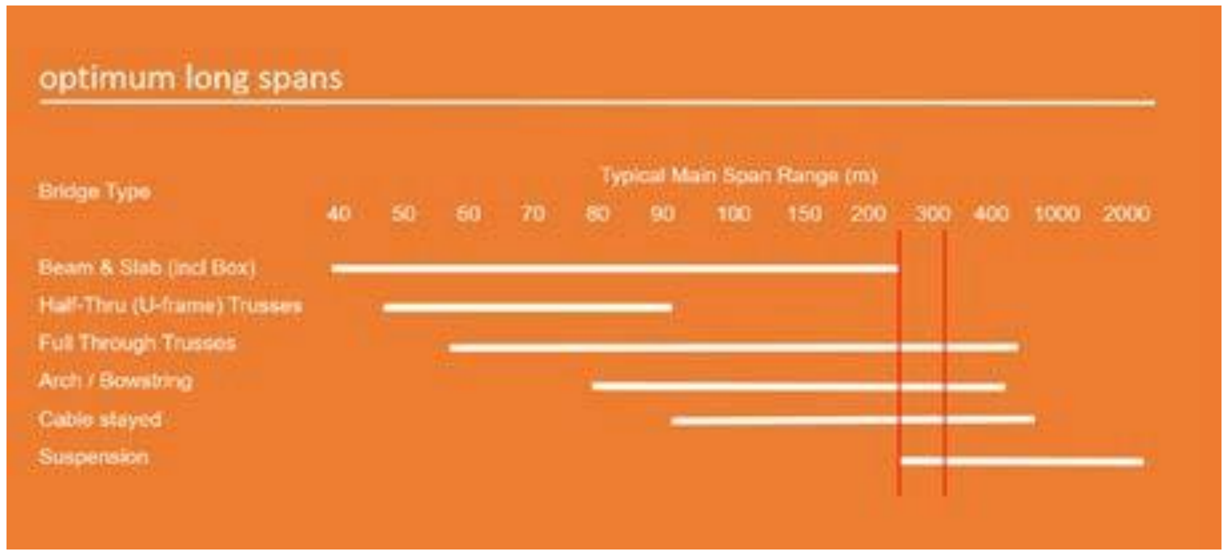
5.5.1 Foundations

The setting of the Corran Narrows provides a range of challenges for constructing a fixed link. The steep bluffs on the eastern shore and the subsea bathymetry and topography pose several engineering challenges.

Based on initial scoping of available data providing information on ground conditions, subsea terrain and water depths, our emerging thoughts are to locate the foundations for any fixed link as close to the shoreline as possible. Due to the profile of the loch bed and the fast-flowing tidal waters, it would be best to construct these foundations in waters no deeper than 5 metres. This depth and associated proximity to the shoreline ensures that construction is feasible, cost effective and limits the impact on the potential for harvesting tidal energy in the future. It is envisaged that the foundations would be constructed using cofferdams. As the structure moves further into the Narrows, where waters get deeper and faster flowing, there would be significant cost escalations if foundations were to be located here due to the engineering difficulties associated with working in such conditions. Once the locations for the foundations have been identified, the length of clear span (the distance between the foundational supports) would dictate the various structural forms suitable for spanning the Narrows.

A fixed link across the Narrows would require a span of circa 485m for a high bridge and circa 520m for a low bridge, with the main span between two supporting pylons varying between circa 200m and 300m. The chart below provides a high-level indication of optimum spans of fixed links by structure type which has, in combination with other factors, provided the required information for determining the long list of potential fixed link structures for spanning the Corran Narrows.

Figure 16: Bridge Spans and Structural Options



Key Point:

It is anticipated that the foundations for any bridge would be located close to the shoreline. The overall span of the bridge would be circa 485m for a high bridge and circa 520m for a low bridge, with the clear span (the distance between the foundational supports) varying between 200m-300m.

5.5.2 Structural Options

A long list of structural options has been developed, building on the STAG principle that all options should be considered and progressively sifted to a working shortlist. These options include both high and low-level bridge options for consideration for route corridors 1 and 3, and a tunnel option for route corridor 5.

Each option has been considered on its own merits as a structure and its suitability for this location. At this stage of the study, the options are discussed in terms of the pros and cons associated with each and have not been considered to the level of detail required to inform overall design. This process would be undertaken if the project were to proceed further, where more detailed analysis of each structure would be undertaken, progressively working towards a preferred option. This would include the actual design of the bridge deck, air draught, cycle and walking infrastructure provision and detailed drawings of the linkages into the existing road network and junction design.

5.5.2.1 Options Long List

Option A: Cable Stayed Bridge
Structure Type: High Level Bridge
Route Corridor: 3

A cable stayed bridge consists of one or more towers, from which cables are suspended supporting the main bridge deck. The most distinctive feature of these bridges is the suspension of the cables directly from the tower(s) to the bridge deck, which normally form one of four designs; Mono, Harp, Fan and Star. This type of bridge has similarities to a suspension bridge as both have bridge decks that hang from cables and both have towers. However, their main difference is related to the way in which they perform their function, supporting the load of the bridge deck. In cable stayed bridges, the cables are attached from the tower(s) to the bridge deck directly, alone bearing the weight of the load. Suspension bridges on the other hand, have cables which ride freely across the towers (as a catenary), transmitting the load to the anchorages at either end.

Cable stayed bridges are preferred for medium length spans, normally between 150 and 900 metres in length. This is due to advances in the materials used in the construction of these types of bridges becoming cheaper, whereby balanced cantilever bridges become heavier and more costly in this distance range. There is also a requirement for less cable with these bridges and combined with the fact these bridges can be constructed out of identical pre-cast concrete, fabricated steel or steel concrete composite sections, put them ahead of suspension bridges also.

There are several well-known examples of these types of bridges including;

- The Queensferry Crossing, which became the world's longest triple-tower cable stayed bridge in 2017
- Oresund Bridge which links Sweden and Denmark between Malmo and Copenhagen
- Ada Bridge, Belgrade, Serbia
- Most SNP Bridge, Bratislava, Slovakia
- Vasco da Gama Bridge, Lisbon, Portugal
- Franjo Tudman Bridge, Dubrovnik, Croatia

FiFigure 17: Queensferry Crossing (Cable Stayed Bridge)

Pros

- **Quick to construct:** The design of these bridges lends itself to a relatively rapid construction timeframe, due to the reduced requirement for anchorage and cabling when compared to the suspension bridge for the span range considered at Corran. There are fewer temporary works as the cable stays are incrementally installed with the prefabricated deck sections in a sequential and relatively balanced manner.

- **Strength of the structure:** The cable stayed bridge is an efficient structural form with the deck loads transmitted upwards to the towers and thence downwards to the foundations in a direct load-path.

- **Cost Advantages:** Its efficient structural form results in less construction complexities, less temporary works, resulting in a reduction in the overall construction time and use of materials. This can reduce installation costs significantly and is one of the main reasons why it is one of the most common bridge types in the world for the span range under consideration at Corran.

- **Design Options:** Although the optimum span length of a cable-stayed bridge is less than that of the suspension bridge type, subject to reasonable substrata being able to support additional towers, one can attach different spans together to create a viaduct bridge of considerable length. An example of this is the infamous Millau Viaduct in France with a total length of 2,460 meters and seven towers.

- **Adaptability:** Cable stayed bridges provide the possibility for a variety of designs enhancing the aesthetics of the structure in its environment. The bridges afford the opportunity for a symmetrical design, four different classes of cabling designs as mentioned above (Mono, Parallel, Fan and Star), and the ability to use any of four arrangements for their support columns. As such, this structural form can be adapted to be sympathetic to the environment in which it is situated.

Cons

- **Unsuited in specific environments:** Although cable stayed bridges can help provide a consistently supportive bridge deck when there are crosswinds present over a span, this option does not work well in locations where the wind speed remains consistently high over significant periods of time. This is due to the rigidity of the cables, which under the pressure of the high-speed crosswinds, may cause the bridge deck to start rocking. Over time this effect starts to loosen the support cables, which will need replacing and constant reviewing, adding to the life-cost of the structure.

- **Challenges for inspection, maintenance and repairs:** Due to the reduced need for anchorage and that the cables are connected into high towers, physical inspection becomes very challenging and maintenance can become intensive. Combined, this can increase maintenance costs significantly compared to other bridge types, often reducing the cost saving benefits during the construction phase. These costs increase depending on the number of towers involved and the length of span.

- **Susceptibility to rust or corrosion:** The majority of cable stayed bridges use a combination of concrete and steel to create a rigid and supportive structure. Unless there are protections in place to maintain the quality of the metals used for the cabling, they can become highly susceptible to corrosion and rust, especially in saltwater conditions. Due to the technique of the cabling for supporting the weight of the bridge deck, even the smallest appearance of corrosion can have a significant impact on the structure. As such, it is necessary to use a water-resistant paint to protect the cabling and structure which can significantly increase ongoing maintenance costs depending on the span and amount of cabling present.

- **Maximum benefits typically apply to medium spans and its connectivity:** The optimum effectiveness of this form of bridge is over medium spans and its agility and flexibility to be linked end-to-end creating a much longer structure / viaduct. For this high-level study, it appears that its linkage benefits are not fully exploited at Corran due to the constraints presented by the Narrows.

Option B: Suspension Bridge
Structure Type: High Level Bridge
Route Corridor: 3

A suspension bridge is a type of bridge in which the bridge deck is hung below suspension (catenary) cables on vertical (or incline) hangers. The suspension cables form a catenary between towers and are anchored at each end of the bridge.

The suspension cables must be anchored at each end of the bridge, since the load on the bridge deck is transferred into tension in these cables. These cables continue beyond the pillars to the deck level supports and then further continue to connections with ground anchors. The bridge deck is then supported by vertical suspender cables called hangers.

There are several well-known examples of these types of bridges including;

- Forth Road Bridge, Queensferry, UK
- Humber Bridge, Hull, UK
- Golden Gate Bridge, San Francisco, California
- Brooklyn Bridge, New York
- Akashi Kaikyō Bridge, Kobe, Japan

Figure 18: Golden Gate Bridge (Suspension Bridge)

Pros

- **Span:** Suspension bridges have the ability to span further than most, if not all, of the other bridge types. The longest bridge in the world from a suspension standpoint is the Akashi-Kaikyo Bridge in Japan at 2,000 metres.
- **Maintenance:** Great strides have been made in recent years in the advent of advances in corrosion protection for suspension cables. Maintenance of suspension bridges has therefore improved but at the expense of a higher initial capital cost.
- **Landmarks:** Suspension bridges have undoubtedly become a feature and an attraction which define many locations, such as the Golden Gate Bridge which immediately strikes an association with a place. They can become a landmark in their own right, drawing visitors to the area.
- **Flexibility:** This type of bridge provides the flexibility of being able to construct the bridge deck in sections, so that they can easily be replaced, without having to have grand overhaul or maintenance project. Additionally, adjustments can be made to the cabling to adjust the amount of weight the bridge can support over time, which infers that the bridge can become flexible and can be adapted to reflect changes in traffic flows and movements across the bridge.
- **Less time to construct:** There is a general reduction in the required amount of materials to construct a suspension bridge than other bridge types. These bridges can be constructed with a reduced need for anchors and as such a reduction in the amount of required cabling to support the bridge deck. This enables the bridge to be constructed in a reduced timeframe from concept design to onsite.

Cons

- **Strength:** Although suspension bridges have the ability to bear the load of traffic through the transfer of tension and weight across the whole structure, there is an upper weight tolerance associated with some designs. If there is a constant focused weight on the bridge that is greater than the weight limit of a single cable, then the whole structure is at risk.
- **Aerodynamics:** High winds are known to cause vibration of the bridge deck due to the interaction with the rigid cabling of a suspension bridge. Newer bridge designs have mitigation methods integrated to reduce the occurrence of this such as aerodynamic profiling, however, this can often result in the support columns not being designed for this extra weight.
- **Lower Deck stiffness:** Typical suspension bridge designs offer a relatively low deck stiffness compared to other bridge designs. This reduces the ability of the bridge to carry intense and focused weight that occurs frequently, such as railway traffic.
- **Extensive foundations work at end anchorages and towers:** If the suspension bridge is built in an area that has soft ground, then there will need to be considerable engineering works to secure the foundations. This is necessary as the weight of the bridge forces downward pressure onto the tower anchors which over time will start to sink into the ground.
- **Redundancy:** It only takes the failure of one of the suspension cables to cause catastrophic results for the bridge, as they need to work in conjunction to provide the necessary support to transfer the tension caused by the weight of the bridge deck. It should be noted, however, after some recent disasters, there have been advances in the safety design of these types of bridges to prevent this from happening.
- **Cost:** Although suspension bridges are one of the most affordable of all bridge types, for certain spans, there are more cost-effective types available, due to the costs of installation of the bridge.

Option C: Tied-Arch Bridge
Structure Type: High Level Bridge
Route Corridor: 3

A tied arch bridge is an arch shaped structure in which the outward horizontal forces of the arch are resisted in tension by the bridge deck itself, rather like a bow (the arch) being restrained by the string (the deck). Vertical hangers or chords connect the bridge deck to the arch at regular spacings to support the deck and the traffic load.

This bridge works by transferring the weight on the bridge deck into tension on the vertical ties, which try to flatten the arch and to push its end tips outward onto the abutments. The horizontal chord provides the stability and constraint on the tension, therefore, allows the bridge to be constructed on less robust foundations because the force on the abutments is low. This design affords great flexibility in locating a structure of this type as they can be built on elevated pylons or in areas of unstable soils as there is less downward vertical pressure onto the foundations and instead the force is pushed horizontally. A further added advantage of this design is that they can be built off-site and transported into place.

There are many variants to a tied-arch that can be considered for most spans including;

Shouldered tied-arch: Half arches at either end of the span support the bridge deck from below and join to the feet of the main arch to prolong the strengthened chord across the span. This makes the whole structure self-anchored and places all vertical loads on all ground bound supports created from the half arches;

There are several well-known examples of these types of bridges including;

- Windsor Railway Bridge, Windsor, UK
- Infinity Bridge, Stockton-on-Tees, UK
- Sydney Harbour bridge, Sydney, Australia
- Birmingham Bridge, Pittsburgh, Pennsylvania
- Fremont Bridge, Portland, Oregon
- Bayonne Bridge, Staten Island, New York

Multi-span discrete tied-arch: Consist of successively lined up tied arches in places where a single span is not sufficient;

Multi-span continuous tied-arch: The tying chord continually spans over all bridge piers, tying the multiple arches feet at the bridge piers. This then enables the distribution of dynamic loads between the spans.

Single tied-arch per span: Two tied-arches are placed in parallel alongside the bridge deck, so that the bridge deck lies in between the respective arches;

Tilted tied-arch: The arches are tilted outward or inward in respect to the central axis running along the bridge deck;

Tied-arch Twin: Two tied-arch bridges constructed side by side to increase carrying capacity, whilst remaining structurally independent.

Figure 19: Bayonne Bridge (Tied Arch Bridge)

Pros

- **Offsite Construction:** As the loads for this structural form is predominantly internal (except for the vertical loads at its supports) this form of bridges lend itself to be fully pre-fabricated offsite, transported to site and either lifted or jacked and lowered onto its prepared foundations. Savings to programme, less site based activities (sustainability and impact on the environment) and reduced temporary works.
- **Length of Span:** The arch design of these bridges affords greater flexibility for spanning greater distances due to the advantages of strength afforded by the design. The arch can travel further between two bridge piers than a straight beam because of how the downward tension is managed, which affords the opportunity to construct a longer bridge deck, whilst providing more horizontal strength to support heavier loads.
- **Resilience:** The curvature of the arch provides the bridge deck and overall structure more strength than other alternatives. A reasoning why, many railway bridges take on this design, as the movement of a heavy load across the bridge, is modified with a downward sagging force, which is then transferred consistently along the full length of the structure by the support columns, reducing the stress over the structure, thus providing resilience longevity.
- **Flexibility of construction materials:** The design affords the possibility of constructing the bridge out of a variety of materials including concrete, steel, aluminum or a combination, due to the way in which the stress of the load is transferred along the structure evenly.
- **Adaptation to local environment:** The arch design and subsequent strength to the structure it affords, provides the structure with the ability to withstand the natural environment better than traditional pillar or abutment style supports. This has been attested to by the number of these bridges and other structures still standing that were constructed over a 1,000 years ago that have an arched design in their construction.
- **Structural Integrity:** Although the arch design is already naturally strong, as the structure continues to age, it is possible for the structure to continually become stronger. This is due to the compression applied over the years, beginning to flatten out the arch slightly, creating a U-shape with less rounding. This process assists in more efficiently distributing the weight of the bridge deck better to the abutments while providing more stability.
- **Design Options:** As the arch shape is so effective at displacing weight across the full length of the structure, it provides the opportunity to design the structure based on many different forms as listed above. This provides a greater degree of flexibility in identifying a structure to best fit the span being considered, whilst combinations of arch designs can improve and provide greater stability.

