Forth Replacement Crossing Study

Report 3 : Option Generation and Sifting

Volume 1 : Main Report

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Authorisation

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EXECUTIVE SUMMARY

INTRODUCTION

The Scottish Executive and Transport Scotland are investing more than £3 billion on transport infrastructure projects to 2012, across all modes of transport. This includes providing funding for local authorities and their partners to improve transport.

Scottish Ministers are committed to a Strategic Transport Projects Review (STPR) and Jacobs with Faber Maunsell were commissioned by Transport Scotland to provide technical advice to the study. The STPR commission involves identifying the strengths and weaknesses of the Scottish strategic transport network, identifying gaps between the future demand and capacity of the network, and producing a prioritised list of interventions for the period 2012-22. The commission also covers a study of the Forth Replacement Crossing.

The objective of the study is to generate robust options for a potential replacement Forth Crossing. This report is the third report produced as part of the Forth Replacement Crossing Study and covers the Generation of Options and Sifting.

CONSTRAINTS MAPPING

A review of the various constraints which exist within and around the Firth of Forth has been undertaken. These constraints play an important part in the development of the preferred options and include environmental, physical and urban constraints together with navigation constraints caused by the varied clearances required at different points along the length of the Firth.

The environmental constraints were documented in Report 1 of this study and include the Special Protection Areas, the Ramsar sites and the Sites of Special Scientific Interest. These have been most influential in the constraints mapping and subsequent development of the corridors, as they cover most of the mudflats between Kincardine to the east of Queensferry. There are also a number of Scheduled Ancient Monuments, listed buildings and landscaped gardens, particularly on the south shore.

GENERATION OF OPTIONS AND INITIAL SIFTING

A long list of 65 potential options was generated.

The long list was subjected to an initial sifting process. This was undertaken with a view to reducing the list by eliminating options which did not satisfy the objectives of the study or were not technically feasible. 19 of the original 65 options were rejected, for these reasons. Those rejected included the use of arch and swing bridge options, which could not provide the required spans. Suggestions of bridges or tunnels crossing between Leith/Portobello to either Kirkcaldy or Burntisland were also rejected as these were uneconomic or beyond practical engineering limits.

Options involving ferries and hovercraft were also considered but rejected as they would not provide sufficient capacity on their own. However, such measures may have a complementary role to play as part of an overall strategy for enhancing public transport choice for cross Forth Travel.

A number of options generated by the long list included heavy rail as part of a new bridge crossing or tunnel. Studies undertaken recently, notably the SEStran Integrated Transport Corridor Study (SITCoS), found that sufficient additional cross Forth rail capacity can be provided by enhancing the services using the Forth Bridge to cater for the expected growth in demand until around 2026. This can be done through the introduction of longer train sets (six cars) with accompanying platform extensions and two additional trains in the peak hour. Beyond 2026 Network Rail have indicated that still further capacity can be provided without recourse to a new rail crossing.

It was therefore concluded that future heavy rail capacity should be provided by enhancing the services across the Forth Bridge. This would provide a more cost-effective increase in heavy rail capacity rather than incorporating heavy rail provision into a new Forth Crossing. Previous studies had indicated that the technical requirements to incorporate heavy rail into a new crossing could possibly double its cost. The issue of cross Forth rail capacity and journey reliability should be considered by the main STPR Commission.

GENERAL DESIGN ISSUES

Before assessing each of the corridors a number of key design issues associated with possible bridge and tunnel crossings were explored. For the bridge options it was considered that the most appropriate structural form for a crossing of this size would be a suspension bridge or a cable stayed bridge.

Using experience and information gathered around the world it was concluded that a suspension bridge would probably take between five and half to six years to construct with a cable stayed bridge possibly taking around 6 months less.

Different forms of tunnel construction were examined. This included bored, immersed tube, cut and cover and mined tunnel. This review concluded that a bored tunnel utilising a tunnel boring machine (TBM) is the most desirable of the methods as it would avoid the main environmental problems associated with immersed tube tunnelling. Bored tunnelling will not impinge on the various SPAs and SSSIs that delineate the banks of the Forth. Mined and cut and cover tunnelling are considered as supplementary methods to the main bored tunnel crossing.

New European design standards, currently issued for consultation and to be introduced in 2007, dictate that the maximum gradient for new tunnels should be no more than three per cent. This will in turn dictate the length of any tunnel beneath the Firth of Forth. In the corridors examined the lengths of tunnels vary between 7km and 10km. Again, using experience and information gathered around the world it is estimated that the construction programme for a tunnelled crossing would be of the order of seven years.

COMPLEMENTARY MEASURES

Possible Complementary Measures have been identified that will be used to improve the performance of the network on, and in the vicinity of the Forth bridges and any new crossing. These measures might be considered interim measures prior to the construction of any Forth Crossing but should also be considered in terms of how they might be maintained as part of the final strategy.

Measures considered for further assessment include High Occupancy Vehicle (HOV) lanes, bus priority measures, park and choose sites, further bus services, additional rail capacity, ferry services, active traffic management and variable tolls.

Some initial testing has indicated that many of these measures will have a role to play in a future Forth Replacement Crossing Strategy. These will be examined in more detail in the next stage of the study.

OPTIONS FOR CONSIDERATION

There is, of course, a possibility that the existing Forth Road Bridge can be repaired without the need for a replacement crossing. Report 2 of this study has demonstrated, however, that this would not provide adequate capacity to meet the study objectives.

At this point in time there is also considerable uncertainty as to the extent of the remedial works associated with refurbishment of the existing bridge and their impact on traffic flows.

In spite of this finding, an option considered during the sifting process was a “No-new crossing” scenario. In this, enhanced public transport (rail and bus) services were introduced together with extensive priority for bus services on both sides of the Forth in combination with HOV lanes on both approaches and across the bridge. Park and Choose would also be built in the Fife bridgehead area with High Occupancy Vehicles priority on the M90/A90 southbound approach. In order to maximise the use of the Upper Forth Crossings at Kincardine for vehicular traffic the A985 was upgraded to Dual 2 lane Carriageway standard between Kincardine and the proposed Rosyth Bypass. It should be noted that this scenario is purely indicative of possible interventions and does not represent a commitment by Transport Scotland to implement any of them.

The Transport Model for Scotland (TMfS) was used to examine the impacts of this No-new crossing scenario and found that it is likely to result in changes to travel patterns and choices throughout the study area in 2022. There is likely to be an increase of up to one third in the number of southbound trips made by public transport in the morning peak hour. It is also possible that southbound peak hour traffic on the Forth Road Bridge could reduce by up to one third in the morning peak.

However, one key finding arising from this scenario is the fact that there is expected to be a reduction of up to 33 per cent in the number of people making journeys between Fife and Edinburgh/Lothians. These journeys are being made instead to other destinations such as the Falkirk/Stirling areas or are remaining within Fife. Although the wider economic impacts of this have not been assessed it is clear that, given the synergy that currently exists between Fife and Edinburgh/Lothians that there will be substantial economic impacts as a consequence of this scenario

Turning to the possible options for a new crossing, following the initial sifting and constraints mapping it was considered appropriate to apply a hierarchical approach to the appraisal to ensure that the major issues were dealt with adequately before focussing on the more detailed issues.

The approach adopted for the purposes of this report was to consider the crossing location and whether bridges and/or tunnels were feasible solutions at each. All other issues would be considered in future reports once a clear view on these primary issues was established.

The remainder of this report therefore considers bridge and tunnel options in the five remaining corridors:

- A – Grangemouth (West of Bo'ness);
- B – East of Bo'ness;
- C – West of Rosyth;
- D - East of Rosyth/West of Queensferry; and
- E – East of Queensferry.

Each corridor has been assessed for its suitability for a tunnel or bridge crossing.

CORRIDOR SIFTING CONCLUSION

The sifting carried out within this report has been undertaken in order to establish which options are unlikely to meet the study objectives. It is equivalent to the pre-appraisal phase of the Scottish Transport Appraisal Guidance (STAG) process. Any options passing this sifting exercise will then be subjected to a Part 1 appraisal during the next work package.

It is clear from the work undertaken that Corridors A and B do not meet the objectives of the study and should therefore be rejected. It is concluded that these corridors should not be considered further within the study.

Corridors C, D and E do, however, perform well to varying degrees against the objectives and it is considered that these should therefore be taken forward to the Part 1 STAG Appraisal.

PROCUREMENT AND FINANCE

An initial assessment of the options to procure, fund and deliver a Forth Replacement Crossing has been undertaken. There are a range of alternatives available for both the procurement and the funding. However, at this stage it is not possible to determine the optimal procurement and funding route for the new crossing. This will only become clearer after the detailed Stage 2 qualitative and quantitative analysis required which will highlight the relative costs and risks associated with each procurement and funding option.

As the project develops, factors may emerge that may require a change or refinement of the procurement and funding strategy. However, from the initial assessment of the crossing options it is clear that there is nothing being identified which would preclude or materially impact on the procurement and funding options so far identified. In summary, the main findings to date are as follows:

- The project clearly demonstrates the attributes for consideration to be implemented as a Public Private Partnership (PPP);
- The risk differentials between the technical options identified at this stage are not material in terms of the ability to develop the procurement options identified;
- It is likely that the PPP options would take a form of a Design, Build, Finance – Operate (DBFO) type structure;
- The eventual form of the PPP will be dependant on the ownership of key risks such as demand, programme and existing bridge condition; and
- Tolling policy and PPP concession length will have a significant impact on the overall affordability of the project.

LEGISLATIVE ISSUES

A variety of statutory mechanisms have been reviewed by which, alone or in combination, the Scottish Ministers will be able to secure the necessary legal authority to construct a Forth Replacement Crossing. In a similar manner to the procurement and finance issues, it is not possible to be defintive at this stage about the best way forward until the following have been resolved:

- the identity of the promoter of the project;
- the type of crossing involved;
- the other parties who may be involved in the construction and operation of the crossing;
- the timing of the project; and
- the extent of the project (for example whether it involves the existing bridge and/or link roads to the new crossing).

As the project progresses and these issues become resolved then a clear picture of an appropriate legislative route should appear.

NEXT STEPS

The recommendation from this report is that Corridors C, D and E should be taken forward for a Part 1 STAG appraisal. Both bridge and tunnel options should be considered in these corridors. This will be done as part of the next package of work, which will also examine how public transport will be incorporated into the crossing.

1 INTRODUCTION

1.1 BACKGROUND

Jacobs and Faber Maunsell were commissioned by Transport Scotland to undertake the Strategic Transport Projects Review (STPR). The STPR commission involves identifying the strengths and weaknesses of the Scottish strategic transport network, identifying gaps between the future demand and capacity of the network, producing a prioritised list of interventions for the period 2012-22. The commission also covers a study of the Forth Replacement Crossing. This element of the work will be reported as follows:

- Report 1 : Network Performance;
- Report 2 : Gaps and Shortfalls;
- Report 3 : Option Generation and Sifting;
- Report 4 : Appraisal Report; and
- Report 5 : Final Report.

This is the third of these reports, Option Generation and Sifting. The objective of this element of the Study is to generate robust options for a potential replacement Forth Crossing. This has been done by utilising the outputs from the first two reports generated by this study together with other information taken from previous studies. It is clear from the findings of Report 2 that the "Do Nothing" option will not achieve the objectives set out and that action needs to be taken.

All options generated have been sifted against the objectives developed for this purpose in accordance with the principles of STAG.

The long list of options include different types of crossing, locations of crossing, the accommodation of different modes, connections to the existing transport network and the use of the existing road bridge for other transport users. The brief further required a number of different scenarios to be examined. For example:

- strategic traffic using a replacement crossing with local traffic using the existing bridge;
- the operation of the new crossing and the existing crossing as a one-way pair;
- a dedicated crossing for cars with the other being used for all other types of traffic; and
- provision for future heavy and/or light rail to be made in the new crossing either immediately or at some time in the future.

The brief calls for all aspects of the new crossing to be examined including:

- alignment of the crossing and its approaches;

- capacity;
- type/form of structure;
- type/form of solutions;
- ground condition; and
- environmental impact.

Construction and maintenance considerations have been examined together with associated risks. An assessment of the procurement and finance issues, together with the likely programme and timescales for the construction have been examined. Legislative issues have also been addressed.

Possible Complementary Measures which may improve the performance and/or capacity of the network have also been examined.

1.2 METHODOLOGY

The methodology adopted follows closely the Scottish Transport Appraisal Guidance (STAG) used by the Scottish Executive in 2003. STAG aims to aid transport planners and decision makers in the development of transport policies, plans, programmes and projects.

The process begins with an analysis of current and future conditions on the transport network. This was reported in Report 1: Network Performance and the key findings of this are summarised in section 1.3.1 below. From this assessment the gaps and shortfalls from expected levels of performance and future problems are identified. This then flows into the setting of objectives for the study. This was reported in Report 2: Gaps and Shortfalls and this document is summarised below in section 1.3.2.

This report (Report 3) contains the findings of the final stage of the STAG pre-appraisal process; the generation of options and initial sifting. It begins with a mapping of constraints in the study area such as environmental or other physical constraints that would influence the development of options to be considered. Once these constraints have been identified a long list of possible options is developed. As will be seen in chapter three the long list includes suggestions for different types and locations for new crossings but also a “No new crossing” option. Other forms of options (which could be introduced either with or without a new crossing) such as public transport and other more sustainable modes of transport are considered at this stage. The generation of options is concerned with the development of an overall comprehensive strategy for the Firth of Forth which covers all modes of transport.

The next step is to sift options into those which may assist in meeting the objectives. This is the final element of the STAG pre-appraisal process. As part of this some general design issues are explored to assist the understanding of how well each of the options might perform. The output from this is a shorter list of options which will be subjected to the appraisal required by STAG. This will be reported in Report 4: Appraisal Report.

This methodology also includes an assessment of financial, procurement, legislative and risk issues associated with the provision of a new crossing. These are reported in chapters seven and eight after the sifting has taken place.

The following section provides a resume of the key findings of Reports 1 and 2.

1.3 SUMMARY OF REPORTS 1 AND 2

1.3.1 Report 1 – Assessment Of Existing And Forecasting Future Condition Of Transport Network Around The Forth

Report 1 examines the current and forecast future (2012, 2017 and 2022) condition of the Forth Road Bridge, Forth Bridge and their surrounding transport networks. It also considers the likely environmental constraints that may be associated with any new crossing.

Forth Road Bridge

In spite of being maintained throughout its lifetime the Forth Road Bridge is showing signs of deterioration. These are mainly as a result of the growth in traffic flows, increasing vehicle weight and the influence of the weather and climate.

The main suspension cables are estimated to have lost between eight and ten per cent of their original construction strength. The current cable factor of safety is between 2.2 and 2.3. Predictions indicate that, at the present rate of corrosion, the factor of safety could fall below an acceptable value of 2.0 in 2013/2014.

It is expected that the installation of a dehumidification system in 2007-09 will arrest the loss of strength. However, should the dehumidification not work steps such as the restriction of Heavy Goods Vehicles (HGVs) would need to be phased in. FETA is currently undertaking a study into the potential replacement or strengthening of the main cables. Following the emergence of new information, the condition of the anchorages is also being considered as part of the Study. This report is due in late 2007.

Increasing maintenance is required to preserve the integrity and life of the Bridge, including;

- strengthening of the stiffening truss of the bridge deck;
- resurfacing of the deck and painting of the structure; and
- replacing the support bearings and bridge parapets.

This increased maintenance is required regardless of the problems of cable corrosion. Such maintenance will require temporary traffic management measures which will restrict the bridge capacity. It will not be possible to limit these to weekends and/or overnight as is currently the case.

Forth (Rail) Bridge

The Forth Bridge and operations of the rail network in the cross Forth corridor have been examined under the headings of route capability, maintenance, currently planned route improvements and potential future route improvements.

The work concludes that current and known potential enhancements are adequate to cater for rail growth for the foreseeable future. Providing these enhancements on the existing rail network is more cost effective than by means of a new rail crossing. Structurally the Forth Bridge has an expected remaining design life of over 100 years and there is no known significant maintenance issues associated with the existing Forth Bridge.

Traffic and Network Operation

Several key points can be highlighted in relation to current and future network operation;

- The Forth Road Bridge carries over 66,000 vehicles per day. This is expected to rise to approximately 79,000 vehicles by 2022;
- Peak conditions are encountered for several hours in the mornings and evenings and the periods over which peak flows are encountered are increasing;
- It is forecast that congestion will worsen significantly;
- Most vehicles crossing the Forth Road Bridge are single occupant cars;
- Rail patronage is expected to increase. This increase can be accommodated by current and likely future route enhancements, which will be more cost effectively delivered through the current rail network; and
- Bus patronage is forecast to decline, linked to increased bus journey times arising from congestion, mainly in Edinburgh.

In addition, on a wider basis, journey times are expected to increase for trips within Edinburgh. Average journey speeds across the entire SEStran area are expected to decline with consequent increases in journey times. Also, carbon dioxide levels across the wider SEStran area are forecast to increase by 23 per cent.

Environmental Constraints

The environmental constraints within and around the Firth have been examined. These will heavily influence the corridor selection for any Forth Replacement Crossing option.

Conclusions

There will be a requirement for increased maintenance on the Forth Road Bridge in the future regardless of the problems associated with the cables. This maintenance cannot be undertaken without temporary traffic management measures being implemented which will restrict the capacity of the crossing.

The forecast increases in daily traffic crossing the Forth will lead to a spreading of the peak periods and exacerbate the high levels of congestion experienced during restrictions or closures on the Bridge. It is also envisaged that due to the type of maintenance works expected to be undertaken on the Bridge in the future it will not be possible to limit these traffic management restrictions to weekends or overnight as is currently the case.

1.3.2 Report 2 – Expectations For Network Performance And Identification Of Gaps And Shortfalls

Report 2 focuses on establishing the high level expectations for transport network performance on, and in the vicinity of, the Forth Road and Rail Bridges. These expectations have been used to derive strategic transport planning objectives. These objectives have, in turn, been assessed against their performance criteria to identify gaps between desired and forecast performance levels.

Policy Background to Forth Replacement Crossing Study

A review of current and emerging policies and action plans at national, regional and local levels was undertaken. This included the National Transport Strategy (NTS), SEStran Regional Transport Strategy and FETA Local Transport Strategy. Broadly similar high level objectives were concurrent through all policy levels: to promote economic growth, social inclusion, health and protection of the environment through a safe, integrated, effective and efficient transport system. Fundamentally, the three key strategic outcomes from the NTS (improve journey times and connections; reduce emissions; and improve quality, accessibility and affordability) will need to be considered in any options being considered in the Study.

The following key priorities were identified;

- to promote modal shift and raise awareness of the need to change;
- promote new technologies and cleaner fuels; manage demand;
- reduce the need to travel;
- deliver reliable journey times for all road users;
- improve services for all transport users; and
- enhance movements of freight by non-road modes.

Development of Objectives

Emerging and current policies and action plans have been examined, together with the key issues arising from relevant consultations. This enabled the development of a number of specific transport planning objectives for the Study. These are as follows:

- to maintain cross Forth transport links for all modes to at least the level of service offered in 2006;
- to connect to the strategic transport network to aid optimisation of the network as a whole;
- to improve the reliability of journey times for all modes;
- to increase travel choices and improve integration across modes to encourage modal shift of people and goods;
- to improve accessibility and social inclusion;
- to minimise the impacts of maintenance on the effective operation of the transport network;
- to support sustainable development and economic growth; and
- to minimise the impact on people, the natural and cultural heritage of the Forth area.

Gaps and Shortfalls

Performance Indicators identified in Report 1 were examined, and linked to the appropriate objective outlined above. The Transport Model for Scotland was then used to measure how the forecast conditions in 2012, 2017, and 2022 performed against each objective. The scenarios included only those infrastructure projects that are likely to be in place by those dates. Other proposed infrastructure and policy improvements such as those included in the SEStran Regional Transport Strategy (which recognises the need for an additional crossing of the Forth) will be considered later in the study.

Conclusions

From the appraisal so far undertaken, it can be concluded that without intervention in the transport network over and above that currently planned, the objectives (outlined above) of the Forth Replacement Crossing Study will not be met. There are specific concerns regarding;

- achievement of air quality targets;
- reliability of journey times for all modes;
- being able to maintain cross Forth transport links for all modes to at least the level of service offered in 2006;
- the need to minimise impacts of maintenance on the effective operation of the transport network; and
- being able to support sustainable development and economic growth.