Cons

- **Finite span with each set of abutments:** Although there is an indefinite span associated with tied-arch bridges, to cover longer spans, you need multiple arches, thus supporting abutments. The longer the span, the more arches required and the more abutments. Without this, the greater the distance between arches reduces the benefits of the design to transfer weight across the structure.
- **Experience and Cost:** These types of bridges are one of the most difficult to design and requires an experienced structural engineer to plan. There is a need to understand the complexities of interior and exterior pressures that the abutments must handle. There is then a need to ensure there is adequate strength in the materials and support processes for enough transference of weight to occur and thus enable the structure to perform its function. This thus increases the cost associated with the design process of the bridge, which increases significantly depending on the complexity of the design.
- **Perfection:** There is a need for absolute perfect alignment of the support abutments with the arch design to ensure that the distribution of weight to the abutments is equally balanced. Any discrepancies in this part of the process are significantly challenging to overcome.
- **Higher levels of ongoing maintenance:** Arch bridges require ongoing maintenance to ensure the supports are distributing the weight to the abutments correctly. Subsequently, there is a need for frequent inspections of the span of the structure as it ages to ensure that the structure is not weakening over time.
- **Construction time:** Due to the level of detail and specifics in the design of an arch bridge, construction time of the bridge can be significantly greater than other types of bridge structures. Again, this can impact overall budget of the structure due to the increased manhours and experience required to build these types of structure.
- **Cost:** Complexity of design, construction and ongoing maintenance can all add up significantly depending on the design of the structure. This can increase the overall cost of this style of bridge significantly above other designs. However, the resilience afforded by this design can improve the lifespan and longevity of the bridge.

Option D: Vertical Lift Bridge
Structure Type: Low Level Bridge
Route Corridor: 1

A vertical lift bridge is a bridge which contains a section of bridge deck that is lifted vertically, while remaining parallel to the remaining bridge deck. Lift bridges generally cost less compared to other types of opening bridges such as bascule and swing bridges.

Lift bridges use a system of counterweights and cables to move the allocated section up and down to allow marine traffic to pass beneath the structure. The average time for the bridge to complete the full operation varies depending on the size of span and required height necessary to facilitate the movement of traffic below it. For example, the Hawthorne Bridge in Portland, Oregon, takes around eight minutes to complete the full cycle – depending on the length of time required by the vessel to pass beneath.

These types of bridges require manual intervention to open and close the bridge and as such require an operator based in a control room on site of the bridge. This is a necessary requirement so the operator can view the bridge to ensure there is no traffic on the bridge deck before beginning the process. The operator can control the movement of the lift span by selecting pre-determined heights or personally manipulating the speed of the motors until the desired height is reached.

The weight of the lifting span is counterbalanced, generally, by two concrete counterbalance weights and are connected to the lift span by numerous heavy tension cables. Turnbuckles on the cables allow maintenance personnel to adjust the tension in the cables and the alignment of the counterweights over time to compensate for any wear and tear.

There are several well-known examples of these types of bridges including;

- Kingsferry Bridge, Kent, UK
- Tees Newport Bridge, Middlesbrough, UK
- The Pont Jacques Chaban-Delmas, Bordeaux, France
- Kattwyk Bridge, Hamburg, Germany
- Aerial Lift Bridge, Duluth, Minnesota
- Tower Bridge, Sacramento, California


Figure 20: Aerial Lift Bridge, Duluth (Vertical Lift Bridge)

Pros

- **Design and construction:** Of all types of opening bridges available, the vertical lifting bridge is the easiest to both design and construct reducing costs of both elements as a consequence.
- **Lifting angle:** The vertical lifting angle can be built with any length required, with the only limitation being the span itself.
- **Strength:** Lifting bridges have the capability to support heavy load structures since the vertical lifting bridge spans are approximately fixed.
- **Versatility:** As the structure only requires both upward and downward movement, it is not as restricted as other opening bridges and, therefore, affords the opportunity to double deck the bridge, which can be moved up and down disregard of each other. Therefore, depending on the clearance required, only one deck may need to be lifted, while the other can continue to function.

Cons

- **Halt to traffic:** The main disadvantage of a lifting bridge is that in the main it restricts the free movement of traffic at all times. In effect it still maintains the characteristics of a ferry to a large extent.
- **Vertical space:** A lifting bridge would still have a restriction to the air draft afforded to vessels to pass through. To overcome this would require higher support towers which would then have a more significant visual impact.
- **Restricted navigation width:** The entire width of the navigation channel cannot be used and navigation is restricted to the relatively narrow corridor afforded by chosen span of the vertical lifting bridge even when the bridge is completely ‘opened’.
- **Construction costs:** Although potentially cheaper than other types of opening bridges, vertical lifting bridges are still expensive, due to the requirement of the lifting towers to be some 18 metres higher than the required air draft due to the mechanical components, structural span depths and cable connections in the common traditional form. As the height of these towers increase, so does its impact and influence on the natural environment, in particular wind effects and visual impact.
- **Resilience:** These types of bridges require frequent maintenance to ensure the counterbalances are correct and that all the mechanisms are working accurately. The water environment they are based within, in particular saltwater can increase corrosion and rust, and impact the operation of the mechanisms controlling the lifting section. As such they need to be continually monitored and inspected.
- **Cost:** In addition to the above construction and ongoing maintenance costs, there are also the additional costs associated with running a control center and operator to manually operate the bridge, although the use of technology could to some extent mitigate but not replace human intervention entirely. This will pose an ongoing cost associated with the lifespan of the bridge.

Option E: Balanced Cantilever Bridge
Structure Type: High Level Bridge
Route Corridor: 3

Cantilever Bridges are built using cantilevers, structures that project horizontally, supported on only one end. Large cantilever bridges designed to carry traffic use structural supports called trusses built from either structural steel or box girders built from prestressed concrete.

In its simplest form, a cantilever span is formed by two cantilever arms extending from opposite sides of the feature that is to be crossed, meeting in the middle. The most common variation of this style of bridge is the balanced cantilever bridge, which involves counterbalancing each cantilever arm with another cantilever arm projecting from the opposite direction, forming a balanced cantilever, which are then attached to a solid foundation. The two counterbalancing arms are called anchor arms and extend away from the feature to be crossed.

For example, a bridge built on two foundation piers, there is a requirement for four cantilever arms, two which span the feature to be crossed and then two anchor arms which extend away from the feature. This design requires additional strength to be provided at the balanced cantilevers support piers, which often takes the structural form of towers above the foundation piers. Balanced Cantilever Bridges can be constructed from prestressed concrete, steel or steel-concrete composites. Variants have included the use of steel trusses.

There are several well-known examples of these types of bridges including;

- Forth Bridge (Railway), Queensferry, UK
- Skye Bridge, Skye, UK (to an extent)
- Vejle Ford Bridge, Vejle, Denmark
- Quebec Bridge, Quebec, Canada
- Minato Bridge, Osaka, Japan
- Crescent City Connection, New Orleans, Louisiana

Figure 21: Vejle Bridge (Cantilever Bridge)

Pros

- **Suitability:** This style of bridge is well suited to spanning features in difficult terrains such as deep and rocky gorges and rivers that are prone to flooding. This is advantageous as they don't need temporary supporting structures during construction which would be difficult in these types of terrain.
- **Support structures:** These bridges permit the use of simple column style supports reducing the complexity of the structures. Additionally, with exception of the piers, these bridges do not require further supports during construction.
- **Length of span:** The span of this style of bridge can be longer than other conventional types of bridges as the beams can be attached at the ends of the cantilevers.
- **Business as usual:** Navigation below the bridge is not obstructed during its construction as the spans are constructed incrementally in a balanced fashion outwards from the support pier.
- **Construction efficiencies:** The bridge deck can be easily constructed in segments, which maintains uniformity and consistency while at the same time ensures quality especially when the segments have been cast or fabricated off-site. Additionally, this segmental construction, also makes the installation repetitive, which ensures efficiency during construction. There is also a reduction in the time required as most of these types of bridges are constructed to contain multiple cantilever spans, which means construction can begin simultaneously from all piers.
- **Strength:** Cantilever decks are generally stiffer than other medium and long-span bridges because they have structural continuity and they do not employ tension only members (e.g. cables) and therefore have better resilience to dynamic responses.
- **Design:** The lack of multiple supporting piers provides the opportunity to expand on the depth, style and geometry of the bridge deck supported by the bridge.

Cons

- **Cost: Cantilever** bridges maintain their stability by a balance between compressive and tensile forces within its relatively 'thin' structural depth in resulting a relatively heavy structure in comparison to other bridge forms. As such, this can increase costs significantly due to the amount of material required for its construction.
- **Large supports:** Due to the weight of these types of bridges, the cantilever deck spans require larger and stronger support piers and their associated foundations. This can potentially be costly where subsurface geotechnical conditions may not be suitable to sustain their heavy loads.
- **Construction Complications:** Although these bridges have benefits associated with being constructed in segments, in addition to providing efficiencies, it can also lead to discrepancies during the installation, increasing the chances of visual differences cropping up between adjacent segments.
- **Span configuration:** At Corran, the optimum position to locate the pier supports conflict with the navigation channel and has the challenge of locating the other pier at the deeper part of the narrows.
- **Extreme conditions:** These bridges are not suitable for environments with prolonged exposure to extreme conditions due to the lack of supporting columns.

Option F: Truss Bridge
Structure Type: High Level Bridge
Route Corridor: 3

A truss bridge is a popular bridge form that has the advantages of the inherent stability and efficiency of member triangulation resulting in a relatively stiff and lightweight structure. Examples of trusses include the Warren and the Pratt and their modified variants. Trusses have also been used as a sub-form in other bridge structural forms, for example a Tied-Arch Bridge may have the primary arch member being form of a curved truss comprising triangulated members.

The two most common truss designs are the king posts which utilise two diagonal posts supported by a single vertical post in the centre and queen posts which use two diagonal posts, two vertical posts and a horizontal post that connects the two vertical posts at the top. There are a further 24 design types of truss in use across the world today.

Truss bridges became very popular due to their resilience and economic builds that require minimal amounts of material for construction. Additionally, truss bridges can also be of fixed form or moveable providing greater flexibility.

There are several well-known examples of these types of bridges including;

- Ballachulish Bridge, Ballachulish, UK
- Connel Bridge, Connel, UK
- Royal Albert Bridge, Plymouth, UK
- Francis Scott Key Bridge, Baltimore, Maryland
- Braga Bridge, Fall River, Massachusetts
- Ikitsuki Bridge, Nagasaki, Japan
- Jiujiang Yangtze River Bridge, Jiujiang, China

Figure 22: Jiujiang Yangtze River Bridge (Truss Bridge)

Pros

- **Structure weight:** This type of structure is one of the lightest available, which allows for greater spans to be crossed without penalising the structure through additional weight.
- **Efficiency of design:** This type of bridge can be installed almost anywhere due to the benefits of its design. Although mostly used for the short and medium spans, the overall design of a truss bridge can be scaled up to bridge into the long-span category.
- **Minimal impact during maintenance:** As truss bridges have their bridge deck on top of the structure and not within it, traffic can continue to use the bridge whilst it is undergoing routine maintenance and repairs without causing delay or closures.
- **Flexibility:** This type of bridge can be constructed from a variety of materials, meaning it is possible to construct a bridge based on specific needs to keep cost down. Additionally, due to the many varied design types of truss, it is possible to construct a bridge that reduces negative visual impact.
- **Affordability:** Due to the reduced need for materials and ability to construct these bridges from a variety of materials, it is possible to construct a truss bridge for a lower fee than other types. Furthermore, most of the pieces that engineers develop with this option can fit together quickly as the bridge builds outward. This makes it possible to save on design and implementation costs, while also reducing the labour needs of the structure.
- **Strength:** The truss design provides additional strength due to the nature of how it distributes weight throughout the entire structure, whilst having minimal impact on the environment upon which it is constructed.

Cons

- **Higher degree of wear and tear:** The interaction between the trusses and the way in which weight and pressure is distributed can cause premature wear and tear to occur. Thus, these bridges are favoured more for shorter spans, as the pressure increases significantly as span lengthens.
- **Perfection:** Both the design and construction of the trusses need to be perfect for this style of bridge to be fully functional and distribute the weight efficiently. If there are errors during this process, such as uneven balancing of weight coming from the deck to any of the frames, then this can further premature wear and tear.
- **Maintenance:** Further to the above, the need to ensure that the bridge is constructed perfectly also has inherent issues for ongoing maintenance. There are higher levels required from maintenance personnel to check the framework to maximise its function. There are several additional connections and components to these bridge designs than others which significantly increase the potential for weaknesses and deterioration over time. Every part of the structure fulfills a role and as such it is important to continually maintain the bridge to reduce any wear and tear which may significantly increase if there are shifts in the load distribution across the entire structure.
- **Width:** Although there is a degree of flexibility in the design of truss bridges, there are width requirements that are necessary for this style of bridge to be successful. As such it is important that the unique spatial needs that the truss bridge will require are considered when investigating potential crossing points.
- **Perceived aesthetics:** A product of the Industrial Revolution of the last century trusses have an “industrial” heritage and have often being perceived to have a negative visual impact on the environment.

Option G: Tunnel
Structure Type: Tunnel
Route Corridor: 5

As alluded to in the case study chapter, tunnels are not frequently constructed in the UK, due to a lack of necessary experience due to the difficulties and risks associated with tunneling.

A major tunnel project must start with a comprehensive investigation of ground conditions by collecting samples from boreholes and other geotechnical techniques to make informed choices over the alignment of any tunnel structure. Additionally, these initial investigations can then inform engineers of what machinery and methods of excavation and ground support are required, which will reduce the overall risks. In planning the route of a tunnel, the horizontal and vertical alignments need to be carefully selected to make best use of best ground and water conditions and is common practice to tunnel deeper than is required in order to excavate through solid rock or other material that is easier to support during construction.

Often smaller pilot tunnels are constructed before the main tunnel to identify any unexpected conditions not identified during the initial investigations. These smaller tunnels are then often incorporated into the main tunnel or else safeguarded to be used as a backup or emergency escape tunnel.

There are several well-known examples of these types of bridges including;

- Clyde Tunnel, Glasgow, UK
- Lincoln Tunnel, Manhattan, New York
- Dartford Tunnel, London, UK
- Detroit-Windsor Tunnel, Michigan
- North Shore Connector Tunnel, Pittsburgh, Pennsylvania

Figure 23: Lincoln Tunnel

Pros

- **Visual impact:** Tunnels have no visual impact on the environment.
- **Shipping lane and tidal energy:** Tunnels have no impact on the operation of the shipping lane or preclude the future potential to harvest tidal energy from the Narrows.
- **Reduced footprint:** Tunnels require less land and footprint than a bridge, with land only needed for the entry and exit portals.
- **Weight capacity:** Tunnels afford a greater weight capacity than bridges in general and negate the need to invest in heavier materials to reinforce a bridge.
- **Resilience:** Tunnels have been found to be more resilient than bridges to the impact of natural disasters such as earthquakes and ground movements. This is important in this context as the Narrows sits on the Great Glen Fault. Additionally, tunnels are not affected by adverse weather conditions such as high winds which can impact on the use of bridges by different vehicles.

Cons

- **Cost:** Tunnels are far more expensive than bridges and costs can significantly increase during construction time due to unforeseen circumstances not identified during initial investigations. This has the ability to increase costs exponentially.
- **Experience:** There is a lack of suitable experience and knowledge in the UK on tunnelling. This would then require the need to bring in external professionals to assist in the design and construction phases increasing timescales and costs.
- **Construction time:** Tunnel construction times can be far more significant than bridge construction times and can vary dramatically depending on the variety of risks associated with tunnelling, such as the collapse of the structure or water leakage into the tunnel.
- **Dangerous goods:** Tunnels can preclude the transit of vehicles based on the goods that are carried in case of risk of fires on the tunnel or mean that other vehicles are not allowed in the tunnel at the same time.
- **Lack of adequate active travel links:** Most tunnels do not include an active travel link, and those that do are often uninviting for active travel users. They can often be dangerous for these types of users, due to risks of vehicle accidents and fire outbreaks.
- **Staff costs:** Tunnels require the installation of control centres to continually monitor the tunnel in case of emergencies such as fires and accidents as mentioned above.
- **Availability of heavy machinery:** The boring of a new tunnel requires the acquirement of heavy-duty machinery to bore through the soil and rock and to construct the tunnel. These machines can often be difficult to source and are costly, which increases overall construction times and costs. Additionally, both gradient and curvature of the alignment of the tunnel can have implications on the manoeuverability of these machines.

5.5.3 Initial Options Sift

The structural options listed above were considered for further discussion within this feasibility report, while some further options were investigated but then sifted out due to the inherent difficulties associated with each and unsuitability for the unique characteristics of the Narrows. These included:

- **Causeway:** This option has been sifted as it would effectively close the shipping lane, which would be an unacceptable outcome.

Figure 24: Causeway

- **Bascule Bridge:** Often referred to as a drawbridge, this option was considered as a low-level bridge for RC1. It was discounted on the basis of:

- being more expensive than a lifting bridge;
- restrictions in the possible span afforded, due to the maneuverability of the mechanisms;
- the wait required for the full cycle, which would not be dissimilar to a ferry;
- costs associated with ongoing maintenance, control centre and operator;
- resilience of the moveable structures which could potentially breakdown and require vehicles to reroute around the loch, which has the same result as the ferry currently during breakdowns and bad weather.

Figure 25: Bascule Bridge

- **Swing Bridge:** This option was considered as a low-level bridge for RC1. It was discounted on the basis of:

- being more expensive than a lifting bridge;
- requires considerable maintenance because of the large number of moving elements;
- a requirement for supporting piers at the centre of the channel makes the bridge vulnerable to collisions and can impact the beam of vessel that can travel through the bridge;
- the extended wait times required for the full cycle over a lifting bridge, which would not be dissimilar to a ferry;
- costs associated with ongoing maintenance, control centre and operator;
- high instances of breakdown due to the fragility of parts and mechanisms used to perform the swing function, which increases the occurrences of malfunction. Again, this replicates the same issues with the resilience of the ferry during breakdowns or bad weather and the requirement for traffic to reroute around the loch.

Figure 26: Tyne Swing Bridge

Other types of opening styles of bridges including tilt, folding and retractable have also been sifted. This is due to the cost of these options and limited benefits on offer, even when compared to the sifted options above.

5.5.4 Estimated Capital Costs

This section sets out the indicative costs associated with each of the structural options described above, broken down by capital and maintenance & operational costs. It is important to reiterate again here that the costing undertaken in this feasibility study is high-level and solely intended to identify whether there is merit in considering one or more fixed link options in detail.

Costs have been derived through a review of completed structures across the world to provide a structure cost by span matrix. Whilst this does not take account of the local procurement, regulatory regimes, cost and contractor experience, it provides a reasonable and consistent basis for comparison at this stage. The charts below provide an illustrative example of the varying degrees of cost associated with building different bridge types.

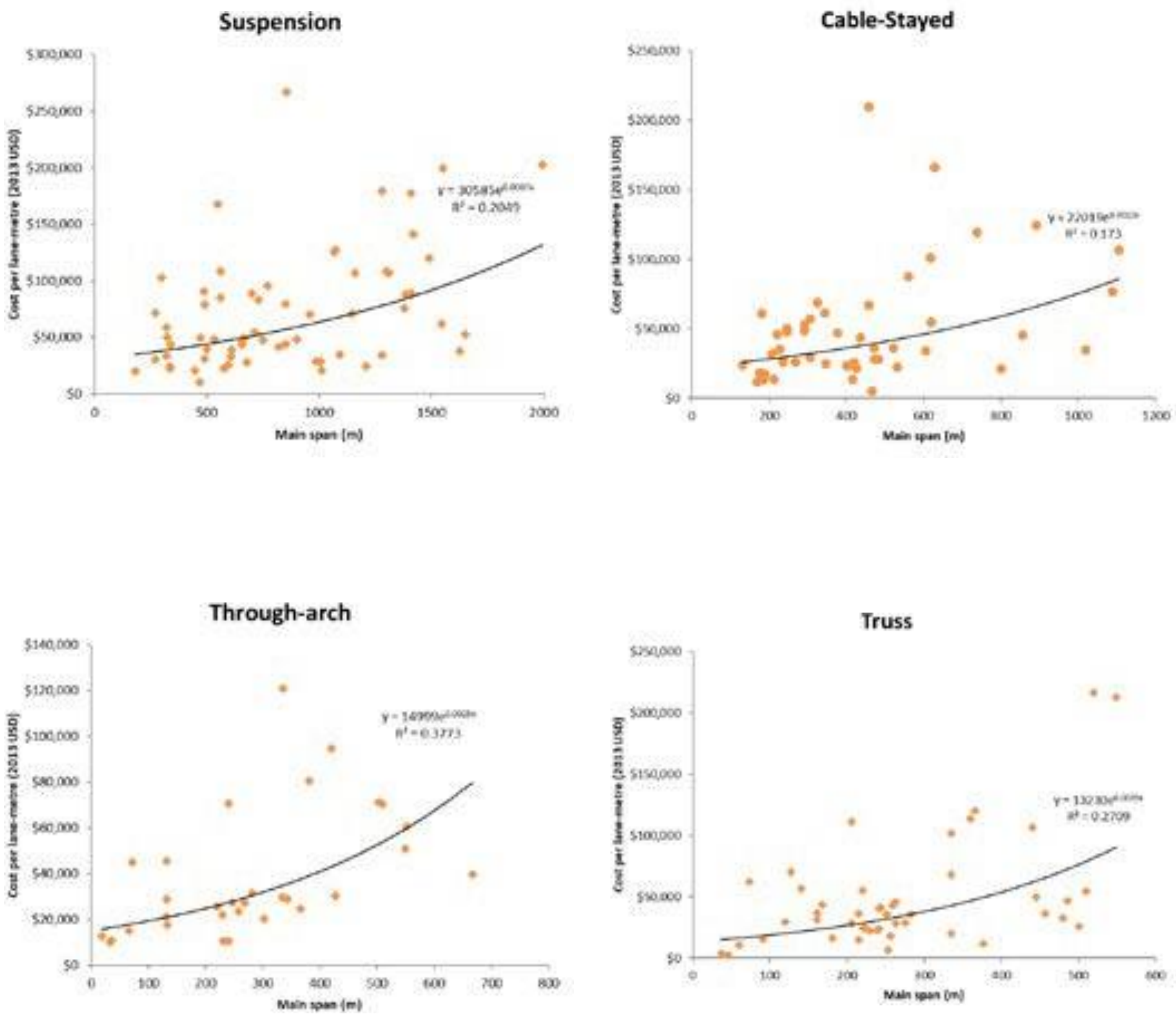


Figure 27: Illustrative Costs of Bridge Structures per lane metre (US Dollars ($))

5.5.4.1 Capital Costs

The table right sets out the estimated capital costs of each of the identified structural options based on the analysis above. These are presented as a 'low to high' range. These costs are for the structure only, including the bridge deck and do not include the costs associated with roadside construction, which is discussed at a later stage. These costs do not include optimism bias at this stage.

All costs for bridge structures have been costed to include an **air draught of 32m**. An increase in height would increase subsequent costs associated with the structure and the road based connections.

Option	Indicative Capital Cost	
	Low	High
A - Cable Stayed Bridge	£35m	£45m
B - Suspension Bridge	£37m	£47m
C - Tied-arch Bridge	£30m	£40m
D - Vertical Lift Bridge	£25m	£30m
E - Cantilever Bridge	£40m	£45m
F – Truss Bridge	£35m	£45m
G - Tunnel	£40m	£65m

Table 5 2: Indicative Capital Cost for Corran Narrows Fixed Link by Structure Type

Key Point:

It can be seen from the above table that the cost envelope for a **bridge** at Corran would be in the region of £30m-£47m. The 'high' **tunnel** cost is by some margin the highest overall cost.

5.5.4.2 Operational and Maintenance Costs

As covered in the supporting text for each of the structural options, different structure types require different levels of ongoing maintenance (low & high bridges) and operational involvement (low bridge), including repairs, replacement parts and human resource. As these will vary on an annual basis, the estimation of operational and maintenance (O&M) costs has been framed in the context of a percentage of the capital cost over the appraisal lifespan of 60 years.

Option	Indicative Capital Cost		Maintenance & Operational	Maintenance & Operational	
	Low	High	%	Low	High
A - Cable Stayed Bridge	£35m	£45m	*25%*	*£9m*	*£11m*
B - Suspension Bridge	£37m	£47m	*27%*	*£10m*	*£12m*
C - Tied-arch Bridge	£30m	£40m	*17%*	*£5m*	*£7m*
D - Vertical Lift Bridge	£25m	£30m	*60%*	*£15m*	*£20m*
E - Cantilever Bridge	£40m	£45m	*13%*	*£5m*	*£8m*
F – Truss Bridge	£35m	£45m	*29%*	*£10m*	*£12m*
G - Tunnel	£40m	£65m	*50%*	*£20m*	*£33m*

Table 5 3: Indicative 60-Year O&M Cost for Corran Narrows Fixed Link by Structure Type

Key Point:

Whilst some bridge structures have a lower overall capital cost, this benefit can be eroded due to higher maintenance costs, an obvious example being a vertical lift bridge. Overall, it is anticipated that a tied-arch bridge would have the lowest O&M cost, but there is little difference from a whole-life cost perspective when compared to a cable-stayed, cantilever or suspension bridge.

5.5.4.3 Optimism Bias

There is a demonstrated, systematic tendency for project appraisers to be overly optimistic – this is known as Optimism Bias (OB), where costs are often under-estimated and benefits over-estimated. In order to account for this in appraisal, the H.M. Treasury Green Book, and in this case the STAG Technical Database, provide a set of factors by which costs should be scaled-up at different stages of the business case.

Table 13.4 of the STAG Technical Database recommends the application of 66% OB at Strategic Business Case (SBC) stage, which is actually one step on from where this study is at present. In all projects, and in line with the guidance, the initial optimism bias should not be 'locked in' and, as the design and cost estimates mature, optimism bias is likely to reduce, reflecting a better understanding of these parameters – this incremental reductions in OB approach is highlighted in the Technical Database.

The table below highlights the low and high ranges for the options based on the 66% optimism bias.

Option	Indicative Capital Cost		Capital Cost + OB	
	Low	High	Low	High
A - Cable Stayed Bridge	£35m	£45m	*£58m*	*£75m*
B - Suspension Bridge	£37m	£47m	*£61m*	*£78m*
C - Tied-arch Bridge	£30m	£40m	*£50m*	*£66m*
D - Vertical Lift Bridge	£25m	£30m	*£42m*	*£50m*
E - Cantilever Bridge	£40m	£45m	*£66m*	*£75m*
F – Truss Bridge	£35m	£45m	*£58m*	*£75m*
G - Tunnel	£40m	£65m	*£66m*	*£108m*

Table 5 4: Risk Adjusted Capital Cost

Key Point:

Given the broad costs presented here, the cost differentials between the bridge options are not overly significant within each low and high band. The tunnel is notably more costly in terms of cost.

5.6 Road Connections

5.6.1 Connecting Road

The final component of the option development process is establishing the requirement in terms of connecting road infrastructure associated with each route corridor and alignment.

Again these costs have been calculated based on providing an air draught of 32m. If an increased air draught was required then these costs would also increase to mitigate against significant increases in inclines of the bridge deck in the case of bridge options.

5.6.1.1 Route Corridor 3: Alignment A

As previously established in the route corridor section, this alignment involves a south-west sweeping curvature of the road from the structure onto the A861. On this western landing, the western approach road would measure approximately 605 metres in length, with the eastern approach measuring approximately 265 metres. To facilitate this alignment of the road network, there would need to a volumetric cut of approximately 114,000m³ and a volumetric fill of 115,000m³.

The costs associated with these works can vary widely under two scenarios, with and without the need for rock excavation. The presence of rock will significantly increase the costs associated with earthworks. From geological data available, it is currently assumed that in both locations, rock is not at shallow depth and that the landscape mainly consists of glacial deposits. To complete initial due diligence, however, the table below provides estimates for the road works involved as part of this alignment for any structure.

Option	Indicative Capital Cost	
	No Rock	Rock
Eastern Approach	£851,000	£851,000
Western Approach	£2,758,000	£12,124,000
Total	**£3,610,000**	**£12,975,000**

Table 5 5: RC3: Alignment A – Indicative Capital Cost of Connecting Roads

As can seen from the table above, there are significant costs differences between a 'with' and 'without' rock scenario. If the project proceeds further, this issue will need to be explored further to establish the actual geology of the area. Site investigation works will be required to determine ground conditions and inform design development.

5.6.1.2 Route Corridor 3: Alignment B

As previously established in the route corridor section, this alignment involves a north-east sweeping curvature of the road from the structure onto the A861. On the western landing the western approach road would measure approximately 257 metres in length, with the eastern approach measuring approximately 265 metres. To facilitate this alignment of the road network, there would need to a volumetric cut of 14,700m^3 and a volumetric fill of 10,700m^3. As with the above alignment, the costs are provided under a without and with rock scenario.

As can seen from the above table, the differential between the 'with' and 'without' rock costs is much less in this case, with the overall cost being lower than Alignment 1. This is due to the significantly reduced earthworks required to facilitate this alignment into the road network. However, the alignment is of a lesser standard than Alignment 1 and careful consideration of the implications of the required 'Departures from Standards' would be necessary before progressing with this alignment.

Option	Indicative Capital Cost	
	No Rock	**Rock**
Eastern Approach	£852,000	£852,000
Western Approach	£974,000	£2,784,000
Total	**£1,826,000**	**£3,636,000**

Table 5 6: RC3: Alignment B – Indicative Capital Cost of Connecting Roads

Key Point:

The cost of the connecting road infrastructure represents only a small proportion of the total cost of the bridge structure. Alignment B is considerably less expensive than Alignment A, although it would require approval for 'Departure from Standards' to 8%.

The cost of connecting road infrastructure varies depending on whether there is a requirement to remove rock or otherwise. This is particularly significant with Alignment A, where the presence of rock would increase the cost of providing connecting roads more than threefold.

5.6.1.3 Route Corridor 5: Tunnel Alignment

The costs for the tunnel alignment only consider the approach roads to each portal, with the road surface within the tunnel contained within the overall indicative cost of the structure.

In terms of the tunnel approach roads, the eastern approach would measure approximately 192 metres, whilst the western approach would measure 84 metres. To facilitate the approach roads, there would need to be a volumetric cut of approximately 36,000m^3. The table below sets out the costs associated with the approach roads only under both a without and with rock scenario.

Option	Indicative Capital Cost	
	No Rock	**Rock**
Eastern Approach	£2,735,000	£7,160,000
Western Approach	£533,000	£1,174,000
Total	**£3,268,000**	**£8,334,000**

Table 5 7: RC5: Tunnel Alignment – Indicative Capital Cost of Connecting Roads

Key Point:

Whilst the cost of the tunnel approach roads are broadly similar to RC3: Alignment A, the cost per metre is significantly higher as this option only requires cut and the removal of soils, whereas the bridge options involves cut and fill and this implies cost savings.

5.6.1.4 Roadside Works Summary

The costs outlined above provide an indicative summary cost for each of the alignments for RC3 and for the single alignment within RC5. As stated, these costs are indicative and would need to be refined at a later stage of the project once more detailed design information is available, and in particular the presence to rock or otherwise.

These costs would need to be included in addition to the previously established structural costs to provide an overall scheme cost of a fixed link across the Narrows, as illustrated in the table below using Alignment A and no rock as an example.