The next phases of the appraisal process will look in more detail at the objective of improving accessibility and social inclusion as well as the NTS expectations of reducing emissions and traffic stabilisation targets.

2 CONSTRAINTS MAPPING

2.1 INTRODUCTION

This chapter presents the various constraints which exist within the Firth of Forth. These constraints are important considerations in the development of the option(s). Within this chapter, an overview of the constraints is presented.

- environmental constraints
- physical constraints
- constraints imposed by condition of existing crossings

2.2 ENVIRONMENTAL CONSTRAINTS

The various environmental constraints are summarised on two drawings in Volume Two.

On Drawing 49550/G/03 the National Protected Sites are shown. These are summarised as follows:

Designation	Definition
Ramsar Site	Wetlands of international importance. Ramsar Sites are effectively protected, through the planning system, under the Wildlife and Countryside Act 1981, as amended, and the Countryside and Rights of Way Act 2000, through their notification as Sites of Special Scientific Interest (SSSI) and through other regulatory systems addressing water, soil and air quality.
Special Protection Area (SPA)	SPAs are the most important habitats for rare and migratory birds within the European Union. The Birds Directive, adopted by the UK in 1979, provides for the protection, management and control of all species of naturally occurring wild birds in the European territory of Member States, including the UK. The provisions of the Birds Directive are transposed into Scottish law by the Conservation (Natural Habitats &c) Regulations 1994

Designation	Definition
Special Area of Conservation (SAC)	SACs are sites that are chosen to conserve the natural habitat types and species of wild flora and fauna listed in Annex I and II of the Habitats Directive. They are the best areas to represent the range and variety of habitats and species within the European Union. The provisions of the Habitats Directive were transposed into Scottish law by the Conservation (Natural Habitats &c) Regulations 1994.
Sites of Special Scientific Interest (SSSI)	SSSIs are the best sites for wildlife, geological and geomorphological features in the UK. They are designated under the National Parks and Access to the Countryside Act 1949 and protected under the Wildlife and Countryside Act 1981, as amended and the Conservation (Natural Habitats &c) Regulations 1994.
Country Parks	Parks are set up by Local Authorities to provide open-air recreation facilities close to towns and cities. All the parks have a rural character and are managed primarily for informal recreation. Some have nature reserve areas and most have a visitor centre and ranger service to encourage and facilitate visitor understanding. Country Park is not a statutory designation. Countryside (Scotland) Act 1967 Section 48 gives local authorities power to assess and review the need for Country Parks in consultation with SNH.
Local Nature Reserves (LNR)	Local Nature Reserves are similar to National Nature Reserves but they apply to the local context. They are sites of value to nature conservation and are designated under the National Parks and Access to the Countryside Act 1949.
Gardens and Designed Landscape (GDL)	Significant historic gardens and designed landscapes are identified by SNH and Historic Scotland for their natural heritage and/or cultural importance. Inclusion on the Inventory of GDLs confers a measure of statutory planning control in relation to the sites concerned and their setting.

Designation	Definition
Scheduled Ancient Monuments (SAM)	A SAM is a protected archaeological site or historic building considered to be of national importance and is the highest level of cultural heritage designation present within the study area. In Scotland, Scheduled Ancient Monuments are defined in the Ancient Monuments and Archaeological Areas Act 1979 and are the responsibility of Historic Scotland.
Listed Buildings	Historic buildings are an important part of Scotland's heritage, providing a link to the history and culture of the country. Certain historic buildings, which are of special architectural or historic interest, can be designated as listed buildings and receive special treatment under the Planning (Listed Buildings and Conservation Areas) (Scotland) Act 1997. Listed buildings in Scotland are defined by Historic Scotland in three categories: A (national or international importance), B (regional or local importance) and C(S) (local importance or less).
Ancient Woodland Inventory Sites	An inventory of woodlands comprising woods recorded as being of semi-natural origin on *either* the 1750 Roy maps *or* the 1st Edition Ordnance Survey maps of 1860.
Long Established Woodlands of plantation origin	Woodlands on the Ancient woodland Inventory that appear as plantations on maps from 1750 or the mid-1800s. Native species of local provenance were generally used. These sites have been continuously wooded to the present day, and many have developed semi-natural characteristics.
Semi-Natural Woodland Inventory Sites	Information gathered by remote means using 1970s sources (maps, aerial photos) about the woodland cover present on Ancient & Long-Established Woodland Inventory sites. It does not contain information about woods not on the Inventory.
Other Plantation	Other historic woods appeared on the 1750 maps, were absent from those of the mid-1800s, but are present today.

Of these constraints the most influential are the combined effect of the SPA, Ramsar and SSSI areas which cover most of the intertidal areas between Kincardine and east of Queensferry. In addition, the location of the SAMs, listed buildings and landscaped gardens particularly on the south shore of the Firth pose localised environmental constraints.

On Drawing 48550/G/04 the Local Protected Sites are shown. These are summarised as follows:

Designation	Definition
Sites of Importance for Nature Conservation (SINC)	These non-statutory sites are sites designated by a local authority as being of local nature conservation value but are not notified as SSSIs. They have a variety of titles dependent upon the designating authority and include: Sites of Importance for Nature Conservation and Urban Wildlife Site.
Area of Great Landscape Value (AGLV) / Area of Outstanding Landscape Quality (AOLQ)	AGLVs and AOLQs may be designated by planning authorities for the purpose of safeguarding locally important areas of outstanding scenic character or quality from inappropriate development. The difference in name reflects the inconsistent approaches local authorities in Scotland have adopted with regard to sub-national landscape designation. In essence AGLVs and AOLQs are the same sub-national level of designation and as such are afforded the same level of protection through local plans and policies.
Greenbelt Areas	Greenbelt is a planning designation that is included within the various Local Plans applicable to the area. The intended function of Greenbelt is to limit and control urban sprawl and to enhance the setting and amenity of urban areas in the long-term. However, such areas of Greenbelt are under considerable pressure as economic growth demands more land to be released for housing and out of town office and business park developments.
Rights of Way	To qualify as a right of way, a route has to meet certain requirements. Principally it has to have been used by the general public for at least 20years and must link 2 public places.

Designation	Definition
Heritage Conservation / Conservation Areas	Provision for Conservation Areas is made in the Planning (Listed Buildings and Conservation Areas) (Scotland) Act 1997. Local Authorities have a duty to identify and designate areas pf special architectural or historic interest, the character or appearance of which it is desirable to preserve.
Tree Preservation Orders (TPOs)	Local Authorities can make provisions for the protection of specific trees or woodland through TPOs. TPOs prevent the felling, lopping, topping, uprooting or otherwise deliberate damage without the permission of the local planning authority.
Scottish Wildlife Trust Reserves	These non statutory sites are managed by the Scottish Wildlife Trust.
Wildlife and Provisional Wildlife Sites	Other non-statutory wildlife sites.

The combination of these locally protected sites again affects significant lengths of the south shore of the Firth and the area on the north shore west of Rosyth.

It should also be noted that in addition to the designated intertidal habitat of the SPAs, other habitats outside the SPA are of integral importance to the Firth and its designations. Sea ducks, divers and grebes feed, loaf and roost outside the SPA in the open waters of the Firth, waterfowl use adjacent fields for roosting and/or feeding in high tides and salmon migrate upstream to spawn in the River Teith Special Area for Conservation (SAC).

There is, therefore. an important relationship between the designated areas and non designated areas of the Firth, where impacts outwith the immediate boundaries of the SPAs may still affect the integrity of the designated areas. At this stage, these relationships are difficult to quantify, and the assessments that follow give more importance to direct impacts affecting the integrity of the SPAs. However, it should be borne in mind that direct impact does not equate, by default, to adverse impact on the integrity of the site; equally, indirect impact could have an adverse impact on the integrity of the site, although it is less likely.

2.3 PHYSICAL CONSTRAINTS

The various constraints have been summarised on drawing number 49550/G/01 and have mainly been obtained using information shown on admiralty charts 736 and 737.

These constraints are summarised as follows:

- oil, gas, electricity lines crossing the Firth;
- firing range protected areas;
- vessel anchorages and berthing areas for H.M. Ships;
- various outfall pipes; and
- BP oil pipeline from Kinneil to Dalmeny and Hound Point

Urban/ industrial/ defence constraints

Both north and south shores of the Firth of Forth are affected by urban and industrial development. Along the north shore these include Longannet Power Station, Culross, Valleyfield, Low Torry, Torryburn, Crombie MOD land, Charlestown, Limekilns, Rosyth Dockyards, North Queensferry, Inverkeithing and Dalgety Bay. On the south shore are located the Grangemouth refinery and town, Bo'ness, Hopetoun House and South Queensferry.

Oil pipeline from Kinneil to Dalmeny and Hound Point

Crude oil, which is refined in Grangemouth, flows via a 30 inch diameter pipeline from Kinneil, near Grangemouth to a storage tank area in Dalmeny. It then flows to Hound Point east of the Forth Rail Bridge via a 48 inch diameter pipeline.

This pipeline represents a critical constraint to construction on the south shore. The pipeline will need to be protected from any envisaged loads arising during and after construction.

Navigation clearances

The navigational clearances vary along the length of the Firth. A navigation channel with a maintained depth of 6.5 metres runs into Grangemouth Docks. From information provided by Forth Ports PLC, the navigational channel is approximately 450m wide between Grangemouth and Rosyth. East of Rosyth, the Rosyth channel width varies as shown on the Admiralty Charts and is limited to the south by Beamer Rock. The headroom clearance for bridge locations from the east of the Forth Bridge to Crombie Point is required to be 44 metres above high water level.

Geological and geotechnical issues

The potential crossing forms include both tunnel and bridge options, the feasibility of which is dominated by the constraints imposed by the geological setting. Specifically, these constraints relate to the rockhead contours in the Firth, the thickness and nature of the overlying alluvial deposits and the water depths in the main channels.

Bridge structures require to span the main shipping channel and to have foundations in the bedrock, or highly competent non-cohesive strata at depths of not more than approximately 40 metres below Ordnance Datum. This depth is chosen as being consistent with the existing bridges. Deeper foundations may be possible in extreme cases, but have not been considered at this juncture due to the significant additional costs that would be incurred. The existing Forth Road Bridge has caisson foundations on rock at about 30 metres depth for the southern pier. The northern pier stands on a submerged natural rock shelf (Mackintosh Rock) in about 10 metres of water. The Firth widens significantly on either side of the existing crossing points, which take advantage of the volcanic rock promontory of North Queensferry. The central support of the existing Forth Rail Bridge is founded on the island of Inch Garvie, a volcanic rock outcrop near to the middle of the Firth.

Tunnels are technically feasible within the alluvial deposits in the Firth and in the rocks that define the banks of the Forth. Transitions to localised hard rocks such as volcanic sills and dykes may present significant obstacles to the progress of the large tunnel boring machines (TBMs) required for a tunnel beneath the Forth. Hence knowledge of hard rock intrusions within the drift materials is of specific interest when considering tunnel options.

The extent of coal bearing strata and mine workings, present in the west of the study area, are of interest for both bridge and tunnel options. The presence of mine workings in or beneath construction zones may necessitate pre-treatment such as grouting to avoid subsequent collapse. The costs associated with stabilising such mine workings may be significant.

Available information

Land based investigations and studies have established the geology of the land area in significant detail. The solid and drift deposits are mapped at 1:50,000 scale and specific areas at 1:10,000 scale (or their imperial equivalents). However, this mapping only extends partially into the Firth. Data is available in the vicinity of Grangemouth, and again across the Firth between North and South Queensferry. Information for the latter was obtained from investigations for a proposed bridge crossing immediately to the west of the existing Forth Road Bridge, as recorded in various study reports for the “Setting Forth" Project in about 1994. It includes a study of rockhead levels on alignments through Beamer Rock, carried out by geophysical methods supplemented by boreholes.

In addition to the British Regional Geological Handbook "The Midland Valley of Scotland' and the Solid and Drift Geological Sheets (31E, Falkirk; 32W Livingston; 32 and 32E, Edinburgh; 39E, Alloa; and 40 Kinross), the British Geological Survey (BGS) has also published a specific report covering the western part of the study area, titled 'Engineering Geology of the Upper Forth,” 1986, (BGS Report Vol 16 No 8). Notably the bedrock surface is referred to as following the Carron depression eastwards along the Firth from Grangemouth and is reported to be generally at a depth of 70 metres along the central axis of the depression, increasing to in excess of 190 metres north of Bo'ness. This feature is described as being "remarkable” and clearly has a profound influence on the choice of sites suitable for bridge foundations. The feature is thought to have been formed by glacial erosion at the base of an ice sheet.

Except for mapping in the Firth near to Grangemouth and again around Beamer Rock, little useful information is available concerning rockhead contours in the Firth, other than close inshore. The BGS Report was commissioned to aid regional land based development, especially heavy industry and concentrates on the assessment of the suitability of the existing strata for founding heavy structures. Mapping provided in the report classifies areas according to bearing capacity and differentiates six categories ranging from “very good,” to “unpredictable (very poor to fair)”. It is noted that the BGS Report has drawn on data obtained from the Bothkennar “calibration” site, 3 kilometres north-west of Grangemouth, in order to characterise the generally soft sediments in the Firth of Forth.

For the preferred option(s), some form of site investigation would be required to establish the drift thicknesses over rockhead in the Firth where presently unknown. The likelihood of volcanic sills and dykes being buried within submarine drift deposits could present a constraint to tunnel construction. A distinctive feature of the geological mapping is the presence of dolerite rocks along the north and south shorelines, including the massive promontory at North Queensferry, and associated islands of Inch Garvie and Beamer Rock. These volcanic intrusions are significantly harder than the native bedrock and are reported as potentially up to 40 metres across where they occur as sills. It is considered that their presence has constrained the development of the Firth of Forth within its current boundaries. Given that the volcanics also remain as islands, it is conjectured that the absence of islands elsewhere in the Firth could be indicative of the absence of dykes and sills buried within the overlying drift deposits. This suggests that if originally present as minor features they are likely to have been removed by the advancing glacial ice sheet(s).

In this study, the available information has been used to create approximate cross sections of the Firth showing the conjectured geology. These cross sections have been drawn approximately along the proposed bridge alignments to establish an overview of the existing geology. This information is also applicable to the tunnel options at these locations. Using these cross sections has permitted a conservative evaluation of the depth to rock level at locations between Grangemouth and Queensferry. This information has been used to evaluate the relative merits of the alignments in the different corridors. As this study progresses into the next stage, and the options have been narrowed down to the preferred option(s), it will be important to carry out some form of site investigation to verify these conservative assumptions.

A further feature of the study area is the presence of numerous faults in the bedrock. Fault throws can range from a few metres to over 30 metres. Mild seismicity is also recorded, principally on the northern shore, and hence the design of any form of crossing will need to examine the implications of this feature in more detail.

More detailed information on the geological features of each corridor is presented later in this report.

2.4 CONSTRAINTS IMPOSED BY THE CONDITION OF THE EXISTING CROSSINGS

In this section, the constraints imposed by the condition of the existing crossings are discussed. This focuses primarily on the condition of the existing Forth Road Bridge as this has the most immediate impact on the study.

Main Suspension Cables

Following inspections of the west cable in 2004, significant corrosion has been detected. It is estimated that the cables have lost eight - ten per cent of their original construction strength. Based on the most pessimistic prediction of rate of corrosion, the factor of safety will fall below an acceptable level of 2.0 in 2013/ 2014. Acoustic monitoring has been installed to detect further wire breaks. Dehumidification of the cable will be installed by 2009 and will attempt to slow down or possibly stop the corrosion.

Studies are currently being carried out by FETA and their consultants to determine possible methods of replacing or augmenting the main cables. This study commenced in the Autumn of 2006 and it is expected that an interim report will be issued in May 2007. Discussions are ongoing between FETA and their consultants regarding a further inspection to establish a benchmark condition status of each cable at the completion of the installation of the dehumidification equipment.

As part of the study, FETA will need to investigate methods of modifying the cable anchorage chambers. There are several problems associated with this work, including possible land issues if the anchorages need to be extended. They also include an investigation into possible methods of testing the existing anchorage strands.

In addition, this study will review the need for traffic restrictions, but it would appear likely that lane or full carriageway closures will be required in order to carry out the cable replacement or augmentation.

Painting of Steelwork

The work necessary to paint the existing Forth Road Bridge requires a high level of containment to prevent pollutants escaping. This, combined with increasingly more stringent health and safety requirements, means that the costs of repainting are high. The work needs to be carried out under a rolling programme in order to avoid storing up future problems.

The stiffening truss supporting the bridge deck has a large number of exposed surfaces and connections which require periodic painting. Although this work is complex the majority of the painting can be carried out underneath the bridge using gantries with no disruption to the bridge users.

The painting needs to be carried out regardless of the loading on the bridge.

Surfacing

FETA estimate that the maximum life of the surfacing is eight years and envisage a phasing of work alternating northbound and southbound carriageways on an eight year cycle. If resurfacing is not carried out regularly there is a real risk that the composite action with the deck plate will be lost with a resulting reduction in the fatigue life of the deck plate.

Anchorages

There is a possibility that the main cable strands will have undergone hydrogen embrittlement and their condition needs to be determined. There are also concerns regarding corrosion of the strands due to the presence of water leeching out of the anchorages.

Due to the inaccessibility of the strands within the anchorages, the only possible method of determining if there is any movement is at the strand anchor bearing plate. As part of the cable replacement study, suitable methods of verifying the condition are being studied. The implications if there is a loss of strength of any of the strands is serious due to the complexity of any possible remedial works.

Bearings

The lateral restraint bearings at the main towers have already been refurbished. It would be reasonable to expect these bearings to have up to 40 years life.

FETA report that some of the bearings at the main towers may have seized and require replacement or refurbishment. This operation is likely to require short term carriageway closures and these may result in severe disruption to traffic.

It is anticipated that the approach viaduct bearings will need to be replaced. It is possible that these bearings can be replaced without major disruption to traffic. However, this cannot be confirmed until feasibility studies have been carried out.

Main Suspended Span Deck Joints and other Carriageway Joints

There is evidence of deterioration of the main expansion joints at the main towers and it is expected that these will be replaced in 2008/2009. Experience of replacing similar joints suggests that long duration carriageway closures will be required.

The carriageway joints are subject to wear and tear and FETA is examining longer term solutions to this problem. It is likely that these solutions will lead to disruption to of traffic during their installation.

The viaduct carriageway articulation and comb joints also need to be replaced as these are getting beyond economical repair. This will also lad to traffic disruption during replacement.

Parapets and Barriers

Following an assessment of the existing parapets compared to to current standards, it has been established that there is a general shortfall in their strength and geometric requirements. It is planned to test the condition of the suspended span outer carriageway barriers off site. The parapets at the edge of the viaduct carriageways have also been found to be understrength and it is planned to replace them.

Stiffening Truss

The top and bottom chords of the stiffening truss are reported to be overstressed under certain load combinations. An independent check on this work is currently being commissioned by FETA. In addition, it is possible that the stiffening truss will need to be strengthened to accommodate alternative connection positions to facilitate replacing the main cables should these be required.

It is likely that strengthening will consist of numerous localised plates which need to be welded to the existing steel. It is likely that the delivery of materials would require night time lane closures. It should also be noted that the addition of this strengthening may add to the weight carried by the overall structure of the bridge.

Effect of Lane and Carriageway Restrictions arising from Maintenance Work

FETA has an excellent knowledge of the effect of lane and carriageway closures in the vicinity of the bridge, and use their own staff to implement the traffic management. FETA seeks to maximise the use of any carriageway possession, for example by carrying out some of their own tasks whilst the carriageway is closed for use by a contractor. Long summer daylight hours are used to the maximum. Maintenance work is carried out whenever necessary overnight and at weekends to minimise disruption to bridge users.

Physical and aesthetic considerations of existing Forth Road and Rail bridges

A significant constraint on siting a new bridge will be its distance from existing structures. There must be sufficient distance between any new structure and the existing bridges to avoid aerodynamic interference. Any new structure must also be sited in such a way to reduce their or interference with the setting of the historic structures, principally the Forth Bridge.