Option	Indicative Capital Cost		Ind Cap Cost (Road, No Rock)	Capital Cost + OB	
	Low	**High**	**Alignment A**	**Low**	**High**
A - Cable Stayed Bridge	£35m	£45m	**£3.6m**	*£64m*	*£81m*
B - Suspension Bridge	£37m	£47m	**£3.6m**	*£67m*	*£84m*
C - Tied-arch Bridge	£30m	£40m	**£3.6m**	*£56m*	*£72m*
D - Vertical Lift Bridge	£25m	£30m	**£3.6m**	*£47m*	*£56m*
E - Cantilever Bridge	£40m	£45m	**£3.6m**	*£72m*	*£81m*
F – Truss Bridge	£35m	£45m	**£3.6m**	*£64m*	*£81m*
G - Tunnel	£40m	£65m	**£3.2m**	*£72m*	*£113m*

Table 5 8: Indicative Capital Cost of Fixed links plus Connecting Roads

5.6.2 Road Junctions

Based on initial analysis of the ferry carryings and traffic flows on both the A82 and A861, a variety of junctions were considered for connecting any fixed link into the existing road network. At this stage, the recently measured A82 two-way AADT flow of 11,000 (September, 2017, Transport Scotland), remains well within the thresholds of a priority junction, based on the values in Figure 2.3.1 of DMRB CD 123 Geometric 'Design of at-grade priority and signal controlled junctions', and as such negates the need to consider a roundabout or signalised junction. Based on current statistics for the ferry, AADT for traffic crossing the Narrows is 750. However, it can reasonably be anticipated that a new fixed link will generate additional traffic, as has been demonstrated by the case study analysis in Chapter 2. However, these are not, at this stage, expected to deliver an overall step change in road based demand to such a level that it warrants the current investigation of a junction more complex than a priority arrangement.

The known traffic flows based on A82 traffic counts and ferry vehicle counts indicate that a 'ghost island' arrangement would be required at the connection point onto the A82. From site observations. there appears insufficient space within the existing highway boundary to implement a ghost island arrangement. Third party land would therefore be required to facilitate the construction of such a junction. This would provide right turners from the A82 onto the bridge adequate space to complete the manoeuvre without causing delay for straight on traffic.

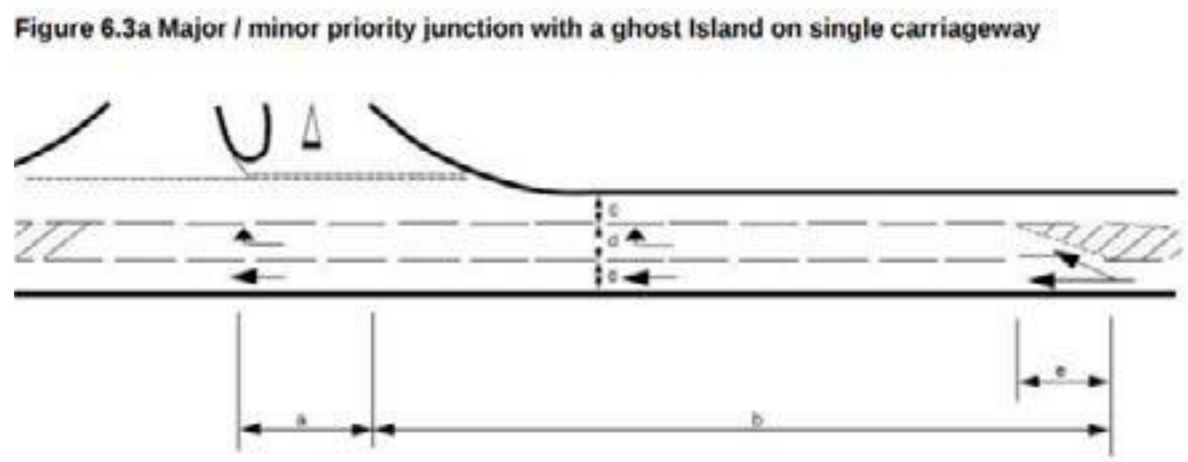


Figure 28: Ghost Island, Source; DMRB CD123 Geometric Design of at-grade priority & signal controlled junctions Rev1

As the flows on the Ardgour side will be far lower, it is anticipated that a simple priority junction would be sufficient at the connection point with the existing road network. However, further investigation and design development would be required to consider whether there was merit in switching the priority to the new road at the connection points and placing the give-way on the existing road. Detailed traffic modelling would be required to determine if the dominant flow will be on the new section of road towards the fixed link in future and, if so, it may be beneficial to switch the priorities to improve traffic flow. A junction assessment can be carried out at the design

5.6.3 Indicative Option Feasibility – RC3 Cable Stayed Bridge, RC5 Tunnel

Based on the analysis above and taking into account all of the individual factors influencing the potential construction of a fixed link spanning the Corran Narrows, computerised modelling was undertaken. The rationale behind this exercise was to determine the actual feasibility of one of these fixed link structures and provide a visualisation of how this structure would look in the Corran Narrows environment. As such, an exercise was undertaken to model RC3, Alignment A, Cable Stayed Bridge as an illustrative example, in addition to entry/ exit portals of a potential tunnel for RC5.

Detailed drawings were created in CAD, before the measurements and geometries were inserted into 'InfraWorks software' to create 3D modelling of the structure to determine whether these measurements are feasible. The images below provide an overview of this exercise and provide the context of a fixed link in the Corran Narrows environment.

Fly through videos of both options have also been created and have been made available to all the funding partners.

stage to determine an adequate solution.


Figure 29: RC3, Alignment A, Cable Stayed Bridge


Figure 30: RC3, Alignment A, Cable Stayed Bridge, Road Connectivity


Figure 31: RC5, Tunnel, Clovullin Portal


Figure 32: RC5, Tunnel, Inchree Portal

MV Corran,
Corran Narrows

6.0 High Level Economic Appraisal of a Fixed Link

This chapter firstly sets out an initial economic appraisal of a Corran Narrows fixed link, considering the potential scale of the quantified TEE (Transport Economic Efficiency) benefits in the context of the costs of fixed link and ferry options across the Corran Narrows.

The second part of this chapter sets out the potential type and scale of wider societal benefits and impacts which may emerge as a result of a fixed link being constructed across the Corran Narrows, illustrated in a logic map approach.

6.1 Transport Economic Efficiency

6.1.1 Appraisal Conventions

This section of the report establishes the TEE benefits of a fixed link spanning the Corran Narrows. TEE analysis captures the benefit or otherwise of a transport scheme by comparing its costs & benefits and deriving a Benefit Cost Ration (BCR). Costs include all capital, operating and maintenance costs of the project. Benefits on the other hand are generally determined through an analysis of the impact of a scheme on transport users, and are thus predominantly, although not exclusively, social welfare, rather than financial benefits. Benefits include:

- changes in the monetary costs of travel, in this case the replacement of a charged ferry with a toll-free bridge;
- journey time savings;
- improvements in journey time reliability; and
- improvements in journey quality.

costs tend to be accrued up-front, with the benefits emerging over a much longer time period. To account for this, an appraisal typically works over a 60-year time horizon to provide an equitable comparison of costs and benefits. This recognises that a cost or benefit accrued a long-way in the future is 'worth' less than a cost or benefit in the present day (this is known as 'rate of time preference'). To account for this, appraisal uses the convention of discounting, which equates future benefits and costs to a single point in time (known as present value), thus providing a consistent and equitable comparison.

This chapter:

- Sets out the scenarios under consideration;
- Estimates the appraisal period costs for all options, and the range of cost increments in moving from a ferry operation to a fixed line;
- Estimates the benefits of a fixed link relative to a ferry, based on a range of implied travel time savings; and
- Compares the Present Value of Benefits (PVB) and the Present Value of Costs (PVC) of the range of fixed link options relative to the range of ferry options to determine whether a fixed link would be likely to generate a benefit cost ratio (BCR, i.e. PVB/PVC) of greater than 1.

6.1.1.1 Wider Economic and Social Benefits

As mentioned previously, it is difficult to determine the wider

economic benefits of these types of schemes in such a sparse rural context. While the economic appraisal in the majority focuses on a 'BCR' figure, it is important to consider the importance of connectivity in the region and the benefits it brings to society. The recently published National Transport Strategy 2 (NTS2) outlines the importance of taking cognisance of social inclusion and reducing the levels of inequality and deprivation. The current STAG methodology does not provide a mechanism for capturing these aspects within the economic appraisal, however, this may change in the future with a potential 'refresh' of the STAG methodology currently being considered.

As such it is important to consider the following challenges and policies within NTS2, and their application within the context of the communities that depend on the Corran Narrows crossing, as for some it is a lifeline service.

NTS2 The Challenges facing society

Poverty and child poverty	Social isolation	Gender inequalities
Disabled people	Scotland's regional differences	Global climate emergency
Decline in bus use	Productivity	Fair work and skilled workforce
Tourism	Digital and energy	Spatial planning
Health and active travel	Information & integration	Resilience
Ageing population	The changing transport needs of young people	Reliability and demand management
Technological advances	Air quality	Safety and security
Trade and connectivity	Freight	

Table 6 1: NTS2 Challenges, Transport Scotland 2020

NTS2 Vision

We will have a sustainable, inclusive and accessible transport system, helping deliver a healthier, fairer and more prosperous Scotland for communities, businesses and visitors.

PRIORITIES	OUTCOMES
	Will provide fair access to services we need
Promotes equality	wellbeing
Takes climate action	
Helps our economy prosper	
Improves our health and	

NTS2 Policy

Policy	Enabler
A. Continue to improve the reliability, safety and resilience of our transport system	Increase safety of the transport system and meet casualty reduction targets **Increase resilience of Scotland's transport system from disruption and promote a culture of shared responsibility** Implement measures that will improve perceived and actual security of Scotland's transport system Increase the use of asset management across the transport system
B. Embed the implications for transport in spatial planning and land use decision making	Ensure greater integration between transport, spatial planning, and how land is used Ensure that transport assets and services adopt the Place Principle Ensure the transport system is embedded in regional decision making
C. Integrate policies and infrastructure investment across the transport, energy and digital system	Ensure that local, national and regional policies offer an integrated approach across all aspects of infrastructure investment including the transport, digital, and energy system
D. Provide a transport system which enables businesses to be competitive domestically, within the UK and internationally	Optimise accessibility and connectivity within business and business-consumer markets by all modes of transport Ensure gateways to and from domestic and international markets are resilient and integrated into the wider transport networks to encourage people to live, study, visit and invest in Scotland Support measures to improve sustainable surface access to Scotland's airports and sea ports
E. Provide a high-quality transport system that integrates Scotland and recognises our different geographic needs	Ensure that infrastructure hubs and links form an accessible integrated system that improves the end-to-end journey for people and freight **Minimise the connectivity and cost disadvantages faced by island communities and those in remote and rural areas** **Safeguard the provision of lifeline transport services and connections**
F. Improve the quality and availability of information to enable better transport choices	Support improvements and innovations that enable all to make informed travel choices Support seamless journeys providing the necessary infrastructure, information and interchange facilities to connect all modes of transport Ensure that appropriate real-time information is provided to allow all transport users to respond to extreme weather and incidents
G. Embrace transport innovation that positively impacts on our society, environment and economy	Support Scotland to become a market leader in the development and early adoption of beneficial transport innovations
H. Improve and enable the efficient movement of people and goods on our transport system	**Ensure the Scottish transport system efficiently manages needs of people and freight** Promote the use of space-efficient transport
I. Provide a transport system that is equally accessible for all	Ensure transport in Scotland is accessible for all Identify and remove barriers to public transport connectivity and accessibility within Scotland Reduce the negative impacts which transport has on the safety, health and wellbeing of people Continue to support the implementation of the recommendations from, and the development of, Scotland's Accessible Travel Framework
J. Improve access to healthcare, employment, education and training opportunities to generate inclusive sustainable economic growth	**Ensure sustainable labour market accessibility to employment locations** **Ensure sustainable access to education and training facilities** **Improve sustainable access to healthcare facilities for staff, patients and visitors**

Will be easy to use for all Will be affordable for all Will adapt to the effects of climate change Will help deliver our net-zero target Will promote greener, cleaner choices Will get us where we need to get to

Will be reliable, efficient and high quality Will use beneficial innovation

Will be safe and secure for all

Will enable us to make healthy travel choices

Will help make our communities great places to live

K. Support the transport industry in meeting current and future employment and skills needs	To meet the changing employment and skills demands of the transport industry and upskill workers
	Support initiatives that promote the attraction and retention of an appropriately skilled workforce across the transport sector
L. Provide a transport system which promotes and facilitates travel choices which help to improve people's health and wellbeing	Promote and facilitate active travel choices across mainland Scotland and islands
	Integrate active travel options with public transport services
	Support transport's role in improving people's health and wellbeing
M. Reduce the transport sector's emissions to support our national objectives on air quality and climate change	Facilitate a shift to more sustainable modes of transport for people and commercial transport
	Reduce emissions generated by the transport system to improve air quality
	Reduce emissions generated by the transport system to mitigate climate change
	Support management of demand to encourage more sustainable transport choices
N. Plan our transport system to cope with the effects of climate change	Increase resilience of Scotland's transport system to climate change related disruption
	Ensure the transport system adapts to the projected climate change impacts

Table 6 2: NTS2 Vision, Transport Scotland 2020

Table 6 3: NTS2 Policy, Transport Scotland 2020

Items in Orange are especially applicable to the Corran Narrows.

6.1.1.2 Assumptions

Recognising the high degree of uncertainty around many of the key parameters at this stage, the analysis set out in this chapter is underpinned by a range of assumptions. In the interests of brevity, only the key assumptions are set out in the text which follows, whilst all the model assumptions and parameters are included in Appendix A. The analysis is based on current WebTAG parameters and best practice.

6.1.2 Scenarios

Two main scenarios will be tested in the proceeding analysis:

- Reference Case: In the Reference case, it is assumed that:
- No fixed link is constructed, with the ferry service providing

  the long-term solution for the crossing of the Narrows.
- New ferries and associated infrastructure are provided on life expiry of current assets. There are a number of variants of the Reference Case and these are set out in more detail below .
- Do-Something: In the Do-Something, it is assumed that:
- A new fixed link will be provided, opening in 2027. This is a generic fixed link between Nether Lochaber and Ardgour as the structural form and alignment would not significantly impact on the scale of the benefits.
- Within the modelling, as a core assumption, it is assumed that there would be a 50% uplift in trips associated with the introduction of a fixed link, which will account for people in the area making more trips and an increase in tourist-based trips. Sensitivity tests around this figure are also considered below.
- A Do-Nothing scenario was originally considered. This scenario assumed that the current ferry service will continue until the existing vessel(s) fail and the service is discontinued. Whereby there would be no crossing provided across the Corran Narrows. This scenario was then discounted on the basis of:
- The provision of no crossing is not a realistic option as it goes against all national policy, especially those particular points highlighted in above in section 6.1.1.1.
- Both the Reference Case and Do-Something will display significant benefits against a no option scenario, due to the importance of a link for the peninsular communities.

A bespoke, WebTAG-based economic benefits spreadsheet model was developed to determine the comparative benefits associated with a fixed link (Do-Something) in the context of the Do-Nothing and Reference Case.

6.1.3 Scheme Costs

6.1.3.2 Reference Case Costs

Ferry based option costs have been considered in line with the work undertaken as part of the Corran Ferry STAG Appraisal, which identified two core vessel options and variations of these, which have been integrated into this study to help inform the TEE analysis. There were four future vessel scenarios emerging from the STAG – these are summarised in the table below:

Ferry STAG Ref	Ferry Scenario	Main Vessel	Relief Vessel	Infrastructure
1a	Quarter Point Ferry Low	Diesel Quarter-point vessel	Diesel Quarter -point vessel	New overnight berth
1a	Quarter Point Ferry High	Hybrid Quarter -point vessel	Diesel Quarter -point vessel	New overnight berth
2d	Straight Through Ferry Low	Diesel straight through vessel	Chartered	New overnight berth and vessel aligning structures
2d	Straight Through Ferry High	Hybrid straight through vessel	Chartered	New overnight berth and vessel aligning structures

Table 6 4: Reference Case Scenarios

In summary:

- Scenario 1a.L involves retaining the current quarter point berthing arrangement using a conventional diesel vessel. It would involve the construction of a new overnight berth to improve the ship-shore interface for the crew.
- Scenario 1a.H is broadly the same as Scenario 1a.L except that the primary vessel would be a hybrid-electric similar to the CMAL vessel MV Lochinvar. This would provide a long-term reduction in emissions but would increase up-front capital costs.
- Scenario 2a.L would involve converting the route to operate with conventional 'straight through' diesel vessels. An additional £9m of infrastructure spending would be required to provide aligning structures at both terminals for these vessels, but it is assumed that this would negate the need to maintain a relief vessel, which could be more readily chartered from elsewhere.
- Scenario 2a.H would be as per Scenario 2a.L except that that the primary vessel would be a hybrid-electric.

The specifics of each scenario are now set out below in terms of the extent and timing of investment.

It should be noted that the analysis assumes that ferry operating costs are broadly covered by fares revenue.

Scenario 1a.L: Quarter Point Ferry Low

Option	Main Vessel	Relief Vessel
2027 – 2030	MV Corran	MV Maid of Glencoul
2031 – 2040	New Vessel 1 (Diesel £8m)	MV Corran
2041 – 2060	New Vessel 1 continues	New Vessel 2 (Diesel £8m)
2061 - 2083	New Vessel 2 continues	New Vessel 3 (Diesel £8m)
	Costs in 2019 prices are: £14m for Infrastructure works (overnight berth) £24m for three vessels at £8m (note ferries are not subject to optimism bias)	

Table 6 5: Scenario 1a.L – Quarter Point Ferry Low

Scenario 1a.H: Quarter Point Ferry High

Option	Main Vessel	Relief Vessel
2027 – 2030	MV Corran	MV Maid of Glencoul
2031 – 2040	New Vessel 1 (Hybrid £17m)	MV Corran
2041 – 2060	New Vessel 1 continues	New Vessel 2 (Conventional £8m)
2061 - 2083	New Vessel 3 (Hybrid £17m)	New Vessel 2 continues
	Costs in 2019 prices are: £14m for Infrastructure works (overnight berth) £34m for two hybrid vessels at £17m (ferries are not subject to optimism bias) £8m for one conventional relief vessel	

Table 6 6: Scenario 1a.H – Quarter Point Ferry High

Scenario 2d.L: Straight Through Ferry Low

Option	Main Vessel	Relief Vessel
2027 - 2053	New Vessel 1 (Conventional £8m)	From CMAL Fleet (assumed @ £100k p.a.)
2054 - 2083	New Vessel 2 (Conventional £8m)	From CMAL Fleet (assumed @ £100k p.a.)
	Costs in 2019 prices are: £23m for Infrastructure works (overnight berth and aligning structures at slipways) £16m for two conventional vessels at £8m £100k p.a. for 60 years for lease of support vessel	

Table 6 7: Scenario 2a.L – Straight Through Ferry Low

Scenario 2d.H: Straight Through Ferry High

Option	Main Vessel	Relief Vessel
2027 - 2053	New Vessel 1 (Hybrid £17m)	From CMAL Fleet (assumed @ £100k p.a.)
2054 - 2083	New Vessel 2 (Hybrid £17m)	From CMAL Fleet (assumed @ £100k p.a.)
	Costs in 2019 prices are: £23m for Infrastructure works (overnight berth and aligning structures at slipways) £34m for two Hybrid vessels at £17m £100k p.a. for 60 years for lease of support vessel	

Table 6 8: Scenario 2a.H – Straight Through Ferry High

In each case, the above timeline of costs has been input to the Economics Benefits model, which calculates the 60-year discounted appraisal PVC associated with these four ferry options within the Reference Case scenario as:

Option	Specification	60 Year PVC
1a.L	Quarter Point Ferry Low	£15.0m
1a.H	Quarter Point Ferry High	£20.1m
2d.L	Straight Through Ferry Low	£19.7m
2d.H	Straight Through Ferry High	£26.1m

Table 6 9: 60-Year PVC of Future Ferry Scenarios

6.1.3.3 Do-Something Costs

Due to the number of options and ranges of costs associated with each of the fixed link options, a proportionate approach to cost estimation was undertaken. This has taken the form of considering one option type for each of the three identified route corridors, RC1, RC3 and RC5. A low and high cost for an option within each route corridor is assumed, providing an overall total of six Do-Something (fixed link).

As there is only one feasible option for RC1, a low and high cost for a vertical lifting bridge was created, as with RC5, the tunnel option. For RC3, there are several feasible options available. As such, the low and high costs of each of the options was plotted and then simplified to provide a proxy low and high cost representation of an option for this route corridor. Based on the range of costs quoted for a cable-stayed bridge and that the range between the lowest and highest costs provides an envelope encapsulating the costs for each of the other structures, the costs associated with this option were used to represent the third set of options for the Do-Something.

The result of this process was the identification of six fixed link options to represent the Do-Something based on the costs outlined in Chapter 4. The Do-Something options all account for maintenance and any operating costs in addition to capital costs. The 60-year discounted PVCs for each of the six Do-Something scenario is shown in the table below:

Option	Specification	60 Year PVC
1	Cable-Stayed Bridge Low	£36.3m
2	Cable-Stayed Bridge High	£51.4m
3	Vertical Lift Bridge Low	£26.3m
4	Vertical Lift Bridge High	£31.2m
5	Tunnel Low	£43.1m
6	Tunnel High	£72.2m

Table 6 10: Fixed Link Scenarios – 60-Year PVC

As expected, the tunnel options provide the highest long-term costs due to the complexities associated with this type of structure.

6.1.3.4 Do-Something vs Reference Case

Here, the key issue is the relative cost of the Do Something compared to the Reference Case. Given the uncertainties surrounding the main appraisal parameters at this early feasibility stage, we developed **72 different scenarios (4*6*3)** to represent the potential costs and benefits of a fixed link compared to an ongoing ferry operation, comprising:

- **4 Ferry Cost Scenarios:**
  - Quarter Point Ferry Low Cost
  - Quarter Point Ferry High Cost
  - Straight Through Ferry Low Cost
  - Straight Through Ferry High Cost
- **6 Fixed Link Cost Scenarios:**
  - Cable Bridge Low Cost
  - Cable Bridge High Cost
  - Vertical Lift Bridge Low Cost
  - Vertical Bridge High Cost
  - Tunnel Low Cost
  - Tunnel High Cost
- **3 Benefits Scenarios:**
  - 5 Minute Wait for Ferry
  - 10 Minute Wait for Ferry
  - 15 Minute Wait Ferry

As mentioned previously, the four ferry options were derived from the preferred options identified through the Corran Ferry STAG Part 2 Appraisal and encompass the variety of costs represented by these options.

The six fixed link scenarios were dervived from the range of costs associated with the options A-G described above. These three core fixed link options provide an envelope of costs comprising the seven options (A-G) to provided a representative cost range.

For appraisals purposes, we have established 24 PVCs reflecting the cost uncertainty at this stage, i.e. there is a PVC for each combination of costs as shown in the table opposite (in £m).

		PVCs (60 Year Appraisal Period) (£, Millions)			
		1a.L	1a.H	2d.L	2d.H
ID	Link Option	Quarter Point Ferry Low	Quarter Point Ferry High	Straight Through Ferry Low	Straight Through Ferry High
1	Cable Stayed Bridge Low	£18.5m	£13.5m	£18.6m	£16.9m
2	Cable Stayed Bridge High	£32.2m	£27.1m	£32.3m	£30.6m
3	Vertical Lift Bridge Low	£9.5m	£4.5m	£9.6m	£7.9m
4	Vertical Lift Bridge High	£13.9m	£8.9m	£14.0m	£12.4m
5	Tunnel Low	£24.6m	£19.5m	£24.8m	£23.0m
6	Tunnel High	£50.9m	£45.9m	£51.0m	£49.4m

Table 6 11: Do Something v Reference Case PVC

The key points of note from the above table are as follows:

- In all cases, the fixed link options are more expensive than the ferry options.
- Under the lower-cost Reference Case Scenarios, all Do-Something Scenarios prove to be more expensive, ranging between £11m to £57m above the Reference Case;
- When compared against the higher cost Reference Case Scenarios, the Do-Something Scenarios (with exception of the 'Tunnel High') become more competitive.
- Comparing the Do-Something Scenarios against the mid-range Reference Case Scenarios, there are less significant cost differences, with the cost envelope provided using the low cable stayed bridge option as a proxy showing differences of approximately 45% above Reference Case Scenarios 1b and 2a.
- Do-Something Scenario 6, 'Tunnel High' cost, is significantly costlier against all Reference Case Scenarios.

Key Point:

In all cases, the construction of a fixed link is more expensive than the costs associated with a continuing with a ferry service, particularly with respect to a tunnel. However, a fixed link will provide a range of benefits over and above a continued ferry operation. These are explored in the next section.

6.1.4 Benefits of a Fixed Link

6.1.4.1 Benefits Model

Within this TEE[40] analysis, the transport benefits that comprise the PVB have been defined as consisting of:

- Vehicle Operating Costs (VoC): which include changes in operating costs incurred by a user, such as fuel, repairs, maintenance etc.
- Travel Time Benefits: including any journey time benefits associated with a scheme and the removal of ferry wait times; and
- User Charges: Any changes in charges incurred by users, such as ferry based vehicle fares.

VoC in the context of this study includes any changes to operating a vehicle under any of the Do-Nothing, Reference Case and Do-Something Scenarios. This includes increased distances travelled in the absence of a crossing with the Do-Nothing option, including both private vehicles and buses.

Travel time benefits within this analysis include changes in travel times associated with making a longer trip in the Do-Nothing option, the removal of ferry waiting times in the Do-Something options (with exception of the Vertical Lifting Bridge option) and the reduction in crossing times. Travel times have been calculated using Transport Scotland's licence to use INRIX data and the extraction of journey time information along the A861 from the current Ardgour ferry slipway in relation to the Do-Nothing and travel times along the A82 within both the Reference Case and Do-Something options.

Journey purpose is important when calculating travel time benefits, as there are different perceived costs associated with journey types – for example, a commute journey has a high value of time than a leisure journey, and therefore a minute saved for a commuter is 'worth' more than for a leisure traveller. As such variables from WebTAG for travel during work time, commute, other and by public transport have been included in the analysis and are summarised Appendix A.

User Charges have been qualified as changes associated with:

- the removal of ferry fares in both the Do-Nothing and Do-Something options;
- changes to bus fares associated with longer distance journeys in the Do-Nothing option; and
- changes associated with the removal of the ferry crossing element of the bus ticket fare in the Do-Something options.

The calculation of PVB within this study is categorised by three ferry-based wait time scenarios, defined as a 5-minute wait, 10-minute wait and 15-minute wait.

40 | https://www.transport.gov.scot/publication/stag-technical-database/section-9/

6.1.4.2 Do-Something vs Reference Case

The benefits of a Do-Something fixed link option compared to a Reference Case involving the continuation of the ferry service, are again significant although to a lesser extent than in the Do-nothing scenario. The table below provides a summary of the expected benefits under this scenario.

Ferry Wait Scenario	Travel Time	User Charges	VoC	PVB
5 Minute Wait	£26.7m	£3.4m	-£4.3m	£25.8m
10 Minute Wait	£43.8m	£3.4m	-£4.3m	£42.9m
15 Minute Wait	£60.9m	£3.4m	-£4.3m	£60.0m

Table 6 12: Do-Something vs Reference Case PVB

6.1.5 Comparison of PVCs and PVBs

6.1.5.1 Do-Something vs Reference Case

Section 6.1.3.5 set out that there were 24 different Do Something versus Reference Case PVCs reflecting the range options range of costs considered here. Combining these with the three benefits scenarios developed in Section 6.1.4.1 means there are 72 PVC/PVB combinations and hence BCRs under consideration here. The values associated with each of the 72 modelled scenarios is listed in the table below.

The figure below however, summarises these results by plotting the PVB on the vertical axis and the PVC on the horizontal axis for each of the 72 combinations. Any point above the diagonal implies a BCR of greater than 1.

Figure 33: Do-Something Scenarios – PVB v PVC

Description	5 Min Wait - Scenarios	10 Min Wait - Scenarios	15 Min Wait - Scenarios
Ferry Type: Quarter point & Low **Fixed link type:** Cable tied bridge with 2 towers & Low	1	25	49
Ferry Type: Quarter point & Low **Fixed link type:** Cable tied bridge with 2 towers & High	2	26	50
Ferry Type: Quarter point & Low **Fixed link type:** Opening bridge & Low	3	27	51
Ferry Type: Quarter point & Low **Fixed link type:** Opening bridge & High	4	28	52
Ferry Type: Quarter point & Low **Fixed link type:** Tunnel & Low	5	29	53
Ferry Type: Quarter point & Low **Fixed link type:** Tunnel & High	6	30	54
Ferry Type: Quarter point & High **Fixed link type:** Cable tied bridge with 2 towers & Low	7	31	55
Ferry Type: Quarter point & High **Fixed link type:** Cable tied bridge with 2 towers & High	8	32	56
Ferry Type: Quarter point & High **Fixed link type:** Opening bridge & Low	9	33	57
Ferry Type: Quarter point & High **Fixed link type:** Opening bridge & High	10	34	58
Ferry Type: Quarter point & High **Fixed link type:** Tunnel & Low	11	35	59
Ferry Type: Quarter point & High **Fixed link type:** Tunnel & High	12	36	60
Ferry Type: Straight through & Low **Fixed link type:** Cable tied bridge with 2 towers & Low	13	37	61
Ferry Type: Straight through & Low **Fixed link type:** Cable tied bridge with 2 towers & High	14	38	62
Ferry Type: Straight through & Low **Fixed link type:** Opening bridge & Low	15	39	63
Ferry Type: Straight through & Low **Fixed link type:** Opening bridge & High	16	40	64
Ferry Type: Straight through & Low **Fixed link type:** Tunnel & Low	17	41	65
Ferry Type: Straight through & Low **Fixed link type:** Tunnel & High	18	42	66
Ferry Type: Straight through & High **Fixed link type:** Cable tied bridge with 2 towers & Low	19	43	67
Ferry Type: Straight through & High **Fixed link type:** Cable tied bridge with 2 towers & High	20	44	68
Ferry Type: Straight through & High **Fixed link type:** Opening bridge & Low	21	45	69
Ferry Type: Straight through & High **Fixed link type:** Opening bridge & High	22	46	70
Ferry Type: Straight through & High **Fixed link type:** Tunnel & Low	23	47	71
Ferry Type: Straight through & High **Fixed link type:** Tunnel & High	24	48	72

Table 6 13: Do-Something vs Reference Case PVB Scenario Descriptions

As can be seen in the chart above, the PVB exceeds the PVC in most cases, i.e. **the benefits of the fixed link outweigh the additional costs of a fixed link over a replacement ferry**. Overall 83% (60 scenarios) provide a BCR greater than 1.

There is a very clear correlation of the benefits and costs under each of the three ferry wait time overarching scenarios. Of those scenarios that fall below the line, where the costs are greater than the benefits, **seven** do so under the 5-minute wait scenario and **four** do so under the 10-minute wait scenario. These individual scenarios, in the main, involve the **tunnel high cost option** and it is these high costs associated with this fixed link type that increase the costs and outweigh the long-term benefits.

6.1.6 Sensitivities

As noted above, we have assumed that traffic volumes over the Narrows would increase by 50% as a result of a fixed link.

These trips derive benefits using the 'rule of a half' convention. To understand the importance of this assumption, two sensitivity tests were also modelled, varying the levels of induced traffic as a result of any Do-Something option.

6.1.6.1 10% Induced Traffic

Reducing the induced traffic to 10% within the Do-Something reduces the PVB associated with any of these options to the following:

- Do-Something vs Reference Case: Under the 5-minute wait scenario the PVB of the Do-Something options is £24.0m (compared to £26.1m with 50% induced traffic). These benefits consist of travel time benefits of £23.1m, user charge benefits of £1.9m (associated with the removal of ferry fares), while there would be VoC disbenefits of -£1.0m.

6.1.6.2 200% Induced Traffic

Increasing the induced traffic to 200% within the Do-Something increases the PVB associated with any of these options to the following:

- Do-Something vs Reference Case: Under the 5-minute wait scenario the PVB of the Do-Something options is £34.0m (compared to £26.1m with 50% induced traffic). These benefits consist of travel time benefits of £44.0m, user charge benefits of £8.5m (associated with the removal of ferry fares), while there would be VoC disbenefits of -£18.5m.

These figures suggest that while important the level of induced traffic is of less significance in the appraisal than the actual quantum of time saving.

6.1.7 TEE Summary

The analysis undertaken here sought to explore the quantum of costs and benefits of providing a fixed link at Corran, primarily compared the on cost of continuing to operate a ferry service. Given the level of uncertainty surrounding many of the key appraisal parameters, we have developed 72 scenarios to reflect this range of potential outcomes. In 83% of cases, a BCR of greater than 1 is derived, with this value being up to 6 under some scenarios. This suggests that the scheme may be feasible from an economic perspective.

If taking this appraisal forward, we would seek to reduce some of these uncertainties by more detailed cost analysis and deriving greater certainty with respect to time savings. This latter point could perhaps be achieved through a programme of Journey Time surveys and/or ANPR surveys to establish true 'road to road' travel times.

6.2 Potential Wider Benefits of a Fixed Link

Having established the TEE benefits of a fixed link across the Corran Narrows, this section considers the wider economic and societal impacts of the proposed scheme.