Clearly Historic Scotland and Architecture and Design Scotland will have an interest in the aesthetic appearance of any new crossing and any visual impact on the existing bridges.

2.5 SUMMARY OF CONSTRAINTS

This chapter has identified a considerable number of very important environmental and physical constraints that will have a significant influence on the development of corridors for a new crossing. These range from the European designated Special Protection Areas containing important habitats for rare and migratory birds to locally protected sites such as Sites of Importance for Nature Conservation.

Physical constraints identified include navigation channels within the Firth, the critically important oil pipeline from Grangemouth to Dalmeny and Hound Point and key geological and geotechnical features throughout the Firth of Forth. All will have to be considered carefully when assessing the suitability of potential corridors.

There are a number of key constraints identified with respect to the future maintenance of the Forth Road Bridge. Many of these planned activities will significantly impact on traffic flow across the bridge as traffic management restrictions will be imposed for health and safety reasons. This will impose constraints on the ability of the Forth Road Bridge to operate normally for prolonged periods in the future and will need to be considered carefully in the context of the no new crossing option.

3 GENERATION OF OPTIONS

3.1 INTRODUCTION

The generation of a long list of options was initiated at a workshop that was held on 27th September 2006. This was attended by representatives of Transport Scotland, Scottish Executive, Jacobs, and Faber Maunsell. The workshop was facilitated by Capital Value and Risk Ltd and all attendees were encouraged to provide their thoughts on possible options. In total, a list of 65 options was generated by the workshop. This list is shown below.

Overall List of Crossing Options

No	Solution option	No	Solution option
1	Bridge at Queensferry for vehicular traffic	**34**	New rail bridge and adapt existing rail bridge for road
2	Bridge at Queensferry for light rail/ road	**35**	Build new road bridge and use existing road bridge for heavy rail
3	Bridge at Queensferry for heavy rail/ road	**36**	Build new road bridge and use existing bridge for guided busway
4	Bridge with hard shoulder for vehicles at Queensferry	**37**	Build new road bridge and use existing bridge for Non-Motorised Units
5	Bridge east of existing rail bridge	**38**	Arch bridge at various locations
6	Bridge west of Rosyth	**39**	Build new bridge for non road modes and use existing road bridge
7	Bridge at Grangemouth	**40**	Build new bridge for Heavy Goods Vehicles and use existing road bridge for light traffic
8	Viaduct at west of Rosyth	**41**	Utilise new bridge to generate energy source
9	Bridge east of Bo'ness	**42**	High Occupancy Vehicle lanes
10	Swing bridge at various locations	**43**	Dedicated bus lanes
11	Bridge at Leith/ Portobello to Kirkcaldy	**44**	Variable tolls
12	Bridge at Burntisland to Leith/ Portobello	**45**	No tolling
13	Cable stayed bridge at various locations	**46**	Multi lane free flow tolling
14	Strengthen existing rail bridge to carry road traffic	**47**	Active Traffic Management

No	Solution option	No	Solution option
15	Suspension bridge at various locations	48	Tidal working - vehicle movements
16	Balanced cantilever bridge	49	Twin bridge strategy - using one bridge south and one northbound
17	Single deck bridge options	50	Twin bridge strategy - using one bridge strategic and one local
18	Double deck bridge options	51	Do nothing
19	Dual carriageway bridge deck	52	Twin bridge strategy - using one bridge toll and one not tolled
20	Dual 2 lane bridge carriageway	53	Use existing bridge as Non-Motorised Unit crossing and use upgraded Kincardine bridge with upgraded road links back to M90
21	Dual 2 lane Motorway Standard	54	Maximise use of infrastructure at Kincardine bridge to create a new strategic north - south corridor
22	Dual 3 lane bridge carriageway	55	Future proofing new bridge for light or heavy rail
23	Dual 3 lane Motorway Standard	56	Immersed tunnels - covering ideas 1- 55
24	Provision for Non-Motorised Units	57	Bored tunnels - covering ideas 1- 55
25	Bus way	58	Combination of tunnel and bridges - covered in options 1-57
26	Light rail	59	Ferry crossing
27	Heavy rail	60	Hovercraft
28	Building in maintenance access facilities to bridge	61	Road ferry
29	Build new capacity onto existing bridge	62	Maximise use of retail/ commerce options with crossing
30	Close and replace/ repair existing bridge	63	Rail shuttle
31	Build new bridge and repair existing	64	Double decker rolling stock
32	Build new bridge and increase capacity of existing rail bridge	65	Travelator
33	Build new road bridge and use existing bridge as light rail		

3.2 LIGHT RAPID TRANSIT OPTIONS

Many of the options considered in the long list comprise forms of Light Rapid Transit (LRT) in the form of either Light Rail or Bus based systems.

The incorporation of LRT into any new crossing of the Forth or inclusion within a refurbished Forth Road Bridge is an issue to be considered as part of the corridor selection process.

There may be opportunities to extend the proposed Edinburgh Tram network across the Forth and into Fife. Clearly Dunfermline and Rosyth are potential markets that could be served by this, as could Dalgety Bay. If this scheme were developed, the tram network could be extended from the current proposed terminus point at Edinburgh Airport to the south bridgehead area via Newbridge, Kirkliston and the A8000.

North of the Forth the network could be formed by a loop which would take in the Dunfermline East expansion area (Dulloch Park), run along the Halbeath Road corridor using a disused rail corridor and forming street running operation southwards through Dunfermline town centre before running back to the Forth via Rosyth. A spur could be formed from this circuit serving Inverkeithing and Dalgety Bay.

There are many other forms of LRT that could be considered to service the markets described above. The market could be developed by firstly running high quality Bus Rapid Transit services (which could include Guided Busways where necessary). These could be formed through an extension of the bus priority measures currently in place in the west of Edinburgh (A8 Greenway and the A90 Quality Bus Corridor). The current draft SEStran Regional Transport Strategy includes schemes to expand the A90 Quality Bus Corridor. Similar bus based infrastructure improvements can be introduced within Fife to ensure journey time reliability to provide a cross Forth Quality Bus Network. Forms of bus priority are discussed further in section 3.4.

This network could then be upgraded to higher capacity forms of LRT as the market is developed and demand increases in the future. An outline of this network can be found on Drawing Number 49550/G/06.

The important issue at this stage of the option generation and sifting is to ensure that the potential for accommodating LRT is assessed in each of the options. This is highlighted in the relevant chapters later in this report.

3.3 HEAVY RAIL OPTIONS

Heavy rail featured in many of the options generated by the long list. Some options included suggestions that heavy rail should be provided for in a new crossing in addition to road traffic. Other options suggested that a new crossing should be built solely for heavy rail with the existing rail bridge being converted for other uses. There were many different options for enhanced heavy rail capacity involving various combinations of the new crossing (or no new crossing), the existing road bridge and the rail bridge.

The case for the inclusion of heavy rail in a new crossing has been considered in chapter four.

3.4 POSSIBLE COMPLEMENTARY MEASURES

Complementary Measures are those schemes which, whilst considered alone would not satisfy the objectives of the study, might be introduced to complement the overall cross Forth strategy. These include public transport enhancements and other sustainable forms of transport. In addition to forming a key element of the overall strategy they could be introduced as early, quick win, stand alone packages in advance of a new crossing.

High Occupancy Vehicle (HOV) Lanes

The introduction of HOV lanes is currently being investigated by Fife Council on behalf of SEStran. The purpose of these lanes will be to encourage drivers to share cars for journeys across the Forth thereby reducing the number of single occupant vehicles. Currently the average car occupancy in the morning peak is 1.2. It is slightly higher in the off peak at 1.4 but falls to 1.3 in the evening peak. The encouragement for drivers to share cars would be the access to the HOV lanes leading to the bridge and potentially across the bridge thereby allowing them to avoid the queues on the approaches in the same manner the bus lanes permit easier access.

An increase in the morning peak hour average car occupancy to 1.5 could be expected to reduce the number of cross Forth vehicles by around 20 per cent.

Fife Council is currently studying two options to implement HOV lanes on the Southbound approach to the Forth Road Bridge. One involves creating a HOV lane in the offside lane of the M90/A90 and the other uses the nearside lane. The latter option is currently favoured by Fife Council and incorporates ramp metering of the slip roads. The scheme primarily involves the use of the hardshoulder for HOV running with some localised additional carriageway widening.

The HOV scheme would be introduced in conjunction with the provision of Park and Choose Facilities in the North Bridgehead area.

Details of the HOV scheme and the benefits arising from it have been discussed between Transport Scotland and Fife Council. It is believed that SEStran are now seeking to develop the scheme further in conjunction with Transport Scotland. It is clear that the scheme, once implemented, could easily be adapted to integrate with the Strategy that arises from the Forth Replacement Crossing Study and will be considered further as part of this work.

Bus Priority

Bus Priority measures were introduced by City of Edinburgh Council on the east bound A90 approaching Barnton roundabout. These enabled buses to avoid the worst of the delays arising particularly in the morning peak through the provision of bus lanes and queue management system. This scheme is considered to be working well and is achieving its objectives.

Further Bus Priority measures could be introduced both within the south bridgehead area and also in Fife. On the south side outbound (or bridge bound) measures can be introduced which would complement the A90 eastbound measures described above. These would facilitate the flow of buses towards the bridge (and perhaps across it) and would be particularly helpful during the evening peak periods.

Within the Fife Bridgehead area a comprehensive bus priority network could be introduced linking the centres of Dunfermline and Rosyth with the M90/A90 corridor. These would be aimed at improving reliability and journey times for existing services and would encourage public transport operators to introduce new services from Fife to Edinburgh and West Lothian. The Fife network could be integrated with the proposed M90/A90 HOV scheme described above to produced an efficient “people movement” corridor across the Forth.

Park and Choose Sites

Park and Choose Sites are a natural extension of the already well established Park and Ride sites. Instead of being particularly focussed on providing interchange with a single particular mode, Park and Choose sites allow the onward journey to be made by a choice of modes. For example the Park and Choose site could be serviced by rail and bus services. Bus services could consist of a mix of feeder services serving the local catchment and express trunk services.

Park and Choose sites would also provide locations where car sharing can take place. Drivers would meet, leave one or more cars parked, and then continue their journey taking advantage of the HOV lanes. Park and Choose sites are currently being considered at Halbeath, Rosyth, Inverkeithing, Ferrytoll and Dalgety Bay.

Maximise Use of Cross Forth Rail Capacity

There will be opportunities to increase the capacity of Cross Forth rail services and this has been detailed elsewhere in this report. This covers the running of additional peak hour service once capacity is freed up when the Stirling Alloa Kincardine Rail line is opened and coal trains are diverted. There is also the opportunity to extend the existing service to six car train sets and perhaps even nine car sets in the future.

Other Measures

Further Complementary Measures to be examined will include:

- Ferry Services
- Active Traffic Management
- Variable Tolls

3.5 INITIAL TESTING OF COMPLEMENTARY MEASURES

Some preliminary testing of the Complementary Measures has been undertaken using the Transport Model for Scotland (TMfS). This work included bus priority measures in Fife and Edinburgh, additional express and local bus services, expanded Park and Ride/Choose sites and an upgrade to Rail capacity.

These tests were undertaken assuming there were restrictions on lane capacity across the Forth Road Bridge. This was to reflect one of two potential outcomes on the Bridge. The first was to reflect the restrictions that might be imposed as a consequence of major maintenance on the bridge. The second scenario assumed that one of the two lanes in each direction was for the exclusive use of buses and HOV. However, it should be noted that it has not been possible to model the likely behavioural response to HOV at this stage.

The test results showed that the additional public transport services would lead to increases in patronage particularly amongst bus users. However, it is clear from the results that the constraints imposed on motorists may have an impact on the number of people making journeys between Fife and Edinburgh/Lothians. A reduction of up to 33 per cent has been identified with the journeys being made instead to other destinations.

4 INITIAL SIFTING

4.1 INTRODUCTION

Following the generation of the long list of options and the development of the constraints mapping, an initial sift of the options was carried out. This was undertaken with a view to reducing the list by eliminating options which did not satisfy the objectives set for the study or were not technically feasible. The initial sifting process was undertaken using the constraints developed in chapter two as well as the study objectives and is detailed in section 4.2.

Once this exercise had been completed the remaining options were ordered into a logical grouping to allow the main sifting to take place. This is covered in chapter five.

The main thrust of the study is to identify a replacement option for the existing Forth Road Bridge. There is, of course, a likelihood that the structure can be repaired such that it can continue to provide transport connections into the future. However, it is clear that even if that was possible, the objectives of this study would not be achieved as illustrated in Report 2. This is discussed further below.

4.2 INITIAL SIFTING

Of the initial 65 options, 19 were rejected. The reasons for their rejection are given below and are summarised in Table 4.2. Many of those rejected were on the grounds of technical feasibility or that they would be uneconomical. Arch bridge and swing bridge options are examples of the former, whilst the suggestion of bridges or tunnels crossing between Leith/Portobello to either Kirkcaldy or Burntisland fell into the latter category.

Options involving ferries and hovercraft were rejected as they would not provide sufficient capacity on their own. They may have a role to play as part of a strategy for enhancing cross Forth public transport choices but are considered inappropriate as a solution for the Forth Replacement Crossing Study in their own right.

In the sections below, a brief summary explanation of the reasons why certain options were rejected is presented.

Option 3: Bridge at Queensferry for Heavy Rail/ Road

It is a requirement of the study brief that any new crossing should consider the inclusion of heavy rail into the new facility. A number of the options generated therefore included heavy rail either as part of a new bridge crossing or a tunnel.

Some preliminary cost estimates prepared by Faber Maunsell in 2004 found that the cost of a road bridge across the Forth combined with heavy rail would be approximately double that of the cost of a road bridge alone. Clearly when the marginal cost is of this magnitude then there has to be a clear case for providing additional heavy rail capacity in this manner.

The SEStran Integrated Transport Corridor Study (SITCoS) examined what the impact of providing additional rail capacity would be on cross Forth rail usage. The additional capacity was provided through the provision of longer trains (all trains assumed to be formed by six-car sets) together with associated platform lengthening. An additional two trains to Edinburgh were provided in the morning peak; one from Markinch via Dunfermline and the other from Kirkcaldy. The overall increase in seating capacity as a result of these improvements was a 120 per cent increase over the level within the May 2003 timetable. SITCoS found that the impact of this increase in capacity was an increase of around 50 per cent in cross Forth southbound morning peak hour rail passengers by 2026. A sensitivity test using a High Growth Land Use Scenario showed that demand could be boosted by a further seven per cent.

It should be noted that all stations in Fife except Ladybank (to Edinburgh platform only) and Springfield (which has a very low use) are now able to accommodate six car trains. The work currently underway at Edinburgh Waverley will permit the operation of more six car trains.

There are plans to introduce a further 1100 seats into Fife morning peak services. An additional 500 parking spaces have recently been added at Kirkcaldy and a similar number are being added at Markinch and Rosyth.

Clearly the provision of this additional capacity will adequately cater for the growth in cross Forth rail demand envisaged by the SITCoS report. Beyond 2026 it was recognised that further enhancements to capacity may be required. However, discussions with Network Rail have highlighted that these can be provided using the existing Forth Bridge and rail network without the need to provide additional capacity by means of a new crossing of the Forth.

Further capacity (beyond six car train sets) could be provided through the lengthening of platforms throughout the Fife Circle to accommodate longer train lengths. This option would also require consideration of the platform capacity at Edinburgh Waverley and the purchase of additional train sets. No work has been carried out by Network Rail on this option. However, it is expected to be in the order of £10m for platform extensions and around £100k per vehicle per year. Around 15 extra vehicles would be required to run an all nine car service over and above that required for an all six car service. It should be noted that Waverley Station can handle some additional nine car train sets. Reconfiguration of the layout would be possible to accommodate further lengthened platforms.

Electrification of the route would improve train performance through enhanced train performance characteristics i.e. the better acceleration performance associated with electric train units. The likelihood of the bridge being electrified would be slim as there are a number of constraints with regard to clearances on the existing bridge structure that would be needed to accommodate the overhead wires and associated steelwork. It is understood that a report has been prepared for Network Rail on the feasibility of electrifying the line between Edinburgh and Aberdeen. This report should be reviewed and updated as part of the Strategic Transport Projects Review to understand and assess if electrification would provide value for money benefits in increasing train performance and capacity across the bridge. It is anticipated that this option would be very expensive, certainly in the tens of millions of pounds.

The upgrade of track on the Fife Circle could enhance capacity, particularly between Thornton and Inverkeithing via Dunfermline. This would permit a higher line speed. Cost would depend on the speed that is to be achieved but it is considered that 70-90mph could be achieved over much of the route for less than £10m. However, the option requires to be assessed in conjunction with timetabling issues to ensure value for money in relation to any increased performance and capacity. Line speed improvements will aid the competitive position of rail as a mode, particularly from north Fife.

Current rail infrastructure technology and, in particular, signalling technology, dictates to a great extent the capacity of a route. As new technology develops it is highly likely that systems will be able to be designed that will increase the capacity of the railway network as a whole and the Forth Bridge route would be no exception. Currently new signalling systems like such as those utilising 'moving block' technology and driverless trains are being developed. These types of new innovative solutions would be likely to improve track capacity over the next 20 to 40 years and possibly beyond.

It is concluded that further cross Forth rail capacity can be provided on the existing rail network (including the Forth Bridge) in a more cost-effective manner than by incorporating heavy rail into a new crossing. It is therefore recommended that any future crossing of the Forth should not allow for further heavy rail and that those options proposing it are rejected from further consideration.

However, heavy rail has a clear role to play in any future cross Forth Transport Strategy. Further capacity and reliability enhancements to services using the Forth Bridge will be examined as part of the main Strategic Transport Project Review Study.

Option 10: Swing Bridge at various locations

A possible method of crossing the Forth could include a swing or lifting bridge over the navigation channel combined with an approach viaduct or continuous causeway. The advantage of a swing bridge is that the bridge vertical alignment can be kept low with consequent reduction in material and cost of the support columns and foundations or causeway. The moving section of the bridge need only be provided at the navigation channels.

The traffic management required for safe operation of a swing bridge would be complex and risky. It will inevitably introduce disruption to vehicles using the crossing. Approximately 400 vessel movements per month in and out of Grangemouth will introduce multiple bridge openings each day.

It has been determined that the largest existing swing bridge, El Ferdan crossing the Suez Canal provides an opening of only 340 metres. This is less than the navigation channel widths required for vessels serving Rosyth and Grangemouth. The time required to open the bridge is approximately 30 minutes leading to excessive closure of the bridge to vehicular traffic.

The longest existing vertical lift bridge has a 170 metres span and is therefore unlikely to provide sufficient navigational clearance.

The maintenance costs and the potential disruption if the heavy lifting machinery becomes inoperative will be high.

The environmental impacts of a multiple span viaduct would be increased due to the high number of bridge piers and foundations in the water or on the areas of SSSI. The barrage would lead to considerable environmental impact.

On this basis this option was rejected.

Option 11: Bridge at Leith/ Portobello to Kirkcaldy

The length of this bridge plus its approach viaducts would be approximately 15 kilometres long. A bridge crossing would need a main span of approximately 2000 metres to span over the Forth deep water channel in order to keep the main piers within a practical depth of water. This span would equal or exceed the largest so far provided in the world.

This option was discarded early on the grounds that it would not be economical.

Option 12: Bridge at Leith/ Portobello to Burntisland

The length of this bridge plus its approach viaducts would be approximately 9 kilometres long. A bridge crossing would need a main span of approximately 2000 metres to span over the Forth deep water channel in order to keep the main piers within a practical depth of water. Again, a 2000 metres span is equal to or greater than the largest so far constructed.

This option was discarded early on the grounds that it would not be economical.

Option 27: Heavy Rail

See option 3 above.

Option 29: Build new capacity into existing Forth Road Bridge

The condition of the existing bridge is described in detail in Report 1: Network Performance. In summary, the condition of the following major elements was described:

- Main Cables
- Painting of steelwork
- Resurfacing

- Anchorages for the main cables
- Support bearings
- Deck joints and carriageway joints
- Parapets and barriers
- Stiffening Truss

There are methods of tackling these issues individually but, with all complex structures, there is a high level of inter-relationship between the elements. Hence work on one element will tend to lead to work being required on the neighbouring elements. The following section provides a description of broader methods considered for building new capacity into the existing bridge.