In conventional transport appraisal, the TEE benefits are supplemented by 'wider economic impacts' (WEI), which quantify how the transport improvement impacts on e.g., productivity and the functioning of the labour market. However, as explained in Chapter 2, WEI only tend to emerge in the context of the largest schemes and are likely to be insignificant in the context of the Corran Narrows.

Of greater relevance here is how the construction of a fixed link would impact on the social and economic structure of both the peninsula, Lochaber and Mull. This is best established through the development of an economic narrative, which explores how the proposed scheme could impact on different aspects of the society and economy of the study area. These are as follows:

- Resilience of the wider transport network, especially for events that require this enhanced connection as a diversion rathe than the primary route
- population;
- labour market;
- productivity and business formation;
- personal travel and access to services;
- tourism;
- supply-chain;
- public service provision; and
- quality of life / sense of community.

It should be noted that, as this is a fixed link feasibility study only, the scope did not include primary research or public and stakeholder consultation. The narrative which follows is therefore based on the case study evidence presented in Chapter 2 and some initial consultation undertaken during the Corran Ferry STAG Appraisal work. It is only intended to provide a framework to establish the type of impacts which may emerge from a fixed link. Should the proposal be progressed further, supporting research (potentially including an Economic Impact Assessment) and a full programme of engagement would be required to more fully establish existence and scale of the anticipated benefits.

When considering the potential benefits, it is important to bear in mind that the peninsula is an expansive land mass, connected throughout much of that area by single track roads. Impacts are therefore likely to be across a very large area most strongly felt in Ardgour, Morvern and Sunart, but less so in Ardnamurchan and Moidart.

6.2.1 Logic Map

In order to present the potential benefits of a fixed link in a systematic manner, there is benefit in developing a 'WEI logic map' – this is an effective way of presenting the linkages between the case for the fixed link, its delivery and the potential transport outcomes and societal impacts which it could generate.

The Logic Map tells the story along the lines of that set out diagrammatically in Figure 34 below. The **Strategic Need** sets out the rationale for intervention, with the evidence showing the current issues and problems. If there is investment of X (**Inputs**) this will then generate **Outputs** which result in certain **Outcomes** and then, ultimately, **Impacts**. If the linkages are correct, these impacts should resolve the problems and issues identified under the Strategic Need / current situation.

The key stages of the Logic Map have been defined as follows:

- Strategic Need: The transport problems and opportunities that the proposed fixed link would address and the rationale for proceeding with the intervention.
- Inputs: The proposal being taken forward, which in this case would need to be further developed through an appropriate business case.
- Outputs: The outputs from the process - e.g. a bridge or tunnel, approach roads, maintenance plan etc.
- Outcomes: The change in travel opportunities and behaviours as a result of the fixed link being introduced.
- Impacts: The long-term effects of the intervention in terms of the economy and society of the study area.

Figure 34: Corran Narrows Fixed Link – Logic Map

Strategic Need

- Nether Lochaber – Ardgour busiest single vessel route in Europe
- Capacity constraints on the ferry service at peak times or when MV *Maid of Glencoul* is operating on its own
- Requirement for major capital investment in ferry service
- Human resource challenges associated with the ferry service – front line and back office
- Limitations on the size of commercial vehicles which can access the peninsula when ferry is off or MV *Maid of Glencoul* is operating on its own
- Social & economic development – supporting development of a fragile community

Inputs

- Corran Narrows Fixed Link Feasibility Study
- Development of Outline and Final Business Cases – these would include detailed option development and established funding, procurement and management arrangements
- Placing of contract following procurement process

Outputs

- Bridge or tunnel across / under the Corran Narrows
- Connecting road infrastructure to the A82 and A861
- Management, operation and maintenance contract in place
- Sale or disposal of the MV *Corran* and MV *Maid of Glencoul*

Outcomes

- Additional trips across the Corran Narrows
- 24-hour access between the peninsula and Lochaber (and vice versa)
- Creation of unrestricted large HGV route onto peninsula
- Reduced journey times
- Overall improved journey time reliability
- Improved resilience for the peninsula and, to a lesser extent, the A82
- Supports active travel corridor along west side of Loch Linnhe (although reliance on Camusnagaul Ferry for 'short' connection to Fort William)
- Increased emissions from more trips
- Reduced emissions from not operating ferries

Impacts

- Population retention / growth
- Expanded labour market catchment & job opportunities
- Increased local / regional productivity
- New business formation
- Increased tourism in peninsula
- Improved access to services – health, education, social & leisure opportunities
- Improved supply-chain efficiency
- Efficiencies in service delivery from the perspective of the public sector
- Quality of life benefits

This section is focused on the Impacts section of the logic map, each of which is explored in more detail below.

6.2.2 Population

6.2.2.1 Population Size

The combined population of the peninsular communities is 4,763 (2018, Mid-Year Estimates, NRS), with a further 2,990 residing on Mull. As well as population being low in absolute terms, the area also has one of the lowest population densities in Scotland. It is thus an economically fragile area, where maintaining and sustainably growing the population is an important consideration.

The evidence from the case studies suggests that a fixed link would contribute towards promoting population retention and growth, creating new opportunities to access employment and services in Fort William and beyond and thus making the peninsula a more attractive place to live. Population levels are of course influenced by a myriad of factors but the improvements in connectivity would create new opportunities for those living in or looking to move to the peninsula.

There may be a particular attraction for Lochaber residents seeking to move to a more remote area or take advantage of lower land costs (albeit development on the peninsula will be limited by the structure of land ownership and planning restrictions).

In absolute terms, any increase would be small given that much of the area would be remote from the crossing and the housing stock is in any case limited. However, in deep rural areas, even small increases in population can be essential in ensuring the area has the right mix of skills to meet community needs and to provide the critical mass to maintain e.g. schools, village shops etc.

It should however be noted that a fixed link may encourage increased out-commuting for employment, creating something of a dormitory effect. This in itself is not necessarily a bad thing as it may increase average incomes in an area, but there is also a risk of a centralisation of economic activity, particularly retail, to larger service centres such as Fort William.

6.2.2.2 Population Profile

As is common across rural areas, the population demographic of the peninsula is also relatively unfavourable (40% of the population combined is, under 16 and over 65), weighted as it is towards older demographics. The limited employment opportunities on the peninsula and the requirement for most to move away for further and higher education means that there is often a 'brain drain' of younger people[41]. Whilst some young people may return after they complete further / higher education or when wider personal circumstances permit, it is more common for them not to return, or not to do so until they are reaching retirement age themselves.

A high 'dependency ratio' (the ratio of the economically active resident population to the economically inactive) is generally considered negative for an area. It can lead to a shallow labour market, with paid and voluntary posts unfilled and challenges in terms of both commercial and public service delivery. Again, this is a deep-rooted challenge across rural areas and a fixed link in itself will not act as a panacea. However, by improving connectivity to employment opportunities in Fort William and beyond and the West Highland College (also in Fort William), a fixed link may encourage young people to remain in the area longer (i.e. for education) or indefinitely (i.e. for employment).

In absolute terms, any such impact would likely be relatively small. However, it is again important to bear in mind that in deep rural areas, such marginal changes can actually be critically important as they may be the difference between a business or a bus service, for example, being viable or otherwise.

The flip side of a fixed link is that it may encourage lifestyle in-migration, which is typically dominated by older demographics seeking a rural lifestyle. This is not in itself a problem, and indeed in-migrants are often highly skilled and have an appetite for engaging in community activities / volunteering. However, it can contribute to worsening the demographic imbalance of an area and in some cases (e.g. Arran, Mull and Sleat) lead to a rise in house prices which makes it less affordable for local people to rent or buy.

6.2.3 Labour Market

A fixed connection between Ardgour and Nether Lochaber could fundamentally change the labour market in the peninsula. The potential impacts are explored in more detail below.

6.2.3.1 Corran Ferry Employment

It is important to note that an immediate implication of a fixed link is that the roles of the current ferry crew would be made redundant. The Corran Ferry STAG Appraisal noted that, in 2018, there were 14 crew assigned to the operation of the ferry, of which 12 live on the peninsula.

As well as the direct financial implications for these individuals, the overall loss of this level of income from the peninsular communities would have a knock-on effect on local aggregate demand, and could encourage out migration by redundant crew members and their families (although it should be noted that several crew members are approaching retirement age). This is an issue which THC Highland Council and HIE along with others should seek to mitigate as far as reasonably possible if a fixed link is progressed. It is noted that the Council already has a positive policy for dealing with redeployment opportunities for at risk staff.

There would be a labour cost saving for THC associated with:

- No longer having to pay the costs of ferry staff, although up-front redundancy costs would have to be paid and long-term pension liabilities would remain.
- THC staff associated with management of the ferry service being redeployed to other duties.

6.2.3.2 Commuting

From the perspective of commuting, the Corran Ferry provides one of the best services in Scotland. It offers a long operating day (06:30-21:30), high frequency and low fares when benchmarked against other routes in Scotland. However, there remain two key challenges for current and prospective commuters:

- The service does not readily facilitate access to shift work in Lochaber, or indeed on the peninsula.
- Whilst fares are comparatively low, they are nonetheless another cost which commuters must accrue when travelling to work.

There are therefore several potential benefits associated with a fixed link from the perspective of commuting:

- Existing commuters will receive a financial benefit equal to the cost of fares they would otherwise have paid. This will represent a direct benefit to the individuals in question but could also have a consequential benefit for the peninsular economy if some of this money is reinvested locally.
- New commuting related employment opportunities would emerge as the range of jobs which could be accessed would be wider. For example, tourism is a major industry in the Lochaber area and jobs in this sector often involve shift, evening and weekend work. Similarly, the proposed development at the Liberty British Aluminum Smelter at Fort William would create a range of new and potentially high value shift-work opportunities. This benefit would accrue to those:
    - currently commuting to work in Lochaber and who may wish to move to a new / more productive job;
    - currently working on the peninsula who may move to a new job, commuting to Lochaber to take advantage of e.g. higher wages, better hours, improved career prospects etc; and
    - those on the peninsula who are not in employment and would have access to a wider range of job opportunities – this could be particularly important for young people seeking weekend / summer work.
- Finally, for those who are currently commuting, there would be increased opportunities to work additional hours or adopt more flexible working practices to suit lifestyle needs.

Taken as a whole, the construction of a fixed link would likely be highly positive from the perspective of commuting and access to employment more generally. Whilst the absolute number of people impacted would be relatively small, the benefits for these people could be significant. This is especially important for an area classified as fragile.

6.2.3.3 Construction – Employment and Skills Development

The construction of a fixed link across the Corran Narrows would be a significant engineering project, particularly in the context of the West Highlands where it would be one of, if not the largest, single transport project delivered in several decades.

There would therefore be an opportunity through the procurement and contracting process to ensure that local contractors secure a proportion of the work and that skills development for local young people is enshrined within the design, build and ongoing management process. The new Firth of Forth Crossing project and others managed by Transport Scotland have included significant numbers of training and employment opportunities in the construction and transport sectors.

6.2.4 Productivity and New Business Formation

The other side of the coin from the labour market is the impact of a fixed link on business productivity and new business formation.

6.2.4.1 Productivity

As with the labour market, the long operating day, high frequency and comparatively low cost of the current ferry service contributes strongly towards business productivity in the peninsula and Lochaber. However, a fixed link would nonetheless remove several of the constraints associated with the ferry service at present. The productivity benefits which could emerge would therefore be as follows:

- There would be a direct financial benefit to existing businesses using the crossing associated with not having to pay a ferry fare (unless the fixed link is tolled). This would be particularly beneficial for haulage firms or those businesses making use of a haulier, such as the high volume and time sensitive aquaculture sector. Several haulage firms interviewed as part of the Corran Ferry STAG Appraisal identified this as a potentially major benefit of a fixed link.
- As well as the cost advantages, the reduction in journey times and improvements in journey time reliability would allow businesses to access current opportunities more cost effectively. For example:
    - Shiel Buses could plan their schedules with greater certainty.
    - Haulage firms would be guaranteed year-round access to the peninsula, removing the restrictions currently imposed by the MV Maid of Glencoul (although this could also be addressed by a ferry solution).
    - It would allow those travelling long distances to / from the peninsula to do so more easily, removing the 'cut-off' at either end of the day. For example, a major local business consulted as part of the Corran Ferry STAG Appraisal noted that their customers often arrive into Glasgow Airport in the early evening but cannot get to the ferry on time to make a same-day crossing, and thus accrue additional time and accommodation costs

41 | https://www.hie.co.uk/media/6492/2018-young-people-maximising-opportunities-slwr.pdf

associated with their business.

- A fixed link would also support businesses on both sides of the crossing to access new opportunities, although the scope for this would be limited as the ferry supports most 'daytime' business.
    - One specific opportunity in this respect however is closer economic integration between Lochaber, the peninsula and the Isle of Mull. Recent business interviews undertaken by Stantec for a project assessing the impact of the Road Equivalent Tariff (RET) fares structure found that, as a result of fares reductions on the Lochaline – Fishnish route, opportunities had increased for tradesmen and other small businesses to extend their activities to Mull (and vice versa, although to a lesser extent). The introduction of a fixed link at Corran would further reduce the time and costs associated with such activities.

Whilst a fixed link would facilitate increased productivity at the regional level, it is important to bear in mind that transport is bidirectional or mutual a 'two-way road'. The lower cost of accessing the peninsula, when combined with the journey time reductions and improved reliability, would open the area up to increased competition from Lochaber and beyond. Evidence from the case studies and the aforementioned RET Evaluation suggests that this would mainly impact on small-scale retail on the peninsula and tradesmen (e.g. painters & decorators, joiners etc).

6.2.4.2 Business Formation

Improved and lower cost connectivity between the peninsula, Lochaber and beyond is likely to increase the demand for movement across the Corran Narrows. This may in turn provide a stimulus to new business formation. Given the large land area of the peninsula and its low population density, this effect is likely to be limited to meeting increased tourism demand (see Section 5.1.6 below) or at specific nodal points, Lochaline for example, where the number of people travelling to the village to access the Mull ferry would likely increase.

6.2.5 Access to services and leisure opportunities

On a day-to-to basis, it can be argued that the most significant effect of a Corran Narrows fixed link would be to improve access to services and leisure opportunities, particularly for peninsular residents. This would include, for example, facilitating improved access to:

- a wider retail offer, including a large supermarket in Fort William (Morrisons), new retail park (Marks & Spencer and Aldi) and lower cost fuel (although it is debatable whether this would be a good thing for the peninsular economy, again highlighting the 'two-way road' effect);
- Belford Hospital in Fort William, and indeed larger hospitals in Glasgow for planned operations.;
- West Highland College (University of the Highlands & Islands) and other educational opportunities such as evening classes;
- evening and weekend social activities in Fort William and beyond, which is likely to be of particular importance for young people; and
- participatory sports events, allowing any sports teams from the peninsula to travel further afield with the guarantee of being able to return across the Narrows, rather than the height restricted 'long way around'.

The evidence from the case studies, and indeed other projects from around the UK where connectivity has been significantly improved, suggests the economy of an area tends to gravitate towards the 'end' of the route with the greater economic concentration. For example, the economies of the Outer Hebrides and the Shetland Islands have becoming increasingly centralised in recent years, with Stornoway and Lerwick becoming increasingly dominant as connectivity across the island chains improved. It is likely that this would also happen in the peninsula, with the economic gravity of the area gradually shifting towards Fort William. However, the large land mass and long journey times suggest that this effect is likely to be weaker than elsewhere, Shetland for example.

6.2.6 Tourism

The volume of tourism in the peninsula could also reasonably be expected to increase with the opening of a fixed link. There are three components to this:

- 'Planned' tourism to the peninsula, either as a destination in its own right or as part of a wider trip incorporating e.g. Mull, Lochaber and onwards to Skye.
- 'Unplanned' tourism, where motorists / cyclists on the A82 make a spontaneous trip across the fixed link.
    - It can be argued that the requirement to obtain information on, wait and pay for a ferry may act as a deterrent to the casual visitor.
- Local tourism, where residents on either side of the crossing take advantage of the new crossing to visit or attend events on the other side.
    - An example of this provided in the Corran Ferry STAG Appraisal is the Three Lochs Book and Arts Festival in Strontian, where it was noted that it was not possible for residents of Lochaber to attend this event and return home on the same evening.

The evidence presented in the case studies highlighted the different ways in which fixed links in the Highlands & Islands have contributed to tourism. For example, the Skye Bridge released significant latent tourist demand, whilst the Kylesku Bridge has become an attraction in its own right as well as a key component of the North Coast 500; and the Berneray and Eriskay causeways have formed an integral part of the Hebridean Way, selling the Outer Hebrides as a single destination rather than as individual islands.