1. Strengthening and widening of the Bridge

On other large suspension bridges it has been possible to widen and strengthen the structure. For example, on Tamar Suspension Bridge near Plymouth it was possible to widen the original three lane road deck such that it now has a 4 lane deck plus a wide footway/cycle track. This was achieved by the addition of cantilevered steel decks, additional cable stays to assist the main cables and strengthening of the stiffening truss.

One of the most important reasons why this strengthening was achievable on the Tamar Bridge was the fact that the original bridge deck was constructed from reinforced concrete supported on steel beams. This form of construction provides a relatively heavy deck. It was found that by replacing the existing deck with a much lighter steel deck, there was little increase in the overall self weight of the bridge. It was also possible to maintain three lanes of traffic at all times by diverting 2 lanes of traffic from the existing deck to the new cantilevered lanes during replacement of the existing deck.

The existing concrete towers and main cables for the bridge were assessed as having sufficient strength and did not require any work.

On the Forth Road Bridge, the existing main span road deck consists of a steel deck. It is, therefore, not possible to introduce a significantly lighter main span deck in a manner similar to that which was of such great benefit to the Tamar Bridge.

Bearing in mind the other issues, highlighted in Report 1, relating to the main cables and anchorages it was considered highly unlikely that the bridge could be strengthened in a similar way to Tamar Bridge without major disruption to the public. This option was therefore discarded.

The feasibility of running only light vehicles on the existing cantilevered footway/ cycle track has also been considered. According to the FETA safety guidelines the maximum weight limit for the footway is 3.5 tonnes. Therefore, it would need to be limited to cars and light vans only. This restriction may prove difficult to enforce. The surfacing is very thin on the footway (approximately 5mm) compared to the existing carriageway surfacing thickness of 38mm. Therefore it is highly likely that the thickness would need to be increased with a resulting increase in the dead load of the bridge.

The introduction of traffic onto the footway would also require upgrade of the parapets which would in turn lead to further strengthening of the structure to resist the design impact loads.

The addition of more load to the bridge would have implications on all the structural elements including the stiffening truss, hangers, main cables and towers. The stiffening truss requires strengthening under the current bridge loading and any increase in load would add to the complexity of the strengthening work. As mentioned above, a study is currently being carried out by FETA into the possible replacement of the main cable. The replacement cables would need to be designed to carry the additional load for any new bridge elements. The hangers and towers have already been replaced and strengthened respectively under previous contracts and these elements would need to be assessed for the further increased loads. The foundations of the bridge would also need to be assessed. The connections of the footway to the truss and also the cross girders underneath the existing carriageway may also require strengthening.

It is likely that modifications may be required to the footways as they pass around the towers to accommodate vehicle movement and minimise the impact risk.

The obvious implication for the bridge in this widened form is the loss of the walkway/ cycle track. This facility is currently used by FETA during their maintenance procedures and any future maintenance would be significantly hampered by the loss of the footway.

The above strengthening work would introduce major disruption to the bridge users. Frequent lane closures would be required to carry out the works and to facilitate the delivery of materials to the work site.

Due to the above issues it is considered that widening of the existing bridge is unlikely to be acceptable to the travelling public as it would create significant delays whilst in progress. It would introduce unacceptable constraints on future maintenance activities by removing the footway.

2. Replacement of the Deck

A radical way forward would be to replace the entire deck and its stiffening truss with a steel box girder deck. The box girder is used on most modern suspension bridges and was used on the Severn and Humber Bridges.

This solution would be extremely disruptive to the public but it has been achieved on the Lions Gate suspension bridge in Vancouver, Canada. On this bridge the bridge was closed at night during which sections of the existing deck were removed and replaced with new sections. This bridge is smaller than the Forth Road Bridge but the work still involved highly complex temporary works and lifting equipment.

This method has several advantages and could be carried out in the same contract as the works required for the replacement or augmentation of the main cables.

There are several advantages associated with this option:

- Significant savings in future painting operations due to less complexity in painted surfaces
- It has been estimated by FETA's consultants that the existing stiffening truss needs to be strengthened in any event. It is highly likely that this strengthening would be composed of localised plates being welded to the existing steel. In addition, it is possible that the stiffening truss would need to be strengthened to accommodate alternative connection positions to the replacement main cables. A new steel box girder can could be designed and fabricated to incorporate these issues.
- The problems associated with resurfacing could be reduced by increasing the thickness of the surfacing to 70mm or so. This is almost double the current 38mm. In this way, the upper thickness incorporating the damaged surfacing can be planed off leaving part of the surfacing adhered to the steel deck. Again, a new box girder could be designed to accommodate this increase in surfacing thickness.

The primary disadvantage with this option is the disruption to the bridge users. As described above, it may be possible to carry out this work using a similar method to that used at the Lions Gate Bridge. However, due to the increased complexity and disruption arising from the night time closures it is recommended that this option should only be considered as a way of building new capacity only when a new bridge crossing has been completed.

This method of replacing the existing deck was therefore not considered further for replacement crossings in this study.

3. Additional main cable and widened deck

Another possible method of widening the bridge is to extend the towers to support a third cable. This has been achieved on a suspension bridge in Rodenkirchen, Germany. In addition, the existing concrete deck of that bridge was replaced by a steel deck, thereby introducing a reduction in the dead load of the existing deck.

The main span at 378 metres is significantly smaller than the existing Forth Road Bridge. Hence the widening of the Forth Road Bridge would be much more complex. The engineering of a project of this nature is very complex. The main reason is the need to redistribute the load evenly into the three cables, rather than the two currently in place. This avoids overloading of the middle cable and the structural elements supporting the cable.

One of the reasons why this approach at Rodenkirchen was possible was that it was possible to make use of the reserve strength in the existing bridge foundations and towers. This strength was gained by the saving in weight from the replacement deck. For the Forth Road Bridge, as explained above, this saving in weight is not possible for the main span. Were it practical to undertake this option, the wider deck would provide improved aerodynamic stability of the structure.

There are several disadvantages with this option. Principally, the widening does not solve any of the existing problems in the bridge and concerns would still exist over the condition of the anchorage strands. Although it was possible to widen Rodenkirchen Bridge whilst maintaining traffic on the existing carriageway, it is highly likely that there would be disruption to the bridge users. Lane closures on the Forth Road Bridge would be required to carry the works and to allow delivery of materials. Such closures on the Forth Road Bridge would be very disruptive to traffic flows.

In addition, safety aspects during construction of the new bridge crossing and in particular the rock cutting through the rock outcrop at North Queensferry and reconstruction of the toll plaza would impose severe restrictions on traffic using the existing bridge.

For these reasons this option was not considered further.

Option 34: Build new rail bridge and adapt existing rail bridge for road

There is insufficient width on the existing rail bridge to provide similar capacity to the existing road bridge. This option was rejected.

Option 35: Build new road bridge and use existing road bridge for heavy rail

A rail bridge needs to have sufficient stiffness as well as strength in order to limit deflections of the bridge deck when trains are passing over. Suspension bridges are well suited to carrying loads placed uniformly along whole spans. They are not as capable at carrying short intense loads such as the weight of a train. The cables carry nearly all the imposed load and tend to deflect sharply where the load is applied. The deformation of a railway bridge under live load is a critical issue in considering options for any crossing.

The existing road bridge would need to be strengthened and stiffened in order to limit the deflections of the bridge. This would be complex to undertake. This option was, therefore, discarded.

The existing road bridge would also need to be strengthened and stiffened to carry light rail or trams. Bearing in mind the condition of the main cable, concerns over the condition of the anchorage strands and the ongoing maintenance requirements, it was concluded that this option was not economical and, therefore, discarded

Option 37: Build new road bridge and use existing bridge for Non Motorised Users

Non motorised users are cyclists and pedestrians. It was considered that limiting the use of the existing Forth Road Bridge solely to these classes of users was not an effective use of network capacity and are likely to increase the scope of works for a new bridge. Therefore, this option was discarded.

Option 38: Arch Bridge at Various Locations

Arch bridges in combination with long approach viaducts were considered as potential bridge types. It is possible to span up to 550 metres with this form of construction. Chao Tian Men Bridge in China will be the longest span arch bridge in the world on completion with a span of 552 metres. For comparison, the Sydney Harbour Bridge has a span of 503 metres. Due to the limitation on the span length, an arch bridge would only be feasible for the crossing options upstream of Rosyth where it is required to span over the Grangemouth navigational channel. However, an arch would not provide the full headroom clearance over the full width of the span. For a span of 500 metres it is likely that an arch bridge would not be as economical as a cable stayed bridge. For these reasons arch bridges were discarded as potential bridge options.

Option 39: Build new bridge for non-road modes and use existing road bridge

This option does not relieve the loading on the existing bridge. Hence in the event that the dehumidification of the main cable is not successful, the traffic on the existing bridge would need to be restricted. For this reason this option was discarded.

Option 41: Utilise new bridge to generate energy source

Using a new bridge as a source to generate energy could be done by constructing a barrage which would form a causeway across the Firth of Forth, allowing traffic to cross. The causeway could then be used as a tidal energy generation station.

Tidal generation through construction of a barrage has been considered for the Severn Estuary for some time to make use of the large tidal range in that estuary. However, these plans have not yet been put in place. A barrage was constructed at St Malo in Northern France in 1965 and has successfully been used to generate electricity. The tidal range within the Firth of Forth is approximately five metres which is significantly less than the Severn Estuary.

A lock would be required to permit vessels to move along the Firth. This lock would need to cater for the largest envisaged vessel which will use the Firth. It may also be possible to provide a smaller lock adjacent to the main lock to cater for leisure craft.

To provide similar traffic capacity to the existing bridge, the causeway would need to accommodate at least two lanes in each direction plus hard shoulders to allow for breakdowns and maintenance. Movable bridges would need to be provided west and east of the lock. To allow for the times when one bridge is open it has been suggested that the causeway should accommodate four lanes in each direction. This would facilitate a minimum of two lanes of traffic in each direction.

The optimum location for the barrage is dictated by several factors including the location of the navigation channels, number of ships, width and depth of the Firth and its effectiveness in providing adequate relief to the existing Forth Road Bridge. A barrage near Queensferry would contain a larger mass of water for generation purposes. However, the locks would need to cater for large ships using Hounds Point oil facility and Rosyth docks as well as those using Grangemouth oil facility and Crombie Point.

The water depth near Queensferry is considerably deeper than further upstream (west of Rosyth) making construction in this area far more risky and costly. In addition, it is likely that two sets of locks would be required for the commercial shipping at the location of the existing Grangemouth and Rosyth navigation channels.

To the west of Rosyth, there are large areas of mudflats, particularly on the south side. The Firth becomes shallower, and a navigation channel is located closer to the north shore. Also, there are located areas for berthing HM Ships and the Charleston Roads area for anchoring small vessels. The locks would need to cater for ships primarily serving Grangemouth oil facility and Crombie Point.

The environmental impacts associated with construction and operation of a barrage in the Firth of Forth would be considerable. Practically all of the inter-tidal areas within the Firth, together with some adjacent coastal habitats such as dune systems, are designated as the Firth of Forth SPA, Ramsar site, and SSSI and in addition many of the islands in the Forth are designated as an SPA. A barrage west of Rosyth would have direct and adverse impact on the integrity of the Firth of Forth SPA, as the barrage would obliterate a substantial area of the SPA in these areas. In addition, there may also be direct impacts on the Forth Islands SPA, as some of its constituent islands, for example Long Craig Island, would be located west of the barrage and, therefore, be potentially subject to changes to water levels and the tidal regime.

A barrage near Queensferry may also have direct and adverse impacts on the Firth of Forth SPA depending on the footprint of the structure, which would be substantially greater than a bridge option. In addition, due to the existing topography, the likely northern landfall for a barrage in this area would be through the St Margaret's Marsh SSSI reed beds which also may be breeding and/or wintering habitat for Schedule 1 species such as marsh harrier.

For all potential locations, a barrage would also cause indirect adverse impacts on the integrity of the SPAs due to the significant changes to hydrology, currents and sedimentation patterns in the Forth. These changes could also mean the loss, or significant alteration of, inter-tidal habitats and species, as well as changes to open water conditions that would affect feeding and other behavioural opportunities for SPA related bird species using areas not directly within the SPAs. Long Craig Island, part of the Forth Islands SPA, is low lying and would, potentially, be flooded with a small increase in water level, as mentioned above. Impacts would not be restricted to the immediate locality of the barrage, but are likely to be widespread, affecting the significant mudflats and wintering bird assemblages of Kinneil Kerse and Skinflats near Grangemouth. Changes to sedimentation may also require significant dredging and sediment management regimes that would also have environmental impact including on the SPAs and SPA related features.

In addition to direct and indirect impacts on the SPAs within the Firth, there would be indirect adverse impacts on the River Teith Special Area of Conservation (SAC), which is designated due to the presence of Atlantic salmon and freshwater pearl mussels. It is likely that migration of salmon to and from the River Teith via the Forth would be impeded by the barrage. Interfering with salmon movements would also adversely impact on the River Teith's freshwater pearl mussel population, which is dependent on the salmon for part of its life cycle. Other protected migratory fish species such as lamprey, eel and sea trout would also be impacted in the upper Forth tributaries. Ecological issues associated with the barrage would also include impacts on European Protected Species such as cetaceans that are known to use the Forth.

The barrage would create a significant visual impact on the landscape and seascape, across what is currently a wide and very open water body. In addition, there may be an increased risk of flooding upstream and possibly downstream of the barrage, depending on tides. Furthermore, during construction there may be significant disturbance of sediments leading to mobilisation of contaminants contained within these sediments.

Finally, bringing forward a barrage scheme that may include energy generation would require significant research effort to determine the likely hydrological, geological and ecological consequences of the scheme, as well as understanding the effects that removing energy from the Firth for power generation would have on these and other receptors. Feasibility studies would have to be commissioned in order to determine whether the environmental and energy costs of constructing the barrage (e.g. its carbon footprint) would ever be offset by the renewable energy that could be generated by the barrage in its operational lifetime. Completion of such studies could significantly delay delivery of a replacement crossing for the Forth.

Information received from Forth Ports PLC has established that the largest vessels serving Grangemouth are 187 metres long, breadth 27.4 metres with a maximum draught of 11.0 metres. On average, the number of vessels serving Grangemouth is 200 and the number of passages through a lock would therefore be 400.

Further information received from both Forth Ports PLC and Rosyth Docks has established that the maximum size of vessels currently using Crombie Point are the Ark Royal type vessels which are 210 metres long, breadth of 36 metres and maximum draught of 8.2 metres. However, there are plans to introduce new Aircraft Carriers up to 300 metres long, breadth of 45 metres at waterline and 60 metres at the flight deck and a maximum draught of 11 metres.

Therefore the main lock would need to accommodate the largest Aircraft Carriers up to 300 metres long and 60 metres wide.

In addition, numerous pleasure craft, tugs and barges need to be accommodated in secondary locks within the length of the barrage.

In order to construct the barrage it will be necessary to provide rockfill down to bedrock level as the upper sediments are described as fair to unpredictable. The bedrock level west of Rosyth, for example, is assumed to be a maximum of approximately 100 metres below the water level. Therefore, assuming a slope of 1 to 1 for the rock infill, the volume of rockfill required is substantial when considered over the 4 kilometres length of the causeway. This will reflect in the very high cost and environmental impacts of quarrying for the material.

The maximum length of ship projected to serve Crombie Point is 290 metres which results in a lock the size required for the Panama Canal.

The lifting bridges will require a clear span of about 80 metres. The complexity of the bridges, their foundations and the maintenance of the mechanical lifting gear will lead to high cost and could lead to severe disruption if the lifting gear becomes inoperative.

The traffic management required for safe operation of the causeway is complex and risky. It will inevitably introduce disruption to vehicles using the causeway. Approximately 400 vessel movements per month in and out of Grangemouth will introduce multiple lock operations each day. If the vessels need to wait for high tides before they use the locks these may coincide with the rush hour for the causeway traffic.

In conclusion, it is not considered that a barrage will provide a feasible replacement crossing to the Forth Road Bridge without incurring high costs and high environmental impact to the Firth of Forth.

Option 51: Do Nothing/Do Minimum

Option No. 51 “Do Nothing” (or Do Minimum”) has also been rejected from this initial sift on the basis that it does not meet the objectives set for the study. This was demonstrated in Report 2: Gaps and Shortfalls which concluded that without intervention in the transport network, over and above that currently planned, the objectives of the study would not be met. A summary of the assessment of this case is given below in Table 4.1 below.

Table 4.1 - Summary of Assessment of Option 51 – “Do Nothing/Do Minimum”

Objective	Measurement	Assessment
Maintain cross Forth transport links for all modes to at least the level of service offered in 2006	Road journey times	Not met
	Bus journey times	Not met
	Rail crowding cross Forth	Not met
Connect to the strategic transport network to aid optimisation of the network as a whole	Average road speeds	Not met
Improve the reliability of	Number of vehicle hours	Not met

Objective	Measurement	Assessment
journey times for all modes	between J4 of the M90 and Echline Roundabout below free-flow speed	
Increase travel choices and improve integration across modes to encourage modal shift of people and goods	Public transport mode share across the Forth	Not met
Improve accessibility and social inclusion	Road journey times between areas of deprivation and major employment centres	Not met
	Public transport journey times between areas of deprivation and major employment centres	Not met
Minimise the impacts of maintenance on the effective operation of the transport network	Total annual average weekday flow on the Forth Road Bridge	Not met
	Annual average weekday HGV flow across the Forth Road Bridge	Not met
Minimise the impact on people, the natural and cultural heritage of the Forth area	Pollutant emissions from transport in the SEStran area.	Not met (CO_2)
Support sustainable development and economic growth	Pollutant emissions from transport in the SEStran area.	Not met (CO_2)
	Annual average weekday HGV flow across the Forth Road Bridge	Not met
	Public transport mode share across the Forth	Not met
	Total annual average weekday flow on the Forth Road Bridge	Not met
	Number of vehicle hours between J4 of the M90 and Echline Roundabout below free-flow speed	Not met

Further examination of the Do Nothing/Do Minimum case was examined given during the sifting process. This involved the examination of a "no-new crossing" scenario in which:

- enhanced public transport (rail and bus) services were introduced together with
- extensive priority for bus services on both sides of the Forth and
- High Occupancy Vehicles priority on the M90/A90 southbound approach. and

- the A985 in south Fife was upgraded to Dual 2 lane Carriageway standard between Kincardine and the proposed Rosyth Bypass

This "no-new crossing" scenario differs from the Do Minimum, as it proposes additional infrastructure to In order to maximise the use of the Upper Forth Crossings at Kincardine for vehicular traffic the A985 was upgraded to Dual 2 lane Carriageway standard between Kincardine and the proposed Rosyth Bypass. It should be noted that this scenario is purely indicative of possible interventions and does not represent a commitment by Transport Scotland or any other organisation to implement any of them.

The Transport Model for Scotland (TMfS) was used to examine the impacts of this No-new crossing scenario and found that it is would be likely to result in changes to travel patterns and choices throughout the study area in 2022. The modelling suggests that in the morning peak hour there would be an increase of up to one third in the number of southbound trips made by public transport to take place in the morning peak hour. It is also possible that southbound am peak hour traffic on the Forth Road Bridge could reduce by up to one third.

However, one key finding arising from this scenario is the fact that there is expected to be a reduction of up to 33 per cent in the number of people making journeys between Fife and Edinburgh/Lothians. These journeys are being made instead to other destinations such as the Falkirk/Stirling areas or are remaining within Fife. Although the wider economic impacts of this have not been assessed it is clear that, given the synergy that currently exists between Fife and Edinburgh/Lothians that there will be substantial economic impacts as a consequence of this scenario.

It can therefore be concluded that the "Do Nothing" or "Do Minimum" case is not an option that should be pursued and that some form of intervention is required.

Option 53: Use existing bridge as Non Motorised Unit User Crossing and use upgraded Kincardine Bridges with upgraded road links to M90

Non Motorised Users are defined as cyclists and pedestrians and as in Option 37 this option was rejected as it was considered to be an inefficient use of the existing road bridge. Further, the diversion of all motorised traffic to Kincardine would be economically unacceptable. It was considered that this option would not satisfy the objectives of the study.

Option 54: Maximise use of infrastructure at Kincardine Bridges to create a new strategic north-south corridor

This option was rejected as it was considered that the use of the Kincardine Bridges corridor would not satisfy the objectives of the study. Studies have shown that the likely diversion of traffic from the Forth Road Bridge to Kincardine resulting from the opening of the new Upper Forth Crossing is likely to be small.

Option 59: Ferry Crossing

A passenger ferry crossing across the Firth of Forth may have a role to play in enhancing cross forth public transport choices. However, it clearly cannot provide the capacity required to be considered as an option for a Forth Replacement Crossing and has therefore been rejected.

Option 60: Hovercraft

The Hovercraft option is rejected for the same reasons as the Ferry given above.

Option 61: Road Ferry

The concept of a road ferry is that of a large multi-axle vehicle used to transport other road-going vehicles. The use of road ferries has been proposed for the existing Forth Road Bridge as an alternative to a new crossing.

In essence, the road ferry aims to increase the traffic capacity of the bridge by two means:

- Reducing the transit time between the two ends of the bridge; and
- Increasing the number of vehicles on the bridge at any time by reducing the distance between adjacent vehicles.

The key features of the road ferries were described in a report by Professor Stephen Salter of Edinburgh University and are reproduced below:

- Large numbers of wide, closely spaced low-pressure tyres with very soft suspensions to reduce local contact stresses in the bridge deck;
- A wide wheel base spanning two lanes to reduce contact stresses in the cross-beams;
- Long ferry lengths to reduce the number of fatigue cycles in the vertical suspension cables;
- Centralised, coherent computer-control with each ferry ‘knowing’ the position, velocity and acceleration of all ferries so that they can travel close together even at high speeds.

The ability of road ferries as described in Professor Salter’s paper to achieve these aims and ideas have been critically reviewed, in terms of the reduced transit time and the reduction of stresses in the bridge structure. It is an essential premise of the scheme that no structural modifications are required to the bridge structure. The practicalities of introducing such a revolutionary scheme to an existing bridge have also been reviewed. However, no review has been made of the detailed mechanical aspects of the proposals.

It is obvious to note that the presence of road ferries will, of course, increase the loads carried by the bridge, by virtue of their own self weight.

The claims made for the road ferry concept in terms of the reduction in transit time and the reduction of stresses on the bridge do not withstand detailed scrutiny. There is a high likelihood that the stiffening truss will need to be strengthened. As the concept is based on untried technology, the time and expense required to develop to the requisite level cannot be accurately determined.

Option 63: Rail Shuttle

The rail shuttle option is rejected for the same reasons as given for Option 3.

Option 65: Travelator

This would not provide sufficient capacity and is therefore rejected.

Table 4.2 – Options Rejected from Initial Sift

No.	Option Description	Reason for Rejection
3	Bridge at Queensferry for Heavy Rail/Road	More effective ways of providing additional heavy rail capacity using the existing rail bridge and rail network.
10	Swing bridge at various locations	Largest existing swing bridge, El Ferdan crossing the Suez Canal provides an opening of 340m. Time required to open the bridge is approximately 30 minutes leading to excessive closure of bridge. Longest existing vertical lift bridge is 170m span and unlikely to provide sufficient navigational clearance.
11	Bridge at Leith/Portobello to Kirkcaldy	Bridge too long and uneconomical.
12	Bridge at Leith/Portobello to Burntisland	Bridge too long and uneconomical.
27	Heavy Rail Option	More effective ways of providing additional heavy rail capacity using the existing rail bridge and rail network

29	Build new capacity into existing bridge	Insufficient capacity in deteriorating main cable. It is not possible to repeat the Tamar Bridge solution as the main span deck is already an orthotropic deck.
34	Build new rail bridge and adapt existing rail bridge for road	Insufficient width to existing rail structure. High complexity of widening the bridge.
35	Build new road bridge and use existing bridge as heavy rail	Insufficient strength and probably insufficient stiffness to limit deformation under rail traffic.
37	Build new road bridge and use existing bridge for Non Motorised Units Users	Uneconomical and inefficient use of the existing road bridge.
38	Arch Bridge at various locations	Not as economical as cable stayed bridges.
39	Build new bridge for non-road modes and use existing road bridge	This does not relieve loading on the existing road bridge.
41	Utilise new bridge to generate energy source	High cost, wide environmental impact and effect on traffic capacity.
51	Do Nothing/Do Minimum	Does not satisfy objectives.
53	Use existing bridge as Non Motorised Unit User Crossing and use upgraded Kincardine Bridge with upgraded road links to M90	Does not satisfy the travel pattern demands on the existing road bridge.
54	Maximise use of infrastructure at Kincardine Bridge to create a new strategic North-South corridor	Does not satisfy objectives.
59	Ferry Crossing	This alone will not provide sufficient

		capacity.
60	Hovercraft	This alone will not provide sufficient capacity.
61	Road Ferry	Unproven and requires strengthening of the Forth Road Bridge
63	Rail Shuttle	More effective ways of providing additional heavy rail capacity using the existing rail bridge and rail network
65	Travelator	This alone will not satisfy the objectives.

5 OPTION DEVELOPMENT FOR SIFTING

5.1 THEMATIC GROUPING

The Initial Sifting saw 46 options taken forward for further consideration. These options fall into seven broad categories:

- crossing location;
- bridge crossings;
- tunnel crossings;
- capacity/operational configuration;
- multi modal capability;
- operational options; and
- miscellaneous others.

Table 5.1 allocates each of the remaining options to one of the categories defined above. A hierarchical approach to the appraisal has been followed to ensure that the major issues were dealt with adequately before turning to the more detailed issues.

Table 5.1 – Options Carried Forward for Further Consideration

Thematic Category	Options
Crossing Locations	1 – 2, 4 – 9, 14
Bridge Crossings	13, 15 – 16, 31 - 32
Tunnel Crossings	56 - 58
Capacity/Operational Configuration	17 – 24, 28, 33, 40, 48 – 50, 52
Multi-Modal Capability	25 – 26, 36, 43, 55
Miscellaneous Others	30, 42, 44 – 47, 62, 64

5.2 CORRIDOR SIFTING CRITERIA

The approach adopted for the purposes of this report was is to consider the first three categories above; namely crossing location, bridge crossings and tunnel crossings. All other issues will be considered once a clear view on these primary issues has been developed.

The remainder of this report therefore considers bridge and tunnel options in the following five corridors:

A – Grangemouth (West of Bo'ness);

B – East of Bo'ness;

C – West of Rosyth;

D - East of Rosyth/West of Queensferry; and

E – East of Queensferry.

Each corridor has been determined by the constraints mapped out in chapter two. In the STAG appraisal process to be reported in Report 4, each option will be appraised against the study objectives (the planning objectives) and the Government's 5 key objectives of Environment, Economy, Safety, Accessibility/Social Inclusion and Integration. At this stage however the sifting aims to assess each corridor for its suitability in achieving the study objectives given the constraints identified in chapter two. It is worth at this stage re-stating the objectives below and identify how each will be used to help sift the corridors.

Maintain cross Forth transport links for all modes to at least the level of service offered in 2006

The corridors have been assessed on the basis of how well each assists in reducing future traffic levels in 2012, 2017 and 2022 on the existing Forth Road Bridge to 2006 levels. The Transport Model for Scotland has been used to predict the likely usage of a crossing in the new corridor and the existing Forth Road Bridge.

Connect to the strategic transport network to aid optimisation of the network as a whole

The corridors have been assessed in terms of the opportunities they can provide to improve the overall efficiency of the transport networks.

Improve the reliability of journey times for all modes

This examines how well a crossing in the corridor will assist in reducing congestion on the road network and therefore increase the reliability of road based journey times. It also examines the opportunities to improve the reliability of public transport journey times through the corridors ability to provide enhanced public transport services either directly or indirectly.

Increase travel choices and improve integration across modes to encourage modal shift of people and goods

This explores how well each corridor is likely to improve the choice of public transport services available for journeys which are currently made by private vehicles

Improve accessibility and social inclusion

This examines how each corridor will make it easier for non-car owners to make journeys to access places of employment, educational and healthcare facilities and other vital journeys of this nature.

Minimise the impacts of maintenance on the effective operation of the transport network

This objective is essentially about how the new corridor can operate in conjunction with the existing Forth Road Bridge during periods of planned maintenance to ensure that delays on the network as a whole are minimised. This also extends to operating during periods of unplanned incidents such as accidents and when high wind restrictions are in force on the Forth Road Bridge.

Support sustainable development and economic growth

This looks at the location of the corridor in the context of known development and economic active areas on either side of the Forth

Minimise the impact on people, the natural and cultural heritage of the Forth area

Finally, the corridors are assessed for the likely environmental impact that might incur if a crossing was to be introduced within it.

5.3 CORRIDOR SIFTING ASSUMPTIONS

For the purposes of this option sifting it has been assumed that the new crossing being examined in each corridor is a dual two lane carriageway with hard shoulders. Other cross section standards will be appraised in the next report of the Forth Replacement Crossing Study. Likewise, the issue of the specific provision for public transport facilities such as Light Rapid Transit (LRT) or busways will be assessed in the next report. However, it is clear that the proximity of the corridor to the existing transport networks will have an influence in the final selection.

The ability of the new crossing to provide flexibility during periods of network maintenance (including the existing Forth Road Bridge) will also be a determining factor in the selection of corridors. However, the detail of operation of the crossing with the existing bridge will also be dealt with later in this study.

Finally, it is assumed for the purposes of this sifting that tolls on the new crossing will be set at the level currently paid at the Forth Road Bridge.

In the next stage of the study a strategy will be developed. This will determine how a new crossing could operate in conjunction with the existing road bridge. This will consider the normal operating condition of the crossings (will they operate as a one-way pair or be dedicated to particular markets/modes). It will also consider how the crossing(s) would operate in tandem during periods of planned maintenance, unforeseen incidents and during periods of high winds.

The strategy will also include details on how public transport and other sustainable modes of transport such as High Occupancy Vehicles could be incorporated into the crossings.

Each of the five corridors vary in terms of the width of water to be crossed, the geological features encountered or the environmental issues to be faced. As a consequence there may be locations where a particular type of crossing may be more suited than others. There are a number of design considerations which have to be considered before the best crossing type can be found. The remaining sections of this chapter explore some of the key design issues associated with bridge crossings and tunnel crossings. Further detail on these matters can be found in Appendix A

5.4 BRIDGE CROSSING DESIGN ISSUES

By the very nature of the wide Firth and the need to span over the navigation channels, any bridge crossing the Forth would tend to have long spans. Any final bridge would, in all likelihood, combine a long span over the navigation channel combined with approach viaducts of shorter length.

The suitability and form of any bridge will depend on several design issues relating to constraints which include:

- navigation channel width and headroom clearance;
- underlying geology and its suitability for foundations;
- environmental constraints;
- archaeological and historical sites;
- pipelines and electricity transmission cables;
- urban developments; and
- proximity to existing bridges.

The above constraints were presented in outline in chapter two. Both suspension bridges and cable stayed bridges would be able to accommodate these constraints and each are now outlined below. Further information on both types of bridge can be found in Appendix A.

Suspension Bridges

Suspension bridges are technically feasible across the Forth and have the advantage that they can provide large spans of up to 2000 metres. This has a clear benefit of providing adequate navigation clearance and minimises foundations for piers in the Firth of Forth. The Forth Road Bridge is a suspension bridge with a maximum span of 1006 metres and the preferred option for the crossing during the Setting Forth study was a suspension bridge with a maximum span of 1375m.

The maximum span suspension bridge achieved to date is the Akashi Kaikyo Bridge in Japan with a maximum span of 1991 metres. The main towers, which are 298 metres above water level, are 142 metres higher than those of the Forth Road Bridge. In the following sections it will be shown that bridges with spans of this magnitude may be necessary to cross the Firth of Forth within some of the corridors under consideration.

Figure: 5.1 Akashi Kaikyo Bridge

Approach viaducts and link roads will be required to connect any new bridge (or tunnel) to the associated transport networks.

The advantages of suspension bridges compared to cable stayed bridges are set out below:

- the long spans provide maximum clearance for navigation channels;
- the design minimises the number of piers and foundations in the Firth;
- by reducing the number of piers a suspension bridge potentially reduces the environmental impact and blockage of the Firth that would be associated with foundation construction; and
- the longer span possible means that foundations of a suspension bridge can be founded in relatively shallow water, so reducing the construction and cost risks of working in deeper water;

The disadvantages of suspension bridges compared to cable stayed bridges are;

- construction risks associated with erection of the main cable and deck in this exposed environment of the Forth. However, significant construction risks are also associated with the deck erection of cable stayed bridges;

- potentially increased risk of methane on the south landfall. During construction of the Forth Road Bridge south anchorage, methane was detected in the anchorages. Current health and safety standards would lead the design to a gravity anchor solution which would minimise any excavation; and

- a suspension bridge has a slightly longer construction programme compared to a cable stayed bridge.

5.4.1 Typical Construction Sequence

The construction of a suspension bridge follows a generally linear programme, with little opportunity for concurrent working. The exception to this is that more than one tower or foundation can be constructed at the same time if the resources, particularly specialist plant, are available. The broad sequence of activities is as follows:

- construct foundations and anchorages;
- construct towers and backspan piers;
- install main suspension cables;
- erect cable hangers and deck units; and
- install finishes (road surfacing, bridge deck furniture, communications, etc.).

5.4.2 Approach Viaducts

Approach viaducts and suitable connecting roads would be required to link any bridge to the associated transport networks. The construction of these elements would not be on the critical path. It is probable that they would be built in conjunction with elements of the main bridge to provide some continuity of work for the operatives. However, it may be considered advantageous to construct them fairly early in the overall programme to provide access to the deck of the main bridge.

5.4.3 Aerodynamic Performance

Aerodynamic stability of long suspension bridges is an extremely important consideration in their design and construction. This issue was most famously illustrated in the example of the Tacoma Narrows Bridge which became unstable under relatively low wind speeds. Should a bridge be the preferred solution for an additional or replacement crossing, models of suitable bridges would be tested in wind tunnel machines. The models would incorporate significant existing topographical features and adjacent structures if present such as the existing Road and Rail Bridges. These tests would be used to determine how well any new bridge remains stable up to critical wind speeds.

5.4.4 Ship Collision on Piers

Bridge piers need to be designed to withstand the impact of errant marine vessels. The only limitation in marine settings is the water depth which limits the size of vessel which could reach the piers. The largest vessel that can be accommodated at Grangemouth is a 33,000 deadweight tonne (DWT) oil tanker. The potential impact force of such vessels will have a major influence on the design of the foundations. For the corridors where the rock level is significantly below the water level, any ship impact forces would need to be transferred by the pile group.

5.4.5 Wind Shielding

The existing Forth Road Bridge has no wind shielding and as a consequence operations are often disrupted during periods of high winds. In the UK wind shielding is provided on the whole length of the Second Severn Crossing. This was a conscious decision to provide protection to traffic on this strategic route, which suffered closures of the first Severn crossing during periods of high winds.

5.4.6 Construction Programme

It is estimated that the construction time for a suspension bridge across the Forth would be between 5.5 and 7.5 years in duration depending on the span and the location. For comparison the construction duration for the world's 10 longest main spans is tabulated below.

Table 5.1 – World's Longest Suspension Bridges

Ranking	Name	Main Span (metres)	Completion Date	Construction Duration (Years)
1	Akashi-Kaikyo, Japan	1991	1998	10
2	Great Belt Bridge, Denmark	1624	1998	7
3	Runyang, China	1490	2005	5
4	Humber, UK	1410	1981	8
5	Jiangyin, China	1385	1999	5
6	Tsing Ma, HK	1377	1997	5
7	Verrazano Narrows, USA	1298	1964	5
8	Golden Gate,USA	1280	1937	4
9	High Coast, Sweden	1210	1997	4
10	Mackinac, USA	1158	1957	2.5

It can be seen from the above table that the estimate is within the range of construction durations for completed long span suspension bridges.

Further technical details relating to suspension bridges can be found in Appendix A.

Cable Stayed Bridges

Cable stayed bridges are also technically feasible across the Forth. However, due to the width of the Firth, and span limitations, it would inevitably require a tower foundation located in the deeper water close to the centre of the Firth unless use can be made of an island such as Beamer Rock. With current technology spans of approximately 1000 metres can be achieved. The maximum existing cable stayed bridge span is 890 metres on the Tatara Bridge in Japan. The towers are 224 metres high making them 66 metres higher than the Forth Road Bridge. Construction is currently underway on the Sutong cable stayed bridge in China with a maximum span of 1088 metres. Several cable stayed bridge options were developed in the Setting Forth project with maximum spans of 650 metres. As noted above, with improvements in technology, increased spans can now be achieved. Rion-AntiRion Bridge, Greece, pictured below was opened in 2004. It has maximum spans of 560 metres and its foundations are founded in water up to 65 metres deep. (See Figure 5.2 below)

Figure: 5.2 Rion-AntiRion Bridge, Greece

The approach viaducts associated with cable stayed bridges would tend to be longer than those associated with suspension bridges as the main span of a cable stayed bridge is more limited in length than that of a suspension bridge. The Oresund Bridge between Sweden and Denmark has a maximum span of 490 metres and carries combined rail and road.

The advantages of cable stayed bridges compared to suspension bridges are:

- slightly shorter construction programme; and
- construction of the foundations at the landfalls are less complex than those for a suspension bridge as they do not need to provide tension anchorage. The foundations and substructure are relatively simple abutments. As a result of reduced excavation the potential problems associated with the presence of methane on the south landfall could be reduced.

The disadvantages of cable stayed bridges are:

- they have shorter spans than suspension bridges, leading to an increased number of piers and foundations in the Firth. It is likely that the foundations would be sited in deeper water than those of a suspension bridge, with a commensurate increase in construction risk affecting costs and contract duration;
- the increased number of piers in the Firth would have a greater environmental impact and would increase the blockage of the Firth; and
- although there are significant construction risks associated with the erection of suspension bridge main cables, the risks associated with the deck erection of a cable stayed bridge also need to be carefully managed.

In the following sections the design considerations affecting a cable stayed bridge are presented.

5.4.7 Typical Construction Sequence

The construction of a cable stayed bridge deck typically uses a cantilever approach. The broad sequence of activities is as follows:

- construct foundations;
- construct towers and abutments;
- erect cantilever deck sections progressively with cable stays; and
- install finishes (road surfacing, bridge deck furniture, communications etc).

Construction Programme

A review of the construction duration for the world's longest main span cable stayed bridges has been made in order to assist in estimating the construction programme for cable stayed options across the Forth.

The maximum spans of the bridge options required across the Firth would be approximately 650 metres. The construction sequence is complicated by the fact that the crossing requires two main spans with a common central tower. Rion-Antirion bridge in Greece consists of several multiple spans and is a reasonable indicator of the construction period. It can therefore be expected that the construction period would be in the region of five to six years.

Table 5.2 – World's Longest Cable Stayed Bridges

Ranking	Name	Span (metres)	Completion Date	Construction Duration (Years)
1	Sutong, China	1088	Expected 2009	
2	Stonecutters, HK	1018	Expected 2008	
3	Tatara, Japan	890	1999	6
4	Pont de Normandie, France	856	1995	7
5	Second Yangtze	628	2001	4
6	SkyBridge, Canada	616	1990	?
7	Rion-Antirion, Greece	560	2004	6 (including dredging)
8	Skarnsund, Norway	530	1991	?
9	Kohlbrandbrucke, Germany	520	1974	4
10	Mumbai, India	500		

Further technical details relating to cable stayed bridges can be found in Appendix A.

5.5 TUNNEL OPTIONS

Construction of a tunnel crossing is regarded as a technically feasible solution for the Forth Crossing and there are a variety of methods available. Previous studies, including the "Setting Forth" study considered and then rejected a tunnelled solution. Tunnelling techniques and equipment have developed significantly in size and ability to cope with a broader range of ground conditions since that report, as have elements of bridge design and construction. Environmental requirements have also developed and their bearing on this type of major project has evolved. It is, therefore prudent to re-evaluate the full range of tunnel options. This evaluation must also include developments in tunnelling technology to allow a balanced and up-to-date evaluation of the Forth Replacement Crossing to take place.