It is highly likely that a fixed link across the Narrows would support tourism growth in the peninsula, whilst also integrating it more widely into the tourism product in the West Highlands, potentially supported by appropriate marketing. Specific research would be required to establish the type, volume and value of this tourism.

6.2.7 Supply-chain

A fixed link would enhance the efficiency of the supply-chain for:

- Peninsular communities, and the hauliers which serve them; and
- The Isle of Mull, both in terms of providing resilience and an alternative route to access markets in the north and north-west of Scotland.

There were several responses from haulage firms to the engagement undertaken as part of the Corran Ferry STAG Appraisal. Whilst they commended the quality of the current ferry service and highlighted its importance to the peninsula, they also reiterated the challenges posed by the following issues:

- The 44-tonne weight restriction when the MV Maid of Glencoul is in operation adds to the cost of serving the peninsula. As large commercial vehicles cannot use the alternative route onto the peninsula, there is a requirement to use smaller vehicles, which compromises the load efficiencies associated with conventional HGVs and reduces already slim profit margins. Whilst the profit level of haulage firms is not an issue for the public sector per se, it is important to note that in deep rural areas, one or a small number of haulage firms can be integral to the economic wellbeing of an area. Any transport initiative which supports the viability of this sector can therefore be considered beneficial.
- It was also noted that ferry capacity-related delays at peak periods or when the MV Maid of Glencoul is in operation can be negative for hauliers. Logistics firms, particularly when carrying time sensitive freight, generally work on a 'just-in-time' basis, working around driver hours, slots at distribution centres and in some cases connecting with onward movements to England or Europe.
- The Corran crossing is also of importance for haulage firms based in or serving Mull, TSL Contractors for example. There are three aspects to this:
    - The Corran Ferry and Lochaline – Fishnish crossing provide the dangerous goods route onto Mull when the closed-deck MV Isle of Mull is operating the Oban – Craignure route on her own during the winter timetable period. It should however be noted that this issue is expected to be resolved in the near future (and well ahead of any fixed link) when the open-deck MV Hebrides is deployed on the route.
    - The introduction of RET on the Oban - Craignure route in 2015 has also led to significant vehicle-deck capacity constraints during peak periods. Whilst block bookings protect a degree of deckspace for hauliers, it can be more challenging to move short notice consignments or for non-account / irregular customers which do not have the opportunity to block book. The combination of the Lochaline – Fishnish route and the Corran Ferry therefore provide much needed additional vehicle capacity to / from Mull.
    - Finally, the combined Corran and Lochaline crossings provide resilience for Mull in the event that the Oban – Craignure route is suspended due to weather (the Lochaline – Fishnish crossing is shorter and more sheltered) or for technical reasons.

The construction of a fixed link across the Corran Narrows would therefore provide efficiency, journey time reliability and resilience benefits for both the peninsula and the Isle of Mull supply-chain (albeit acknowledging that the latter still has a dependence on a second ferry crossing) and also communities that might be impacted by unplanned closures on the trunk road network who would then require a diversion route via a new fixed link. Strong support for a fixed link was expressed by several haulage firms as part of the Corran Ferry STAG Appraisal.

6.2.8 Public service provision

A prominent outcome of other fixed links in the Highlands & Islands has been the delivery of cost savings to the public sector, either through reducing the cost of service delivery or facilitating a rationalisation of services.

In the context of the peninsula, it is likely that these impacts would however be less prominent. Consultation with THC Health & Social Care, the NHS, THC Education and THC Waste Management as part of the Corran Ferry STAG suggested that the ferry service largely meets their needs. Whilst there would be some efficiency benefits to be gained from reduced wait and journey times, it was not considered that these would lead to a fundamental reorganisation of services. A fixed link would provide a cost saving for these organisations associated with the removal of fares.

From a wider public sector perspective, the following benefits of a fixed link were however identified:

- From the perspective of Police Scotland, a fixed link would reduce the road safety risk associated with traffic backing out from the ferry terminal during periods of peak demand. This is a particularly key issue on the A82 as it is a trunk road, but there is also a safety risk on the A861 where traffic can queue back onto the blind bend.
- In the event of a road closure incident between Corran and Fort William, a fixed link would more readily allow the peninsula to be used as a diversionary route, the current diversionary route being several hours long. It is though important not to overstate this potential benefit as much of the road network on the peninsula is single track and there are also height restrictions on all routes to the A830. It may

- nonetheless provide a diversion opportunity for the emergency services, cyclists and some motorists, particularly those bound for Mallaig, facilitating routing via Salen and Acharacle.

- The removal of the capacity constraint and fares associated with the Corran Ferry would increase the attractiveness of Lochaline - Fishnish, and a to a much lesser extent Kilchoan – Tobermory, as a route onto Mull. This could, at the margins, assist in relieving some of the pressure on the Oban – Craignure route, an important issue for Transport Scotland and its contracted operator CalMac Ferries Ltd. It should though be acknowledged that this could bring its own challenges, not least motorists 'racing' to catch a ferry at Lochaline or Kilchoan on single track roads.

6.2.9 Quality of life / sense of community

The key, but much less tangible, question around a fixed link is how it would impact on the quality of life and sense of community. This issue has been touched upon in each of the above sections, weighing up for example the benefits and disbenefits of increased out-commuting or lifestyle in-migration, and is to some degree summarised here.

The case studies presented in Chapter 2 suggest that, on the whole, the construction of fixed links have made highly positive contributions to rural and island communities. The quality of life benefits have included:

- Improved employment opportunities and, by extension, higher disposable incomes.

- Improved business confidence

- Contributing towards population stability / growth, particularly amongst younger cohorts (albeit the causal evidence with respect to this is limited). In-migration has typically been a factor in this, but brings both positives and negatives.

- 24-hour access to nearby service centres for health, education, personal business and leisure opportunities

    - Improved access to education and leisure opportunities are essential in retaining young people / families in an area.

- Increased tourism, creating new business opportunities for local people.

- Reduced cost of living, particularly in terms of removing the need for overnight accommodation when a journey has to be made outwith the ferry service hours.

- Ability to visit / receive visits from family and friends more easily.

Whilst fixed links have on the whole been positive, they have also brought a range of negative quality of life impacts, although the extent of these impacts varies from project to project, principally due to geography. These impacts have included:

- An increased concentration of economic activity in the nearest major service centre - this includes:

    - Employment, which can lead to a 'dormitory' effect in communities.

    - Leisure, retail etc spending being off-island / peninsula, undermining the economic viability of local businesses.

    - It should be noted that these effects are likely to be limited in the context of the peninsula as Fort William can be readily accessed at present, but they may occur at the margins.

- A watering down of the local culture / character of the area due to in-migration, particularly if this puts upward pressure on house prices making them less affordable for local young people.

- Increased second-home ownership, which can lead to vacant properties for much of the year, again undermining the local businesses and the public service base.

- An influx of tourism demand which the local infrastructure cannot accommodate – for better or for worse, the ferry service effectively provides a cap on the level of demand which can access the peninsula at any one time. This has been a very prominent problem in several remote and island communities - not least neighbouring Mull - where transport links have been improved or the cost of travel reduced. Example issues include:

    - Increased traffic on local roads, and the 'platooning' effect on single track roads.

    - An increase in larger vehicles, such as motorhomes, which can cause verge damage on single track roads.

    - Wild or irresponsible camping, on occasions borne of a lack of official campsite provision.

    - Littering and waste dumping, again on occasions as a result of limited or no official provision.

- Rationalisation / centralisation of public services, albeit this is not anticipated to be a major issue in this context.

Overall, whilst fixed links can bring their own challenges and problems, the evidence suggests that, on balance, they have been a good thing for the communities to which they have been introduced. Moreover, the impact of some of the perceived disbenefits at the community level (e.g. out commuting, undertaking leisure activities elsewhere) are questionable. Whilst the above may be seen as disadvantageous for the community overall, the fact that individuals are making these choices suggests that they derive a benefit from doing so, and indeed it may be a benefit that convinces them to stay in rather than leave the area.

In summary, this section has presented a qualitiative summary on the potential wider societal impacts of a fixed link across the Corran Narrows, exploring how such a scheme may change the way in which individuals, businesses and the public sector behave. Should a commitment be made to further explore the concept of a fixed link, a parallel programme of research should be undertaken to explore the likelihood and scale of each of the above impacts, positive and negative, in the context of the peninsula.

Ferry Slips,
Corran Narrows

7.0 Conclusions And Next Steps

7.1 Conclusions

This high-level feasibility study has demonstrated that, subject to more detailed option development and costing, a fixed link across the Corran Narrows appears a potentially viable proposition. In particular, it should be noted that:

- There are no 'showstopper' issues preventing the construction of a fixed link, albeit there are environmental, planning and construction issues which would need to be taken into consideration. The fixed link is therefore technically feasible.
- The costs of a fixed link are not significantly out of step with a continued ferry service when set against the range of benefits on offer from the former.
- BCR for fixed link options vary from <1 to <13

Under the majority of the scenarios developed here, the fixed link proposal generates a benefit-cost ratio of greater than 1. The analysis and evidence presented in this report therefore suggests that there is a case for further exploring the comparative merits of a fixed link, either within the context of STPR2 or as a standalone business case.

The feasibility work suggests that there are three potential corridors in which a fixed link could be delivered, two for a bridge-based option and one for a tunnel. Whilst a preferred option is not specified within this study:

- There are potentially significant obstacles to be overcome with regards to Route Corridor 1, and in particular the requirement to develop temporary arrangements to maintain the ferry service during construction and build a structure which maintains the shipping lane without causing disproportionate delays to motorists.
- Route Corridor 5, which would accommodate a tunnel, is by some margin the most expensive.
- Route Corridor 3, which would entail a high-level bridge option, appears the most advantageous alignment at this feasibility stage.

Whilst RC1 and RC3 would require a low-level and high-level bridge structure respectively, there are a range of structural options available within each corridor, each with varying costs and benefits.

In all cases, the construction and lifetime maintenance costs of a fixed link are more expensive than the capital costs and O&M costs associated with a continuing with a ferry service, particularly with respect to a tunnel. However, a fixed link will provide a range of benefits over and above a continued ferry operation ranging from, and in the majority of scenarios considered here, a benefit cost ratio of greater than 1 is derived.

In addition to the quantified economic benefits of a fixed link, a key question is how such a connection would impact on the society and economy of the peninsula in particular. Case study evidence suggests that a fixed connection would offer a range of benefits over and above a ferry, including improved connectivity to employment & key services; improved business confidence; improved tourism access; a more efficient supply-chain; and the promotion of population retention, particularly amongst younger cohorts. Whilst the impacts are likely to be largely positive, there would of course also be negatives such as increased pressure on peninsular infrastructure and a potential erosion of the character of that area.

7.2 Next Steps

Whilst this study has demonstrated that a fixed link is a potentially viable option for the Corran Narrows, it is essential to bear in mind that it is only a feasibility study, drawing together high-level option development, costing and economic narrative. Further development work will be required if a fixed link at Corran Narrows is to be taken forward as a major infrastructure investment similar to the Skye Bridge and Kyelsku Bridge.

7.2.1 STPR2

The Lochaber Area Committee meeting on 19th February 2020 confirmed the proposal to submit this report to Transport Scotland for consideration within the STPR2 options appraisal process. There are however a number of issues to consider in the context of STPR2, namely:

- The process, outcomes and timelines of STPR2 are not entirely clear at this stage. In particular, it is not evident at this stage whether the reporting will identify specific schemes to be progressed or whether there will be a commitment in principle to explore concepts such as new fixed links that provide more resilient connections to the ferry connections to the islands
- In the event that a Corran fixed link is specifically sifted-in to the long list of options within STPR2, it is unlikely that it would be an immediate priority and delivery of the scheme could therefore be some time after 2022. This potentially creates a dilemma for THC in that investment in the ferry service may still be required until such a time as a fixed link is delivered, and thus investment priorities at this stage will have to be considered in this context. The need for potentially 'sunk' investment in ferry infrastructure should prioritise early investment in the fixed link if this scheme emerges from STPR2.
- Finally, it is unclear at this stage whether any options sifted-out in STPR2 have an 'alternative route' back into the Scottish Government spending envelope. Whilst STPR2 represents an important opportunity to realise a fixed link at Corran, it should not be considered the only avenue for realising this aspiration. There is therefore will be a requirement for further development of the case for investing in a fixed link.

7.2.2 Corran Transport Link – Outline Business Case

There are now two recent studies exploring future transport

provision across the Corran Narrows:

- Corran Ferry STAG Appraisal: This report was published in 2018 and considered the different options for the future of ferry services at Corran, mainly form a technical and financial perspective. This study did not cover fixed links and thus was focussed on ferry-based options only.
- Corran Narrows Fixed Link Feasibility Study (i.e. this report): This report develops the fixed link options to a level equivalent with ferry options in the Corran Ferry STAG Appraisal.

Transport Scotland has published guidance with respect to the development of business cases in Transport Scotland[42]. This guidance provides a framework for the delivery of transport projects and sets out a 3-stage process comprising Strategic, Outline and Final Business Cases (SBC, OBC and FBC respectively). Each Business Case comprises five 'cases', these being: Strategic, (Socio)Economic, Commercial, Financial and Management and these five 'cases' are developed to differing degrees as the three stages progress.

The SBC is broadly the equivalent of a STAG-based project, whilst the OBC develops the analysis to determine a preferred option. The FBC deals with the procurement stage.

To ensure compliance with best practice, the two studies undertaken to date should be brought together under an 'umbrella' **Corran Narrows SBC**. As no further substantive technical development of the options would be necessary, around two-thirds of the material required for this task is already available. The two existing reports would be brought together under a single overarching narrative (incorporating the key 'case for change' stage) and a common set of Transport Planning Objectives. The main 'gap' in terms of the SBC would be public and stakeholder engagement. No engagement has been undertaken to date as the two studies have been focussed more on technical matters and engineering feasibility. Whilst the Covid19 situation is likely to preclude face-to-face engagement for some time, it is still possible to undertake this type of engagement effectively remotely by using online material, webinars etc. Resident and business survey-based primary research would be required to establish the extent to which current arrangements prevent / impact on travel and how a fixed link would change travel behaviours. Additional, largely qualitative appraisal would be undertaken to cover all the requirements of STAG not covered to date and this would be captured in Appraisal Summary Tables.

This study has scoped out a range of potential **social and economic impacts** of a fixed link with respect to the peninsular communities served by a fixed link, and these have been set out in a Logic Map. In order to further inform the case for a fixed link, there would be merit in now gathering the evidence to support or otherwise the potential impacts which have been highlighted in this study, including population, labour market, productivity, the potential for new business formation, the benefits of improved access to public services and leisure and sporting opportunities, and public sector efficiencies. This would be framed in the context of the impacts of fixed link on

the fragile peninsular communities and the prevailing policy context.

This evidence would be important in informing the narrative within both the SBC and the OBC and / or could be used as supporting information in the SPTR2 context.

The 'umbrella' SBC would therefore bring the two options together on a common footing, completing the Strategic Case, progressing the (Socio)Economic Case and bringing in the early stages of the Commercial, Financial and Management Cases.

The SBC would then be progressed to an Outline Business Case (**OBC**) where a preferred option for the long-term future of transport across the Narrows would be definitively determined. This OBC would include:

- Further refinement and costing of the preferred Route Corridor, alignment and structural form of a fixed link, homing in on a preferred fixed link option and increasing cost certainty. This would be undertaken in line with DMRB up to and including Stage 3, Scheme Assessment.

More detailed modelling of the benefits of a fixed link relative to the ferry option. This would refine the assumptions regarding induced traffic in the light of public engagement, and determine the average travel time savings across the year, based on surveys carried out of current ferry traffic, all allowing the development of more robust benefit-cost ratios.

- Further refinement of the ferry options to arrive at a preferred infrastructure solution and, ideally, delivery model.
- Further stakeholder, business and public engagement on the process to date, the emerging ferry and fixed link options and views on the preferred option.
- Establishment of an ultimate preferred option - fixed link or ferry. This would have to be determined within the prevailing institutional and financial position.
- Through the Financial Case, establishment of the full life financial costs of the preferred option.
- Through Commercial and Management Cases, establishment of how the preferred option would be procured, managed and delivered.

The OBC would therefore provide the basis for then procuring the preferred option, a process with would be covered in a subsequent **FBC**.

7.3 Recommended Next Steps

The immediate priority is to collate and supplement the work undertaken to date to produce a **Corran Narrows Strategic Business Case (SBC)** which is compliant with Transport Scotland guidance, as set out above. As noted above, around two-thirds of the material required for this exists in the current reports, with the key additional activity revolving around engagement. Effective engagement can still be undertaken in the current climate.