To determine the most applicable methods for a tunnel and therefore the basis for tunnel option generation, it is necessary to understand the requirements for tunnel design in terms of alignment geometry, internal spatial requirements, ground conditions and risks.

Design Standards for Tunnels

UK road tunnelling projects of over 250 metres length are designed to the “Design of Road Tunnels”, Part 9 of the Design Manual for Roads and Tunnels, BD 78/79 and associated Standards and industry practices. For the purposes of design it is assumed that the route will form part of the trans-European road network. Its design will therefore be compliant with the European Parliament and Council Directive No. 2004/54/EC “The Road Tunnel Safety Regulations 2007”. These are under consultation at the time of writing and may be refined further before being implemented. For the purposes of this report it has been assumed that any Forth tunnel would have to be designed under the current consultation criteria.

Provision for Light Rapid Transit in Tunnels

One of the objectives of a future Forth Replacement Crossing is to make provision for a future multimodal crossing solution. This may incorporate Light Rapid Transport (LRT) such as Light Rail or other modes such as guided busways.

For the tunnel solution, the combination of a dual two-lane road crossing with LRT would require a very large diameter tunnel and complex internal arrangement or an additional single tunnel for LRT alone. For this reason LRT and modes other than conventional road vehicles are assumed to be incorporated in an independent structure. This frees these alternative crossing modes to adopt their own optimum alignment and tunnelling methodology. This may be significantly different from any road crossing as tie in to existing networks and geometric requirements can vary from mode to mode. This approach may increase efficiency and cost-effectiveness over a combined approach. Therefore, tunnelling options discussed here only consider the road tunnel crossing solutions.

Tunnel Spatial Requirements

Creating an economic and efficient tunnel for several modes of transport requires accommodating these within a defined space whilst minimising the overall diameter of the structure. Given that the primary objective of any Forth Replacement crossing is to provide a level of service equal to that of the existing road bridge, a dual two-lane crossing is proposed. This matches the level of capacity offered b the existing crossing.

There may be a number of temporary possibilities for a shared use tunnel, or tunnels carrying road and either light rail or guided bus way. These possibilities will be evaluated when the overall crossing strategy, that includes the temporary and permanent function of the existing road bridge, is further refined.

To understand the size of a road tunnel and hence the options available for its construction it is necessary to identify the individual building blocks that would be used to build up the tunnel cross section. There are many services and safety functions that must be accommodated in the tunnel along with the roadway itself. Tunnel design elements can broadly be categorised into the following:

- Roadway Provision;
- Ventilation; and
- Safety and Fire.

Each is discussed in greater detail in Appendix A.

Safety Provisions

The 2007 EU directive, currently out for consultation but due to be introduced in 2007, gives enhanced safety provisions over and above those identified in the Design Manual for Roads and Bridges.

Maintenance and Operating Costs

Maintenance and operating costs can form a significant proportion of the whole-life costs of a road tunnel. It can often be the case that a tunnel with reduced construction costs can have a much higher whole life costs due to operation and maintenance requirements. Key operational elements include the following:

- Ventilation – influenced by traffic volume, length of diameter of congestion risk, tunnel gradient, sifting of ventilation plant.
- Lighting – Influenced by length of tunnel, operating light levels, type and position of lighting and fixtures.
- Pumping and Drainage – Influenced by tunnel inflow, groundwater pressure outside tunnel, quality of construction and pipework, amount of rain and other water entering the portals, the number of sumps and pumping distances.

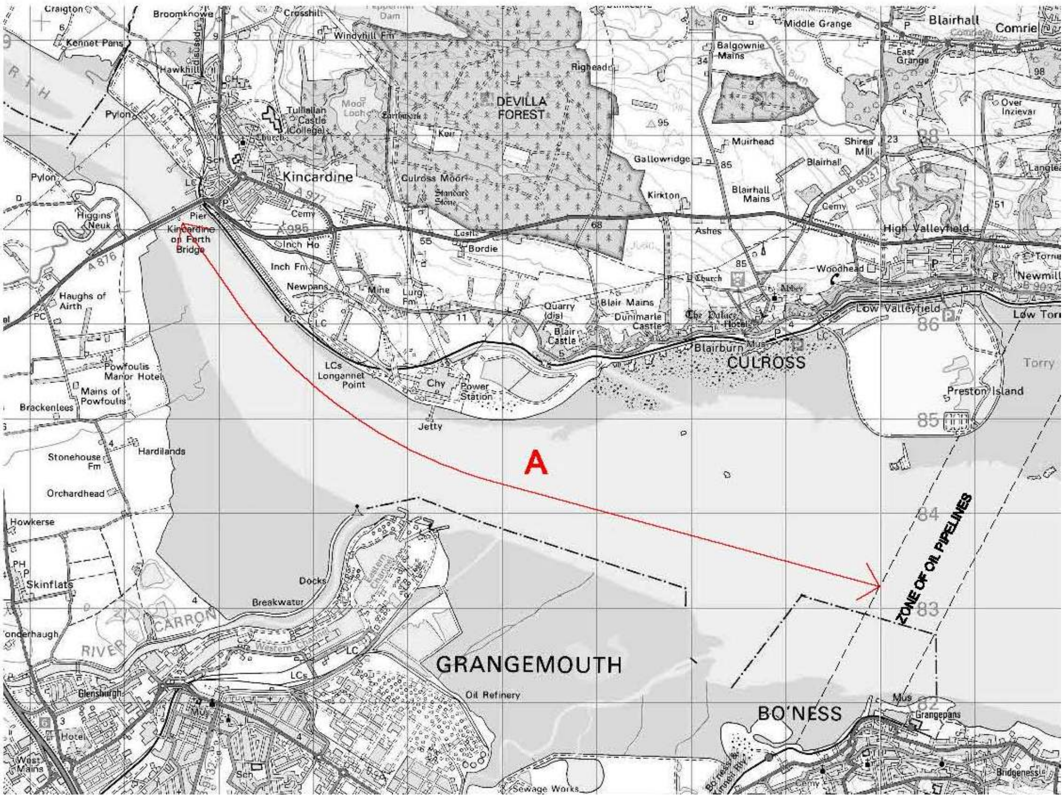
Further details relating to design and construction issues relating to tunnels can be found in Appendix A.

6 CORRIDOR ASSESSMENT

6.1 INTRODUCTION

In this chapter the sifting of the five corridors is summarised. Further details can be found in Appendix B to F. Costs of the different options have been expressed in terms of indices where the lowest cost option equates to 1.0. It should be noted that these costs include the construction costs for the crossing including linkages to the trunk road network. At this stage the costs do not include the maintenance, operational or other “whole life” costs. These will be examined in the next report.

6.2 CORRIDOR A



Corridor A is the most westerly of the five options and, as shown in Drawing Number 49550/G/02, is defined by the west boundary formed by the existing Kincardine Bridge and the east boundary is formed by the oil pipeline which crosses the Firth between Bo’ness and Torry Bay. From an assessment of the geological conditions it was found that foundations of a bridge would be very problematic in Corridor A. The depth of the bedrock will lead to deep and uneconomic foundations. Hence it has been considered that an alignment in this corridor will be difficult to justify in overall terms when compared to other corridors.

A test of Corridor A's operational performance has been undertaken using the Transport Model for Scotland (TMfS). This test is representative of both a potential tunnel and bridge option in this corridor. In this test the crossing is connected to the M9 at or around Junction 4. On the north side it connects to the A985 to the west of Culross. The section of the A985 eastwards to the A823(M) is upgraded to dual two lane carriageway standard.

This test has been run in two different scenarios. The first assumes that the new crossing is simply added to the existing network and there are therefore two crossings available to the motorist. This test has been run for the forecast years of 2012, 2017 and 2022.

Clearly this corridor is some distance from the existing Forth Road Bridge and the results from the TMfS reflect this. In the first model scenario around five per cent of traffic divert from the existing Forth Road Bridge in all three forecast years.

The second scenario modelled assumes that the existing Forth Road Bridge is closed to all traffic and therefore only the new crossing is available. This latter case is representative of the situation that might exist when the existing bridge has to be closed for maintenance purposes. This test has been run for 2012 only.

In this scenario there is an increase of one per cent in total daily travel time and a six per cent increase in the daily distance travelled. This increase is unsurprising given the extra distance that all vehicles are forced to travel and the additional time incurred as a consequence within the study area.

It is considered that this corridor would have little value in providing support to the Forth Road Bridge during periods of major maintenance. Also the distance from the existing Forth Road Bridge would mean that this corridor would have little advantage over the Kincardine crossings as a high winds diversion route.

With both crossings available (the first scenario) the daily traffic flow on the Forth Road Bridge is envisaged to be around 68,000 in 2012 growing to 75,000 in 2022. It is clear therefore that the objective of maintaining cross Forth transport links to at least the level of service offered in 2006 will not be met by a crossing in Corridor A.

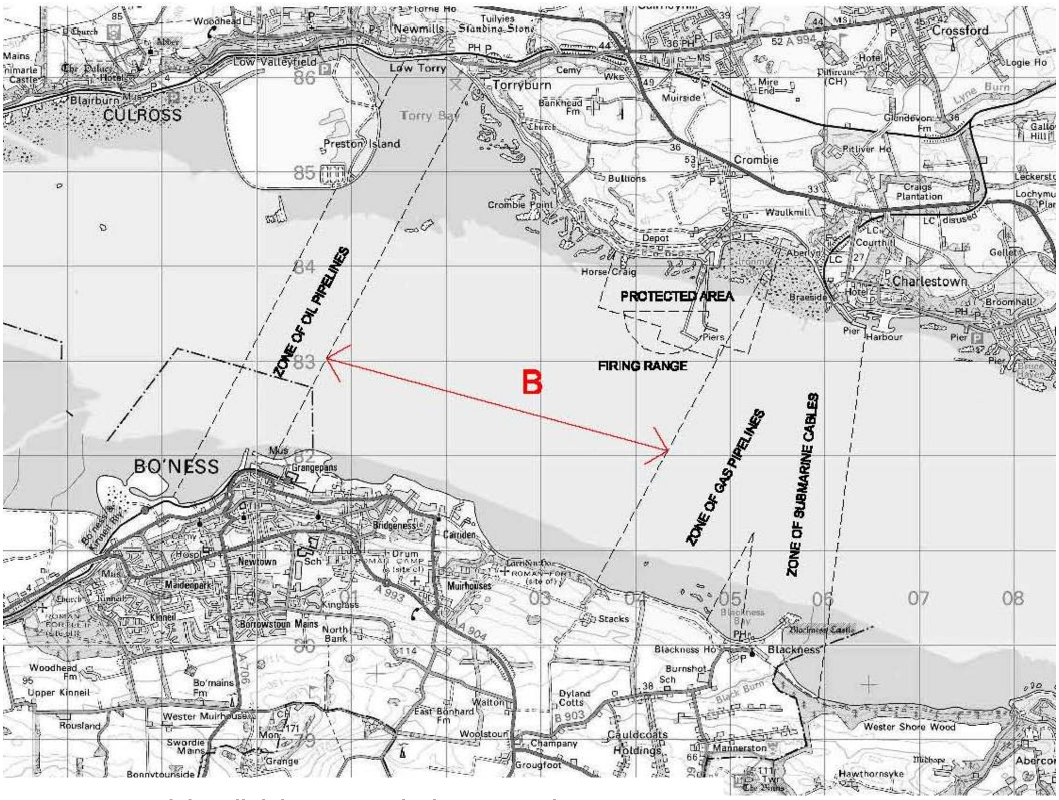
The increase in total distance travelled and extra time incurred during the closure of the Forth Road Bridge will result in additional economic costs. In addition there would be consequential environmental impacts resulting from the additional distance travelled.

Further, this corridor is remote from the main public transport cross Forth corridors and the ability to integrate enhanced public transport services into a new crossing will be remote. There would be little prospect of new LRT modes being usefully incorporated into a crossing in this corridor. However, public transport priority could be introduced onto the existing Forth Road Bridge on completion of the new crossing.

The remote location of this corridor (in terms of distance from the existing Forth Road Bridge) results in this performing poorly against the objectives. This corridor was dismissed quite early in the studies as a consequence. In addition, this crossing is likely to have significant environmental impacts on people and the natural and built environment.

Further details on this corridor can be found in Appendix B.

6.3 CORRIDOR B



Corridor B is the second of the options to be assessed and, as shown in Drawing Number 49550/G/02, is defined by the west boundary formed by the oil pipeline which crosses the Firth between Bo'ness and Torry Bay. The east boundary is formed by the gas pipelines which crosses the Firth between the area west of Blackness Bay and Ironmill Bay.

East of Grangemouth, between Preston Island on the north and Bo'ness on the south, (both substantial rock outcrops within Corridor B), from the information available, it is suggested that rockhead plunges to an anticipated depth of 190m in the middle of the Forth. The maximum depth to rockhead is anticipated to decrease eastwards, although conjectural depths have not been mapped.

The log of one borehole near the northern edge of the current shipping channel was extended to over 100 metres without reaching rockhead. In this corridor the overlying sediments are classified as ranging from fair to unpredictable. In the absence of more detailed information the sediments are judged unsuitable as founding strata for the main towers of a suspension bridge of this size.

A test of Corridor B's operational performance has been undertaken using the TMfS. This test is representative of both a potential tunnel and bridge option in this corridor. In this test the crossing is connected to the M9 at Junction 3 (Linlithgow). On the north side it connects to the A985 to the west of Cairneyhill. At this point options were available for the subsequent connection to the M90 corridor. One option was to simply upgrade the A985 eastwards to the junction with the A985(M) as was assumed for Corridor A. The other option is to create a new bypass around the north of Dunfermline joining the M90 at Hill of Beith. For the purposes of the modelling tests the former option was used as it was considered that this would meet the demands of the expected users better.

Although this corridor is closer to the existing Forth Road Bridge than Corridor A it is still some distance from the existing Forth Road Bridge and once again the results from the TMfS reflect this. In the first model scenario around eight per cent of traffic divert from the existing Forth Road Bridge in each of the three forecast years.

The second scenario modelled assumes that the existing Forth Road Bridge is closed to all traffic and therefore only the new crossing is available for cross Forth trips. This latter case is representative of the situation that might exist should the existing bridge be closed for maintenance purposes. This test has been run for 2012 only.

In the scenario when only this new corridor is available, there is an increase of one per cent total daily vehicle hours and four per cent increase in daily vehicle kilometres across the network. This increase is unsurprising given the extra distance that all vehicles are forced to travel and the additional time incurred as a consequence.

It is considered that this corridor would have little value in providing support to the Forth Road Bridge during periods of major maintenance.

With both crossings available (the first scenario) the daily traffic flow on the Forth Road Bridge is envisaged to be around 67,000 in 2012 rising to 74,000 in 2022. It is clear therefore that the first objective of maintaining cross Forth transport links to at least the level of service offered in 2006 will not be met.

The increase in the distance travelled and extra time spent travelling during closure of the Forth Road Bridge will result in additional economic costs. In addition there will be consequential environmental impacts resulting from the additional distance travelled.

Although this corridor is closer to the Forth Road Bridge and the Forth Bridge than Corridor A it is still remote from the main public transport cross Forth corridors and the opportunity to integrate enhanced public transport services into a new crossing in this corridor will be reduced as a consequence. There would be little prospect of new LRT modes being usefully incorporated into a crossing in this corridor. However, public transport priority could be introduced onto the existing Forth Road Bridge after completion of the Crossing.

The Firth of Forth SPA (which is also a Ramsar site and a Site of Special Scientific Interest) represents the over riding constraint on the northern and to a lesser degree on the southern fringes of the Firth. It is afforded the highest level of protection in the UK and there is a presumption against causing adverse impact unless the development is of over riding public interest and there are no alternatives. In addition, any impacts to the qualifying bird species using the Firth out with the SPA may impact on the ecological integrity of the SPA.

Other significant constraints comprise the Scheduled Ancient Monuments in the vicinity of the Antonine Wall at the southern end of the route corridor. In addition, some areas of Ancient Woodland and listed buildings would be affected by this corridor.

Construction of a bridge in this area will impact on local communities and will impact on visual amenity as well as introducing a new noise source to the area. The bridge is also likely to reduce local air quality as well as contributing to increased global CO_2 due to overall increases in traffic capacity across the Forth.

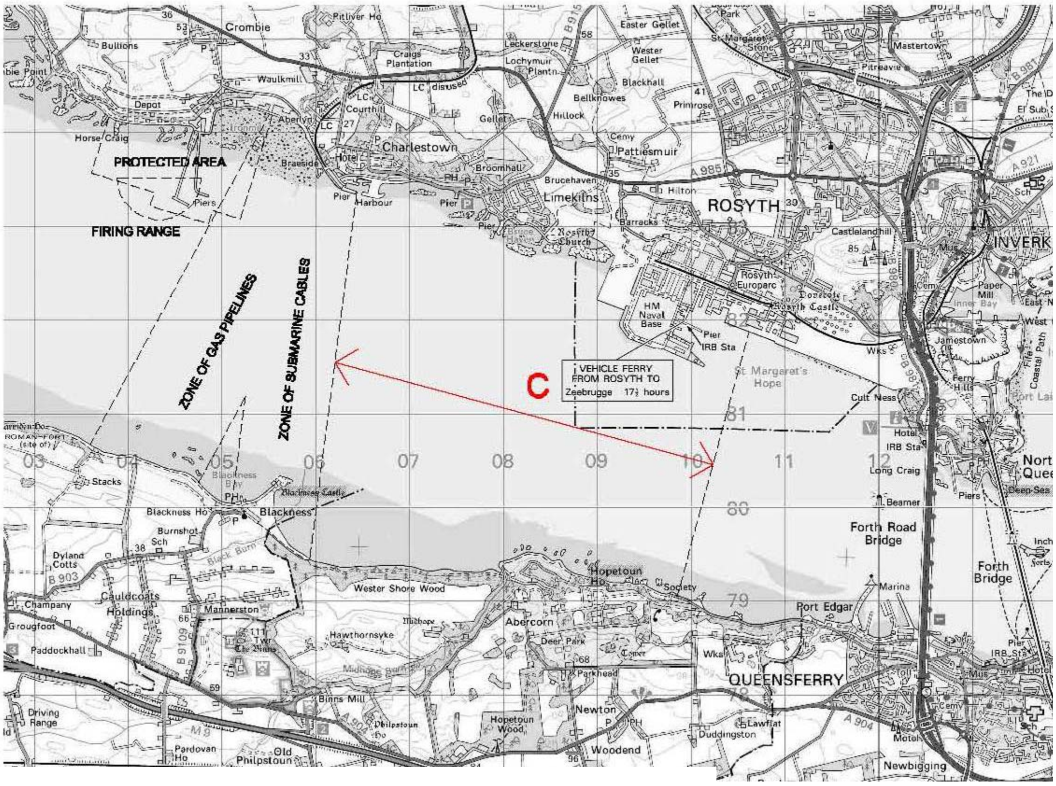
This corridor has performed in a similar manner to Corridor A. It performs poorly when assessed against the objectives. A suitable structure can be provided in the form of a suspension bridge with a main span of 1500 metres. However the cost is likely to be 1.6 times the cheapest crossing option considered. In addition, this crossing is likely to have significant environmental impacts on people and the natural and built environment.

A tunnel option in this corridor would be around 10km long. This has not been costed or assessed for its environmental impact due to the poor performance against the objectives.

In summary therefore Corridor B performs poorly against the planning objectives for this study.

Further details on this corridor can be found in Appendix C.

6.4 CORRIDOR C



Corridor C is the third of the options to be assessed and, as shown in Drawing Number 49550/G/02, is defined by the western edge at the zone of electricity lines crossing between Blackness and Charleston. The eastern edge is just east of Rosyth. The geotechnical considerations relating to crossing Corridor C are subject to the same limitations as those that apply to Corridor B, as there is equal uncertainty as to the depth to bedrock and the nature of the overlying sediments. At this location, the main channel is both wider and deeper than in Corridor B.

A test of Corridor C's operational performance has been undertaken using the TMfS. This test is representative of both the tunnel and a bridge option in this corridor. In this test the crossing is connected to the M9 in the vicinity of Junction 2 (Philipstoun). The current junction would be incorporated into the new junction and expanded to allow all turning movements to take place. On the north side it connects to the A985 at Limekilns and then form the Rosyth Bypass connecting to the A823(M) at Pitreavie.