Given the fragility of the local economy, we also recommend undertaking bespoke, freestanding analysis of the potential **economic and social impacts** of the fixed link. The findings of this analysis would be vital in 'making the case' for this investment and would strengthen the evidence base for both the SBC and the OBC.

Ideally, a programme of **data collection** would also be undertaken to establish

- true end to end journey times at the ferry - this could be ANPR based
- foot passenger use of the ferry
- cyclists on the ferry

In the current climate of disruption to travel, the data collection programme should not however be undertaken.

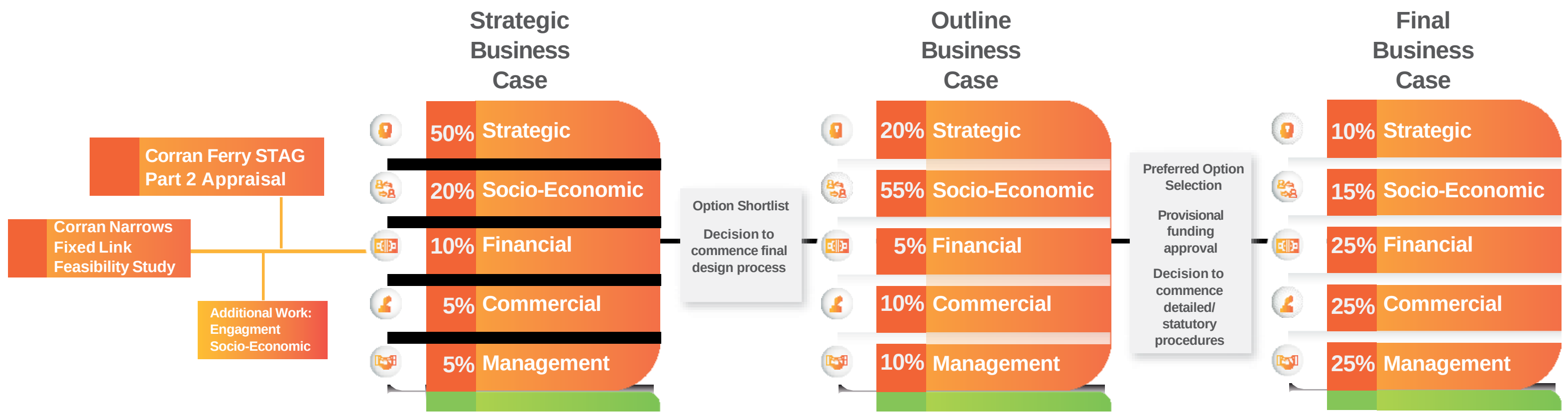


Figure 35: Workflow and Business Case Process

42 | https://www.transport.gov.scot/media/10165/idm-guidance-annex-d-business-case-guidance-for-publication-jan-2016.pdf

Appendices

A. Model Assumptions

ASSUMPTIONS

Value	Description	Source
All Scenarios		
Assesment Years		
2019	Current Year	-
2027	Opening Year (DS/Reference)	PBA Assumed
2056	Forecast Year	Traffic growth assumed to plateau at 30 years
2086	Final Year in Appraisal Period	60 year appraisal period agreed with THC
Ferry Carryings		
1	Average CV Occupancy	PBA Assumed
30	Bus capacity (including driver)	PBA Assumed
94%	% passengers travelling by car	PBA Calculation
2%	% passengers travelling by bus	PBA Calculation
2%	% passengers travelling by CV	PBA Calculation
0%	% passengers travelling by bike	PBA Assumed
2%	% passengers travelling on foot	PBA Calculation
15%	% Cyclists as a proportion of Pedestrians + Cyclists	PBA Calculation
1.1%	Average Annual Walk/Cycle Passenger Growth	PBA Assumed
1.1%	Average Annual Car Traffic Growth (2007-2017). Assumed to already capture effects of declining occupancy.	PBA Assumed
1.1%	Average Annual CV+Bus Traffic Growth (2008-2017)	PBA Assumed
-0.6%	Average annual change in car occupancy	Table TD9, SHS Tables, TATIS 2018
0%	Average annual change in Bus/CV occupancy (neither assumed to change - bus services would be cut/added in	PBA Assumed
85%	% Adult Passengers	CHFS RET Evaluation - Travel Surveys 2019
12%	% Child Passengers	CHFS RET Evaluation - Travel Surveys 2019
3%	% Infant Passengers	CHFS RET Evaluation - Travel Surveys 2019
Travel Purpose		
100%	% CV Pax travelling In Work	PBA Assumed
100%	% Walk/Cycle Pax travelling for non-work other purposes	PBA Assumed
13%	% Bus passengers travelling in work	PBA Calculation
9%	% Bus passengers commuting to/from work/education	PBA Calculation
78%	% Bus passengers travelling for non-work other purposes	PBA Calculation
8%	% Car passengers travelling in work	PBA Calculation
9%	% Car passengers commuting to/from work/education	PBA Calculation
82%	% Car passengers travelling for non-work other purposes	PBA Calculation
Travel Characteristics		
	Travel by car/bus: Destination (North) - Fort William town centre	PBA Assumed
	Travel by car/bus: Destination (South) - North Ballachulish	PBA Assumed
	Travel by car/bus: Origin - Approximately Glenborrodale (estimated based on distribution of respondent origin	PBA Assumed
Bus Ticket Revenue		
£ 9.27	Average Bus Fare	PBA Assumed
2%	Annual increase in bus fares (approximately equivalent to Bank of England CPI forecasts for next 5 years)	PBA Assumed
Do Nothing		
2031	Year ferry ceases operation	PBA Assumed
50%	**Loss of trips as a result in end of ferry service (all modes)**	**Variable to be adjusted by user**
	Assumed that lost car/cv/bus trips are not rerouted or transferred mode	PBA Assumed
	Ferry fares revenue is equal to ferry operating and maintenance costs	PBA Assumed
	Growth in trips transferred from ferry to road, as expected on ferry.	PBA Assumed
Access - When ferry operating		
50%	% Users travellng between peninsula and the north (Fort William assumed)	PBA Assumed
50%	% Users travellng between peninsula and the south (North Ballachulish assumed)	PBA Calculation
50	Average speed by car/CV kph	PBA Assumed
40	Average speed by bus (kph)	PBA Assumed
57	Average distance driven if travelling between peninsula and the North if using ferry (Used data from 2014 surv	PBA Calculation
53	Average distance driven if travelling between peninsula and the South if using ferry (Used data from 2014 surv	PBA Calculation
55	Average distance driven if travelling between peninsula and North+South if using ferry (Used data from 2014 s	PBA Calculation
66	Average travel time by road between Peninsula and North+South (min)	PBA Calculation
82	Average travel time by bus between Peninsula and North+South (min)	PBA Calculation
15	**Wait Time for car/bus/cv passengers (min)**	**Variable to be adjusted by user**
5	Crossing Time (min)	PBA Assumed
Access - When ferry service ends		
87	Average distance driven entirely by road if travelling between Peninsula and North (Used data from 2014 surve	PBA Calculation
109	Average distance driven entirely by road if travelling between Peninsula and South (Used data from 2014 surve	PBA Calculation
98	Average distance driven entirely by road if travelling between Peninsula and North+South (Used data from 201	PBA Calculation
117	Average travel time by car/cv between Peninsula and North+South (min)	PBA Calculation
147	Average travel time by bus between Peninsula and North+South (min)	PBA Calculation
Bus Ticket Revenue - When ferry service ends		
15.0%	% reduction in bus fare to address fact that no ferry fare component once ferry fails	PBA Assumed
£ 10.50	Average Bus Fare based on mileage - once ferry fails	PBA Calculation
Reference		
	Ferry fares revenue is equal to ferry operating and maintenance costs	PBA Assumed
Ferry Access		
15	**Wait Time for car/bus/cv passengers (min)**	**Variable to be adjusted by user**
Ferry Replacement Schedule		
2031	QP Main Vessel Replacements Year 1	PBA Assumed
2041	QP Support Vessel Replacement Year 1	PBA Assumed
2061	QP Main Vessel Replacement Year 2	PBA Assumed
2024	ST Main Vessel Replacement Year 1	PBA Assumed
2054	ST Main Vessel Replacement Year 2	PBA Assumed
Capital Costs (Straight through - High)		
£ 23,000,000.00	Infrastructure cost	PBA Calculation
£ 17,000,000.00	Main Vessel Replacement ferry cost	PBA Assumed
£ -	Support Vessel replacement cost	PBA Assumed
1	No. years construction	PBA Assumed
£ 100,000.00	Annual Calmac fleet vessel cost	
Do Something		
50%	**Uplift in trips as a result of bridge opening/replacement of ferry with bridge**	**Variable to be adjusted by user**
£ 7.88	Average Bus Fare based on mileage - once ferry fails	PBA Calculation
	Growth in trips transferred from ferry to road, as expected on ferry.	PBA Assumed
Fixed Link		
56	Average distance driven entirely by road (Used data from 2014 survey on passenger origins to generate weight	PBA Calculation
67	Average travel time by road (min)	PBA Calculation
84	Average travel time by bus (min)	PBA Assumed
8%	% car/van occupants travelling In Work	PBA Calculation
17%	% car/van occupants commuting	PBA Calculation
75%	% car/van occupants travelling for other purposes	PBA Calculation
5%	% bus occupants travelling In Work	PBA Calculation
21%	% bus occupants commuting	PBA Calculation
75%	% bus occupants travelling for other purposes	PBA Calculation
Costs (Tunnel, Low)		
£ 69,267,982.40	Capital Cost (Low End Estimate)	PBA Calculation
£ 333,333.33	Operating & Maintenance cost (Low end estimate, assumed to be distributed evenly across lifetime)	PBA Calculation
3	No. years construction	PBA Calculation

B. Model Parametres

KEY DATA TO SUPPORT ASSUMPTIONS

Value	Description	Source
All Scenarios		
Carryings		
580,000	Annual passenger carryings on Corran Ferry (2017)	STS No 37, Table 9.16
257,500	Annual car carryings on Corran Ferry (2017)	STS No 37, Table 9.16
12,600	Annual Bus + CV carryings on Corran Ferry (2017)	STS No 37, Table 9.16
7%	Buses as a proportion of buses +CVs	2017-2018 Corran Ticket Sales data
1%	Average annual growth in vehicle km in Highland Council area	STS No 37, Table 5.5
96%	% Respondents who usually travel on the ferry accompanying a vehicle driven by them or another household member	Corran Ferry Socio-economic Study, Aecom, 2014
2%	% Respondents who usually travel on the ferry as foot passengers (assumed to include foot+cycle passengers)	Corran Ferry Socio-economic Study, Aecom, 2014
2%	% Respondents who travel by bus	Corran Ferry Socio-economic Study, Aecom, 2014
15%	% Camusnagaul Ferry passengers who travel with a bicycle (walk/cycle pax only)	Camusnagaul ferry cycling data.xlsx
-1%	Average annual change in car occupancy (Based on 2008-2018 SHS Travel Diary)	Table TD9, SHS Tables, TATIS 2018
85%	% Adult Passengers	CHFS RET Evaluation - Travel Surveys 2019
12%	% Child Passengers	CHFS RET Evaluation - Travel Surveys 2019
3%	% Infant Passengers	CHFS RET Evaluation - Travel Surveys 2019
Travel Purpose		
10%	% Pax travelling In Work (Corran Ferry)	CorranFerry Socio-economic Study, Aecom, 2014
9%	% Pax commuting across (Corran Ferry)	Corran Ferry Socio-economic Study, Aecom, 2014
81%	% Pax travelling for other non-work purposes (Corran Ferry)	Corran Ferry Socio-economic Study, Aecom, 2014
Travel Characteristics		
10-15 min	Timetabled Headway (min)	2019 Corran Ferry Timetable, THC Website
Ticket Revenue		
0%	% Cars which travel free	2018-19 Corran Ferry Revenue Data
42%	% Cars paying standard single fare	2018-19 Corran Ferry Revenue Data
£ 1.00	Foot passenger fare - Adult - 2019 prices	Item 7, Lochaber Committee Minutes 29/08/19, THC Website
£ 1.50	Cycle passenger fare - Adult - 2019 prices	Item 7, Lochaber Committee Minutes 29/08/19, THC Website
£ 0.27	Average cost of Single Ticket for adult foot passenger if using 30 ticket book - 2019 prices	Item 7, Lochaber Committee Minutes 29/08/19, THC Website
£ 0.40	Average cost of Single Ticket for adult cycle passenger if using 30 ticket book - 2019 prices	Item 7, Lochaber Committee Minutes 29/08/19, THC Website
19%	Average rate of indirect taxation in the UK economy	STAG Technical Database Section 9.2.2.5
Do Nothing		
Bus Ticket Revenue		
£ 12.35	Average Bus Fare based on mileage - once ferry fails	PBA Calculated based on Aecom report distribution of passenger
Ferry Access		
2.5	Multiplier to reflect higher value of time spent waiting for PT services IW	STAG Technical Database, Section 9, Economy, December 2017
Reference		
Capital Costs		
£ 14,800,000.00	Quarter Point Ferry Infrastructure Cost (Option 1a infrastructure costs (2019 prices))	PBA Calculation
£ 23,000,000.00	Straight Through Ferry Infrastructure Cost (Option 2b infrastructure costs (2019 prices))	PBA Calculation
£ 8,000,000.00	Conventional ferry cost (low end cost estimate, 2019 prices)	PBA Calculation
£ 17,000,000.00	Hybrid ferry cost (high end costs estimate, 2019 prices)	PBA Calculation
£ 100,000.00	Annual cost of use of 'straight through' vessel from Calmac fleet for support vessel (2019 prices)	PBA Calculation
Do Something		
47%	Uplift in vehicular trips (Average uplift seen in year following opening of a fixed link. Figure relates to tolled links, but data does not suggest big variation between tolled and untolled)	Shetland Fixed Links Strategy: Socio Economic Study: Final Report
Bridge Access		
1.00	Length of new link (km)	
General Traffic on A82		
1.57	Average car occupancy - Highland Council Area	Table 6, LA Tables, TATIS 2018
12%	% car/van drivers travelling In Work	National Travel Survey, 2018
24%	% car/van drivers commuting	National Travel Survey, 2018
64%	% car/van drivers travelling for other purposes	National Travel Survey, 2018
2%	% car/van passengers travelling In Work	National Travel Survey, 2018
5%	% car/van passengers commuting	National Travel Survey, 2018
93%	% car/van passengers travelling for other purposes	National Travel Survey, 2018
1%	% bus passengers travelling In Work	National Travel Survey, 2018
21%	% bus passengers commuting	National Travel Survey, 2018
77%	% bus passengers travelling for other purposes	National Travel Survey, 2018
Capital Costs - Cable Tied Bridge with 2 towers (Option A)		
£ 61,609,511.92	Capital Cost (Low End Estimate, 2020 prices)	PBA Calculation
£ 150,000.00	Operating & Maintenance cost (Low end estimate, assumed to be distributed evenly across lifetime, 2020 prices)	PBA Calculation
£ 87,975,106.36	Capital Cost (High End Estimate, 2020 prices)	PBA Calculation
£ 183,333.33	Operating & Maintenance cost (High end estimate, assumed to be distributed evenly across lifetime, 2020 prices)	PBA Calculation
Capital Costs - Opening Bridge (Option D)		
£ 42,000,000.00	Capital Cost (Low End Estimate, 2020 prices)	PBA Calculation
£ 216,666.67	Operating & Maintenance cost (High end estimate, assumed to be distributed evenly across lifetime, 2020 prices)	PBA Calculation
£ 50,000,000.00	Capital Cost (Low End Estimate, 2020 prices)	PBA Calculation
£ 250,000.00	Operating & Maintenance cost (High end estimate, assumed to be distributed evenly across lifetime, 2020 prices)	PBA Calculation
Capital Costs - Tunnel (Option E)		
£ 69,267,982.40	Capital Cost (Low End Estimate, 2020 prices)	PBA Calculation
£ 333,333.33	Operating & Maintenance cost (Low end estimate, assumed to be distributed evenly across lifetime, 2020 prices)	PBA Calculation
£ 116,333,805.72	Capital Cost (Low End Estimate, 2020 prices)	PBA Calculation
£ 550,000.00	Operating & Maintenance cost (Low end estimate, assumed to be distributed evenly across lifetime, 2020 prices)	PBA Calculation