Although this corridor is closer to the existing Forth Road Bridge than Corridors A and B it is still some distance from the existing Forth Road Bridge and once again the results from the TMfS reflect this. In the first model scenario around 10 per cent of traffic divert from the existing Forth Road Bridge in 2012 but this increases to around 20 per cent in 2022.

The second scenario modelled assumes that the existing Forth Road Bridge is closed to all traffic and therefore only the new crossing is available. This latter case is representative of the situation that might exist when the existing bridge has to be closed for maintenance purposes. This has been run for 2012 only.

In the second model scenario when only this new corridor is available there is a two per cent increase in daily vehicle kilometres but no increase in daily vehicle hours.

With both crossings available (the first scenario) the daily traffic flow on the Forth Road Bridge is envisaged to be around 65,000 in 2012 and 2022. This is less than current levels and it is therefore considered that the first objective of maintaining cross Forth transport links to at least the level of service offered in 2006 is more likely to be met than in Options A and B.

There is a small increase in distance travelled during closure of the Forth Road Bridge which will result in additional economic costs. In addition there will be consequential environmental impacts from the additional distance travelled.

It is considered that this corridor would provide better flexibility during periods of major maintenance at the Forth Road Bridge purely as a consequence of its proximity. The operation of the new crossing as a high wind diversion route when closures are imposed on wind susceptible vehicles is also a better prospect with Corridor C compared with A and B.

This corridor is closer to the Forth Road Bridge and the Forth Bridge than Corridors A and B and there are slightly more possibilities available to include public transport services into this corridor. This option would lend itself well to providing direct public transport services connecting into Dunfermline and may go some way to improving linkages between Dunfermline and West Lothian. It is therefore considered that this option performs better than Corridors A and B when measured against the public transport and accessibility objectives. LRT connections are certainly possible within this corridor. However, the southern landfall would require lengthy linkages to the Edinburgh tram network. Possible network connections are shown in Drawing Numbers 49550/N/02 and 03.

In addition, public transport priority could be introduced onto the existing Forth Road Bridge after completion of the new crossing.

Both a bridge structure and a tunnel can be provided within this corridor. In the case of the bridge it is most likely to be a suspension bridge with a main span of 1800m. A span of this length would be among the longest in the world. The cost of this option is likely to be around 1.6 times the cost of the cheapest option.

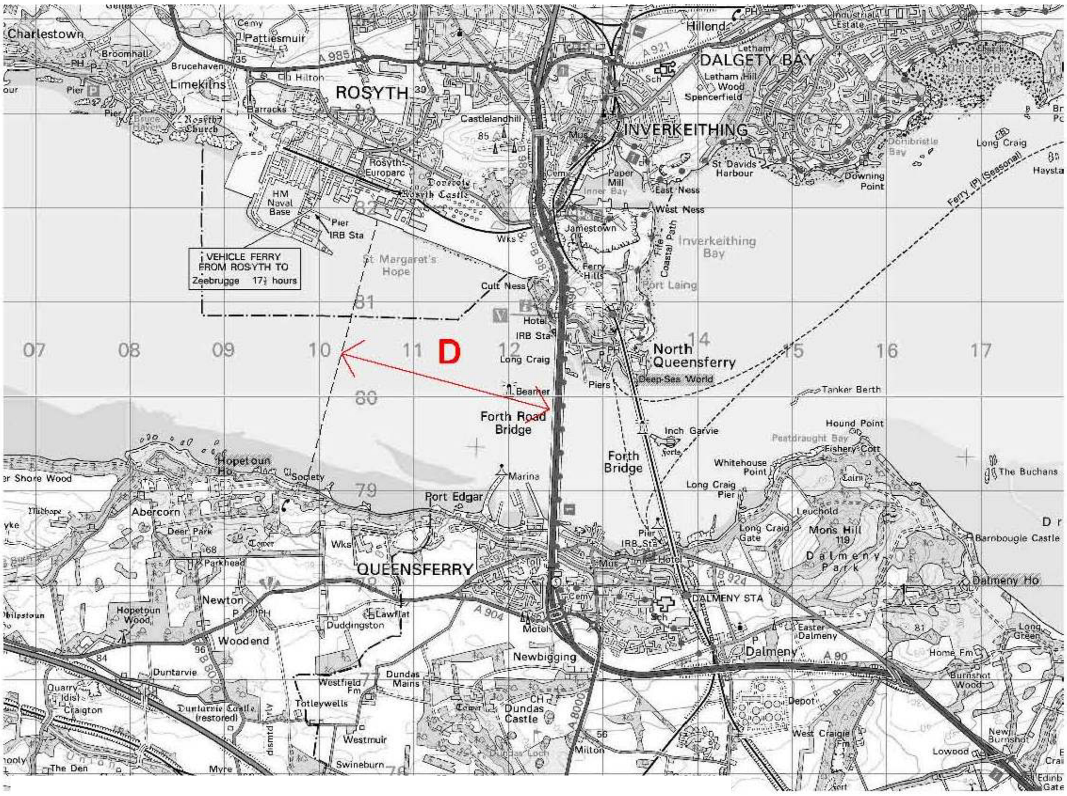
A tunnel option is likely to be around 9 kilometres long and would cost around 2.4 times the cost of the cheapest crossing.

This corridor performs better than Corridors A and B against the objectives. However it is still some distance from the existing Forth Road Bridge and therefore its ability to integrate effectively during periods of planned maintenance or during periods of high winds will be limited. This corridor would not serve public transport markets very efficiently although the north landfall would make it suitable for services to Dunfermline.

The bridge option will potentially impact upon the SPA particularly on the north side, through direct intrusion of piers, etc., and through disturbance of sediments during construction. However the tunnel option will avoid any such impacts, as well as having lower visual and noise impacts and as a consequence is a better option than the bridge when viewed against the environmental objective.

Further details on this corridor can be found in Appendix D.

6.5 CORRIDOR D



Corridor D is the fourth of the options to be assessed and, as shown in Drawing Number 49550/G/02, is defined by the western edge just to the east of Rosyth and the eastern edge is formed by the Forth Road Bridge. Rockhead founding depths for proposed bridge towers standing in the Firth would be at a minimum depth of about 30m.

A test of Corridor D's operational performance has been undertaken using the TMfS. This test is representative of both the tunnel and a bridge option in this corridor. In this test the crossing is connected to the M9 to the west of Junction 1 (M9 Spur). On the north side it connects to the A90/M90 immediately to the north of the Forth Road Bridge.

This test has been run in two different scenarios. The first assumes that the new crossing is simply added to the existing network and there are therefore two crossings available to vehicles. This test has been run for the forecast years of 2012, 2017 and 2022.

This corridor is the closest of the five to the existing Forth Road Bridge. In the first model scenario around 17 per cent diverts from the existing Forth Road Bridge in 2012 rising to 23 per cent in 2022.

The second scenario modelled assumes that the existing Forth Road Bridge is closed to all traffic and therefore only the new crossing is available. This latter case is representative of the situation that might exist when the existing bridge has to be closed for maintenance purposes. This test was run for 2012 only.

In this scenario there is a two per cent increase in daily distance travelled.

Clearly this corridor caters better for both the northern and southern ends of the trip ends than the previous three corridors.

With both crossings available (the first scenario) the daily traffic flow on the Forth Road Bridge is envisaged to be around 60,000 throughout the 2012 – 2022 period. This is less than current levels and it is therefore considered that the first objective of maintaining cross Forth transport links to at least the level of service offered in 2006 is more likely to be met than with the previous corridors.

There is a small increase in daily distance travelled during closure of the Forth Road Bridge and there will be additional economic costs incurred as a consequence. In addition there will also be consequential environmental impacts from the additional distance travelled.

It is considered that this corridor would provide better flexibility during periods of major maintenance at the Forth Road Bridge purely as a consequence of its proximity. The operation of the new crossing as a high wind diversion route when closures are imposed on wind susceptible vehicles makes Corridor D a better prospect compared with A, B and C.

This corridor is closer to the Forth Road Bridge and the Forth Bridge than Corridors A, B and C and there are greater possibilities available to include public transport services into this corridor. This corridor could include extensions of the Edinburgh Tram Network across into Fife or the expansion of Express Bus services serving a variety of destinations including Dunfermline to West Lothian. In addition, public transport priority would be introduced onto the existing Forth Road Bridge after completion of the new crossing.

Both a bridge structure and a tunnel are feasible options for Corridor D. A suspension bridge and a cable stayed bridge have been examined The former will have a main span of 1375 metres and the latter would have spans of 650 metres and 600m with the central tower being founded on Beamer Rock. The cost of a bridge in this corridor would be the cheapest of all the crossings examined and is therefore given the cost benchmark of 1.0. This cost is based on a suspension bridge.

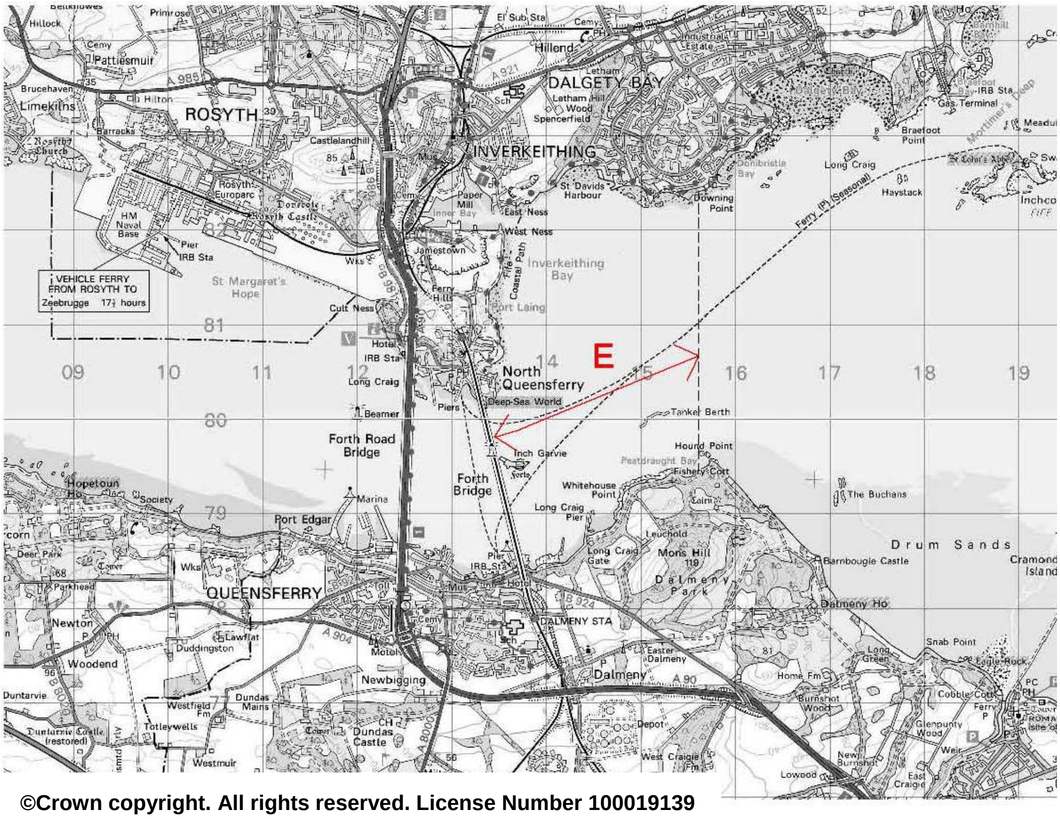
A tunnel option is likely to be around 7 kilometres in length. The cost of a tunnel in this location is estimated to cost 2.7 times the cheapest crossing option.

In terms of environmental impacts the bridge does not directly impact on the Firth of Forth or Forth Islands SPAs, although there may be indirect impacts which may be significant. In addition, there may be direct and/or indirect impacts on the St Margaret's Marsh SSSI and the Ferry Hills SSSI. However, the tunnel is likely to avoid direct impacts on the SPA and SSSIs, although there may be direct impacts on St Margaret's Marsh SSSI if cut and cover techniques are used in this area.

In summary therefore Corridor D performs well against the majority of the planning objectives for this study.

Further details on this corridor can be found in Appendix E.

6.6 CORRIDOR E



Corridor E is the fifth and most easterly of the options to be assessed. As shown in Drawing Number 49550/G/02 is defined by the western edge of the Forth Bridge. No routes were considered east of Hound Point within this corridor.

In contrast to Corridor D, the geology of this section of the Firth downstream of the existing Forth Bridge, Corridor E, is relatively unrecorded. The zone is beyond the study area included in the British Geological Study Report on "Engineering Geology of the Upper Forth". Consequently there is no information relating to rockhead levels in the Firth, conjectural or otherwise.

A test of the operational performance of Corridor E has been undertaken using the TMfS. This test is representative of both the tunnel and a bridge option in this corridor. In this test the crossing is connected to the A8000/M9 Spur Extension (which is currently under construction) and will sweep across the A90 near Dalmeny. On the north side it connects to the M90 either at a remodelled Junction 2 (Masterton) or further north at a new junction.

This test has been run in two different scenarios. The first assumes that the new crossing is simply added to the existing network and there are therefore two crossings available to all vehicles. This test has been run for the forecast years of 2012, 2017, 2022.

This corridor is the second closest of the five to the existing Forth Road Bridge. In the first model scenario around 20 per cent of peak hour traffic diverts from the existing Forth Road Bridge. Between 25 and 30 per cent of traffic diverts during the day when given free choice of the two crossings.

The second scenario modelled assumes that the existing Forth Road Bridge is closed to all traffic and therefore only the new crossing is available. This latter case is representative of the situation that might exist when the existing bridge has to be closed for maintenance purposes. This has been run for 2012 only.

In the second scenario modelled when only this new corridor is available there is a two per cent increase in daily distance travelled.

Given the volume of traffic utilising this crossing it is clear that this corridor caters better for both the northern and southern traffic origins and destinations than the previous four corridors.

With both crossings available (the first scenario) the daily traffic flow on the Forth Road Bridge is envisaged to be around 54,000 in 2012 rising to 58,000 by 2022. This is significantly less than current levels and therefore it can be considered that the objective of maintaining cross Forth transport links to at least the level of service offered in 2006 is likely to be met.

There is a small increase in the total distance travelled by vehicles during closure of the Forth Road Bridge. This indicates that a replacement crossing in Corridor E will not minimise the impacts of maintenance on the effective operation of the transport network when compared to other corridor options. There will be additional economic costs incurred as a consequence of the additional mileage driven. In addition there will also be consequential environmental impacts from the additional distance travelled.

It is considered that this corridor would provide better flexibility during periods of major maintenance at the Forth Road Bridge purely as a consequence of its proximity. The operation of the new crossing as a high wind diversion route when closures are imposed on wind susceptible vehicles makes Corridor E a better prospect compared with A, B and C. There is little difference when compared with D.

There are similar opportunities to Corridor D for introducing public transport into this corridor. This corridor could include extensions of the Edinburgh Tram Network across into Fife or the expansion of Express Bus services serving a variety of destinations including Dunfermline to West Lothian. In addition, public transport priority could be introduced onto the existing Forth Road Bridge completion of the new crossing.

Two bridge crossings options have been found feasible for Corridor E. One would result in a suspension bridge with a main span of 1850 metres and the other 1650 metres. A span of 1850 metres would be one of the longest in the world. The costs of these two crossing options would be between 1.5 and 1.7 times the cost of the cheapest crossing looked at within this study.

A tunnel option measuring 9 kilometres in length would be required for this corridor. As with Corridor D, the use of the bored tunnelling method would be limited in places due to the presence of the dolerite intrusion. The cost of this option would be approximately three times the cost of the cheapest crossing option.

In terms of environmental impact the one of the bridge options would cross the SPA on the south side only whereas the other would cross the SPA on both shores. The tunnel option would clearly avoid any direct impacts on the SPA through direct intrusion of piers, etc., and through disturbance of sediments during construction. In addition, in terms of impacts on cultural heritage, landscape, visual impact, noise and local air quality the tunnel option is likely to perform better than the bridge options proposed.

In summary therefore Corridor E performs well against the planning objectives for this study.

Further details on this corridor can be found in Appendix F.

6.7 SUMMARY AND RECOMMENDATIONS

This chapter summarises the key issues arising from the sifting of the Corridor Options A to E. The detail of this process is reported in Appendices B to F. Each corridor has been initially assessed against the eight planning objectives for the Forth Replacement Crossing study, namely:

- maintain cross Forth transport links for all modes to at least the level of service offered in 2006;
- connect to the strategic transport network to aid optimisation of the network as a whole;
- improve the reliability of journey times for all modes;
- increase travel choices and improve integration across modes to encourage modal shift of people and goods;
- improve accessibility and social inclusion;

- minimise the impacts of maintenance on the effective operation of the transport network;
- support sustainable development and economic growth; and
- minimise the impact on people, the natural and cultural heritage of the Forth Area.

This initial sift has been carried out prior to the STAG Part 1 Appraisal which will consider the sifted options against the planning objectives in more detail. It will also consider the performance against the Government's five main objectives of:

- environment
- economy
- safety
- accessibility and social inclusion; and
- integration.

This will be reported in the next phase of the study.

It is clear from the summary above that overall the option which performs best against the objectives is a crossing within Corridor D. It is closest in distance to the existing Forth Road Bridge and will therefore be best placed to maintain Cross Forth transport links for all modes to at least the level of service offered in 2006. It is relatively straight forward to connect into the strategic transport network and again, its proximity to this network, will ensure that optimisation of the network operation will be achieved.

Corridor D is well placed in terms of the major settlements on either side of the Forth and this can provide public transport options within the crossing with minimum diversion. However, it should be noted that public transport priority could be provided on the forth Road Bridge in all the corridor options.

It is considered that this option (together with Corridor E) is the best performing option in terms of improving accessibility and social inclusion.

A crossing in this corridor will allow the impacts of future maintenance of both crossings to be minimised due to their proximity to each other.

A bridge (or tunnel) in Corridor D (and E) will ensure that economic development and economic growth is supported.

The environmental impact on people, the natural and cultural heritage of a bridge in Corridor D is the least of all bridge corridors. It is not likely to have any direct impacts on the Firth of Forth or Forth Islands SPAs although there may be indirect impacts which may be significant. There is likely to be an impact on the St Margaret's Marsh SSSI and the Ferry Hills SSSI. Tunnel options perform better against this objective. They are likely to avoid direct impacts on the SPA and SSSIs, although there may be direct impacts on St Margaret's Marsh SSSI if cut and cover techniques are used in this area.

Finally, a bridge in Corridor D is the lowest cost option of all options considered. The next option in order of cost would be a bridge in Corridor E which is estimated to be some 50 per cent more expensive. The environmental assessment of a bridge in Corridor E is slightly worse than Corridor D. All other objectives are similar but no better than those of D. This additional cost of 50 per cent does not achieve any greater value when viewed against the objectives.

Tables 6.1 and 6.2 summarise the operational characteristics of each corridor in terms of the diversions to the new crossing and the residual flow on the Forth Road Bridge.

The cheapest tunnel option is in Corridor C and this is estimated to cost 2.4 times the cost of the Corridor D Bridge. However a tunnel in Corridor C does not perform well against the objectives when compared with a bridge in Corridor D except the environmental objective.

This section has summarised the performance of the options against the objectives. This sifting is undertaken in order to establish which options are unsuitable in making progress towards meeting the study objectives. It is equivalent to the pre-appraisal phase of the STAG process. Any options passing this sifting exercise will then be subjected to a Part 1 appraisal during the next work package.

It is clear from the above that Corridors A and B do not meet the objectives of the study and should therefore be rejected from further study.

Corridors C, D and E however do perform well to varying degrees against the objectives and should therefore be taken forward to the Part 1 Appraisal.

Table 6.1 – Percentage of Diverted Traffic from Existing Forth Road Bridge

Year	Corridor				
	A	B	C	D	E
2012	5	8	10	17	20
2022	5	8	20	23	25-30

Table 6.2 – Forth Road Bridge Daily Traffic Flows

Year	Base Case	Corridor				
		A	B	C	D	E
2012	73,000	68,000	67,000	65,000	60,000	54,000
2022	79,000	75,000	74,000	65,000	60,000	58,000

7 PROCUREMENT AND FINANCE

7.1 INTRODUCTION

This chapter summarises the work undertaken to date in assessing the procurement and financing options available to a project such as a Forth Replacement Crossing.

There are a number of possible options to procure, fund and deliver a Forth Replacement Crossing. As part of the overall project assessment and to satisfy the overriding requirements of the Scottish Executive's Value for Money guidance ("the Guidance"), Transport Scotland ("TS") are required to evaluate the procurement and funding options for the delivery of the emerging preferred option for the replacement Crossing. Additionally public sector procurement guidance (The Scottish Executive Procurement Manual) states:

> *"PPP procurement should be considered when the evidence of the benefits that PPP can deliver gives a strong case for considering PPP for a Project or Programme. These characteristics include:-*
>
> - *A major capital investment programme, requiring effective management of risks associated with construction and delivery;*
> - *The private sector has the expertise to deliver and there is good reason to think it will offer value for money;*
> - *The structure of the service is appropriate, allowing the public sector to define its needs as service outputs;*
> - *The nature of the assets and services identified as part of the PPP scheme are capable of being costed on a whole-of-life, long term basis;*
> - *The value of the project is sufficiently large to ensure that procurement costs are not disproportionate;*
> - *The technology and other aspects of the sector are stable, and not susceptible to fast paced change;*
> - *Planning horizons are long term, with assets intended to be used over long periods into the future; and*
> - *There are robust incentives on the private sector to perform.*
>
> *In such circumstances, there is a prima facie case for considering PPP procurement. The public sector bodies (and where applicable Procuring Authorities, Agencies and Departments) are required to confirm that these areas have been reviewed. "*

Given the scope and nature of the replacement Crossing it is suggested that it meets the characteristics identified above creating a requirement to assess the funding and procurement options in detail. For practical purposes the Guidance has been used as a broad framework for assessing the procurement, funding and delivery options for the replacement Crossing. This has been broken down into two broad stages as follows:

Stage 1**:** Identification of procurement and funding options together with a qualitative assessment of key risks or constraints; and

Stage 2: Quantitative and qualitative analysis of the detailed procurement structuring and funding options in line with the Guidance.

An initial long list of options was identified which has been filtered to the current shortlist. In order to progress the funding and procurement assessment, Stage 1 has been undertaken in parallel with the technical and transport appraisal of the replacement Crossing options. This being the case, the Stage 1 assessment has focussed on identifying any major differences in risks or issues relating to the technical options that would constrain potential procurement and/or funding options. The remainder of this section sets out the findings to date and highlights the analysis that will be undertaken in Stage 2.

7.2 STAGE 1 – IDENTIFICATION OF PROCUREMENT & FUNDING OPTIONS

7.2.1 Key Procurement Objectives

As part of the Stage 1 assessment, an initial list of procurement objectives was identified that will be used in the detailed assessment of the options for the delivery of the replacement Crossing. The key procurement objectives were agreed They are, in no particular order, as follows:

- Cost certainty;
- Flexibility over funding;
- Programme certainty;
- Appropriate control over design; and
- Affordability.

The initial assessment of risks and issues was considered in terms of their impacts on key procurement objectives. As the emerging preferred crossing option is developed, it is intended to develop this initial list of objectives and give consideration as to whether a weighting should be attributed to the objectives to reflect their importance.

7.2.2 Procurement Options

In broad terms the output that is to be procured is a replacement Crossing, whether it be a tunnel or bridge. The generic Crossing options available are represented in the table below:

Generic Crossing Option	Description
New Crossing	A tunnel/bridge across the Forth with the size, type and location to be determined.
New Crossing and Existing Bridge	A tunnel/bridge across the Forth with the size, type and location to be determined with use of the existing bridge wrapped into the concession in some form.

There are broadly three principle procurement options to deliver the replacement Crossing as follows:

- Traditional Procurement;

- PPP Procurement; and
- DBFO.

Traditional Procurement

For major road or crossing schemes, the procurement is typically undertaken through a Design and Build Contract ("D&B"). A significant element of the risks and rewards of the scheme would remain with the public sector and would require to be quantified to compare like with like with the other procurement options. Whilst the cost of funding under the traditional route may be the lowest, this must be balanced against the following key risks that would remain with the public sector:

- Potential cost increases on construction due to unforeseen risks; delay; geological conditions;
- The risks inherent in traditional procurement - the risk that costs may increase both during the construction and operational period to a level that the public sector body could not afford; and
- Shortfall in expected revenues if a tolled crossing is adopted.

PPP Procurement

There are several methods of procurement with varying degrees of risk transfer, that come within the umbrella of PPP Procurement. However, it is likely under the current project that a design, build, finance and operate ("DBFO") arrangement would be the principal form of procurement option. Ultimately any PPP procurement route would have to be tested against the traditional option to demonstrate the potential VfM, before any commitment was made.

In order to assess the risks and key issues at this stage the funding and procurement assessment identified the potential PPP procurement options for this initial Stage 1 review. In broad terms these were as follows:

- A PPP for the DBFO of the replacement Crossing, be it either a tunnel or a bridge across the Forth with the size, type, function and location to be determined as part of the transport appraisal; and
- A PPP as above but the inclusion of the existing bridge for a period and functionality to be determined by the existing bridge condition and transport appraisal.

DBFO

A DBFO structure requires the private partner to deliver the infrastructure and operate the roads over an agreed period, typically 30 years. However, recent developments in the United States with respect to existing toll roads have pointed to concession lengths much greater than 30 years. This raises the question regarding the structure and length of the concession or the options to refinance/restructure post construction completion.

Financing is generally provided in the form of both debt and private equity, with returns being generated from a mix of availability payments and tolling income. Under this structure the key risks that will be taken by the private sector include:

- Construction and operational overruns;
- Delay in the delivery of the service;
- Design in the underlying asset not delivering the agreed service; and
- Changes of law, including tax law changes, which impose additional or increased costs on the operator (other than any change of law which discriminates against private sector operators).

A major risk that will significantly impact on the overall cost of funds will be in relation to the degree of demand risk that the private sector is expected to take.

As part of Stage 1 the scope of the potential PPP options were set out appreciating that the structure, ownership, duration, level and type of funding would be analysed in greater detail at Stage 2. In broad terms the PPP options were agreed as follows:

Type of PPP	Description
DBFO - Availability /Performance	A private partner delivering the infrastructure and operating the roads/crossing over an agreed length of time, typically 30 years or more. The availability / performance refers to the way in which the private partner is paid for the services. An availability payment will generally be a fixed payment for the availability of the existing road. A performance payment can be based on two aspects; safety performance payments and lane closure charges.
DBFO - Shadow Toll	As above and incorporating a shadow toll mechanism whereby payments are made by the procuring body directly to the private sector partner (no impact on end road user) per vehicle using a certain distance of project road. Different payments are due for traffic within different traffic bands and dependant on the length of vehicle.
DBFO - Real Toll	As a DBFO Availability /Performance with tolls that are paid by the end road user.

If the existing bridge is to be included within the PPP then the scope of the above options would be amended to include the agreed responsibility for the existing bridge.

In addition the shareholding structure and/or control that Transport Scotland wish to exert over the Special Purpose Vehicle (SPV) will also have to be considered.

7.2.3 Potential Funding Options

The key consideration on the preferred funding option is that it is deliverable and provides value for money. There are several potential funding options available and each depends on the particular procurement option selected. The broad categories of funding option are as follows:

- Public Sector Grant;
- Public Sector Borrowing;
- Private Capital;
- Debt Funding (Senior bank funding or capital markets funding);
- Equity Funding; and
- A Hybrid of both public sector and private sector monies.

Public Sector Grant

This is how traditionally procured projects are typically funded and would ultimately depend upon whether there is capacity within the transport budget against competing demands of other projects.

In the traditional procurement approach the funding is likely to come from the Scottish Executive ("SE") in the form of a capital grant, typically matched against the cost of the infrastructure being provided. This is likely to be the lowest cost of funding but must be balanced against the cost of the risks associated with this method of procurement. The quantitative analysis in the next stage would highlight the level of risk that is likely to be retained which will demonstrate whether the traditional method of procurement would provide a better value solution when compared to a DBFO arrangement.

Public Sector Borrowing

Currently Scottish Ministers do not have borrowing powers but local authorities have the ability to borrow through the Prudential Borrowing Code (“the Code”). The borrowing powers under the Code were used as the basis for the first ever UK municipal Eurobond issue by Transport for London for £200million as part of a £3.3billion Euro Medium Term Note Programme. Public bonds have also been used to finance highway projects in the United States.

This could be an option to smooth the affordability impact of the replacement Crossing. The advantages and risks associated with this option would need to be fully assessed before such an option is considered.

Private Capital

A DBFO type concession is a highly geared structure, funded through a combination of debt (on a limited or non recourse basis) and equity funding. The exact nature and structure of a particular projects funding structure would depend upon the project risks that are being assumed by the private sector party.

Debt funding

Any PPP transaction would generally be structured around an SPV that is formed specifically for the purposes of the PPP project for which the funding is required. This means that the debt providers would have no recourse back to the project developers with exception to any committed equity funding or guarantees pledged by the contractors. Consequently the debt providers would be extremely concerned with regard to the security of income streams to the SPV and the nature of risks retained in the SPV.

The security available to the lender would be based on:

- The future cash flows of the concession;
- A change over the shares in the SPV;
- The right to step into and take over the management of the project if the SPV is in default; and
- Various covenants as defined by the funder that the SPV needs to adhere to.

The level of debt funding that can be raised is a function of the risk in the project. PPP type projects can generally accommodate high levels of gearing because the risks in the project are carefully packaged and managed by various parties. The ability to maximise the debt element of the capital structure is important as this is generally the cheapest form of funding. Typically gearing levels of approximately 90 per cent are found across a range of sectors.

Debt funding can be provided either in the form of:

- Senior bank funding; or
- Capital markets funding (in the form of a bond issue).

Senior Bank Funding

Bank funding in the form of senior debt is provided by commercial banks. The senior debt would be made available to the SPV during the initial construction phase and can be drawn down to meet the project's funding requirements. Typically, repayment of the debt will start once operations have commenced.

Interest rate risk in the project would be eliminated at financial close by the SPV taking out an interest rate swap. This ensures that the SPV is not exposed to any interest rate movements and fixes its debt service requirements over the concession term.

Depending on the size of the project, the senior debt could either be provided by a single bank or a syndicate of banks.

Capital Markets Funding

Capital Markets funding would involve the SPV issuing a corporate bond that would normally be taken up by investors, such as pension funds and insurance companies. The bond could either be a public offering or a private placement made with individual institutions. In a public offering the bond may need an appropriate rating, from a rating agency, or else take out the appropriate insurance to protect (wrap) the bondholders and reduce the cost of funds (monoline insurance).

Bond funding must be drawn down up front and placed in a restricted account. Funds are then drawn from this account to meet the project funding requirement. Interest payments on a bond take place on a semi annual basis after drawdown and repayment of the bond would take place once the operational phase commences.

Suitability of Senior Bank Funding Debt or Capital Markets Funding

The decision over whether to go with senior bank funding or capital markets funding is ultimately a value for money decision which can be taken after appointment of a preferred bidder It is not uncommon for the preferred bidder to be selected and then run a separate funding competition. Under this option it is usually a requirement that bidders demonstrate their proposals are bankable through securing backing in principle from potential funders as part of the tender requirements. The decision would be based on both a qualitative and quantitative judgement. The quantitative decision would be based on running a funding competition, which would allow the public sector party to benefit from the best terms in the market at that present time. Other such factors to consider include:

- Term of debt - it may be a longer term of debt can be obtained more readily in the bond market which is likely to reduce the annual amount payable as the repayment of the debt is spread over a longer term;

- Cost of funds - the private sector party should be encouraged to run both bond and bank funding solutions in parallel;

- Up front costs - the costs in relation to bonding are significantly higher than bank financing costs and are a consideration in the quantitative analysis as part of the funding competition; and

- Flexibility - senior debt is typically more flexible and is easier to arrange. This would also include the ability to refinance at a later date to share in improved market terms with the private sector party.

Equity Funding

The equity funding in PPP projects is also known as risk capital. This is either ordinary share capital or subordinated debt. As equity finance bears the highest risk of all funding instruments it commands the highest rate of return, typically c.13 per cent – 15 per cent. However the level of return would be dependant on the overall risk profile and in particular the treatment of demand risk. The return generated by equity and subordinated debt is in the form of dividends and interest respectively.

Hybrid Funding

It is possible to include elements of both public sector grant and private capital into the financing structure. This could involve an element being structured as a series of milestone payments against construction target dates. These milestone payments would be capital payments made by the public sector party to the private consortium in relation to achieving certain stages of completion. These might include completion of the design or ancillary works etc, with an annual unitary payment being made to cover the construction costs not covered by the milestone payments. These payments would supplement any tolling income as necessary.

The assessment of the funding options will be considered further as part of the detailed quantitative and qualitative analysis at Stage 2.

7.2.4 Stage 1 Summary

At this stage it is not possible to determine the optimal procurement and funding route for the new crossing. This would only become clearer after the detailed Stage 2 qualitative and quantitative analysis required which will highlight the relative costs and risks associated with each procurement and funding option.

Even then, it will still be a relatively early stage in the overall project development and, as the project develops, factors may emerge that may require a change or refinement of the procurement and funding strategy. However, from the initial assessment of the crossing options it is clear that there is nothing being identified which would preclude or materially impact on the procurement and funding options identified at this stage. In summary the main findings to date are as follows:

- The project clearly demonstrates the attributes for consideration to be implemented as a PPP;
- The risk differentials between the technical options identified at this stage are not material in terms of the ability to develop the procurement options identified;
- It is likely that any PPP options would take the form of a DBFO type structure;
- The eventual form of any PPP would be dependant on the ownership of key risks, such as demand, programme and existing bridge condition; and
- Tolling policy and PPP concession length would have a significant impact on the overall affordability of the project.

7.3 STAGE 2 – QUANTITATIVE AND QUALITATIVE ANALYSIS

As part of the assessment of procurement and funding options, it is necessary to undertake a detailed quantitative and qualitative analysis of the options. As part of this assessment the differing risk and cost, impacts will be compared across the options to establish a robust audit trail to help justify the preferred procurement route.

This will involve comparing the procurement and funding options against the Guidance assessment areas (qualitative, quantitative and wider factors) to justify the indicative procurement route. Factors to be considered include:

- A detailed qualitative assessment under the key heads of desirability, viability and achievability, and

- A detailed quantitative assessment which include amongst other things, affordability, the identification, allocation and quantification of the key risks.

The focus of Stage 2 will be on establishing the emerging preferred procurement and funding option(s). The PPP options identified are likely to have significantly different risk profiles and these require to be identified, quantified and allocated between contracting parties, on the basis of standard commercial terms. This identification, quantification and allocation will be undertaken by the project team and its advisers. It will be the risk adjusted costs which will help inform the relative VfM of the differing procurement options.

The risk quantification will build upon the high level risks identified at the initial Risk Workshop held on 28 November 2006 and the follow up session on 18 December 2006 as part of Stage 1. The key risks will be quantified using a discounted cashflow to determine the impact of the risk for each procurement option shortlisted in today's prices.

As well as different risk profiles there will be different funding costs associated with each procurement option shortlisted. The additional cost of funding together with the risk adjusted costs will be further analysed by way of financial modelling to quantify the effect of each procurement route. The analysis will also consider affordability issues assessing the impact on overall funding requirements for differing demand scenarios. Finally the impact of differing implementation programmes will also be considered.

The above process will provide a robust evidence base for the justification behind the emerging preferred procurement and funding option.

7.4 INITIAL RISK ASSESSMENT

One of the key considerations in selecting a procurement option is in the treatment and valuation of risks. Maximising the potential for cost effective risk transfer is not simply a function of specifying the corresponding private sector obligations when contracts are let. The private sector could be reluctant to accept risk, at cost effective rates, where it cannot control the risks or the risks are introduced into the project too late to enable adequate risk mitigation. This in turn requires the terms of the contract to be co-ordinated in order to achieve the optimal risk spread in the project.

As the Crossing option has not been determined at this stage an initial risk assessment has been undertaken to identify risks associated with either a tunnel or bridge option. Additionally, risks were identified for the existing Crossing. The initial assessment, undertaken through a Risk Workshop on 28 November 2006 and subsequent follow up session on 18 December 2006, identified a number of risks associated with the planning, design, construction and operation of a new Crossing. This assessment also made an initial qualitative assessment of the materiality of risks which categorised the risks from critical through to routine.

The materiality of risks from critical to routine was assessed as the product of the impact and probability of the risk occurring.

The primary purpose of this initial risk assessment was to identify risk that may be materially different between the tunnel and bridge options that precluded the application of a particular procurement or funding route. The following key risks (categorised as critical or major from the initial risk assessment) and issues have been highlighted as part of this initial risk assessment below.

External Objections

The Crossing is high profile and has attracted significant media interest to date. It is likely that there will be significant risk of objections and therefore cost that will require to be mitigated as a result of an extended public inquiry process or issues with the aesthetics/design of the relevant Crossing type. It is not possible to transfer this risk to the private sector but careful consideration of the Crossing specification or design at this early stage will be required as they could have significant impacts on procurement and funding options that may be available during implementation. The development and planning phase of the new Crossing will be a lengthy process. As the preferred Crossing option emerges consideration will be given to the optimal time to involve the market and/or commence procurement.

Programme Constraints

This is the risk that stakeholder expectations are unrealistic and this leads to a lack of time to deliver the new Crossing. Given the strategic importance of the replacement Crossing to hundreds of thousands of commuters there is a critical need to deliver the new Crossing on time and before the existing Crossing is decommissioned, if appropriate. TS have commenced the process to determine the preferred procurement route which has, as part of its key procurement objectives, identified programme certainty as of paramount importance. This will help ensure that as options are identified and short listed that only procurement routes which have the capability of being delivered within the required timescale will be considered.

Environmental

This is the promotional risk associated with issues such as the impact on the ecology/environment which could lead to significant delay and cost to the new Crossing as issues are debated/resolved with Scottish Natural Heritage and/or as a result of a challenge in the European Court. It is not possible to transfer this risk to the private sector for the initial approval stage and this risk will require careful management by TS to avoid both excessive delay and cost to the Project.

Traffic Demand Management versus Revenue Growth

This is a potential conflict between the objectives of managing traffic demand and optimising the affordability of the new Crossing. The balance between delivering wider transport and environmental benefits and making the new Crossing as affordable as possible will need careful consideration. As a preferred Crossing option emerges the Stage 2 analysis will be undertaken to assess the impact of differing demand scenarios and their impact on overall affordability of the project.

Tolling Policy and Potential National Road User Charging Scheme

The SE policy on tolling of existing Crossings is currently under consideration. Depending on the outcome of the current review and the future policy on tolling crossings, a real toll PPP may be precluded as an option. Similarly the time horizons for the development of the new Crossing are such that a national road user charging scheme may be implemented during or shortly after the implementation of the new Crossing. The ability to ring fence Crossing charges or secure allocations from a national scheme will be of critical importance to any privately funded option. Again the impact of differing tolling policy on the overall affordability of the new Crossing will be assessed during the Stage 2 assessment.

Condition of the Existing Bridge

It is considered that a PPP for a new Crossing should include responsibility for ongoing operation and maintenance of the existing bridge, depending on the tolling review outcome, it may provide an existing income stream to contribute to the cost of the new Crossing. However this income stream is unlikely to offer a material contribution to the new Crossing. As part of the assessment of risk it was felt that it would be extremely difficult to transfer any significant condition risk associated with the existing bridge or any attempts to transfer this risk would attract a high pricing premium from the market. As the condition of the existing bridge becomes clearer an assessment of the merits or otherwise together with the financial impacts of its inclusion in a PPP for the new Crossing will be undertaken.

8 LEGISLATIVE ISSUES

8.1 INTRODUCTION

This chapter outlines a variety of statutory mechanisms by which, alone or in combination, the Scottish Ministers may be able to secure the necessary legal authority to construct a Forth Replacement Crossing.

This part of the report is necessarily provisional. Which mechanism might be available and which might be most appropriate will depend on a number of variables including:

- the identity of the promoter of the project
- the type of crossing involved
- the other parties who may be involved in the construction and operation of the crossing
- the timing of the project
- the extent of the project (for example whether it involves the existing bridge and/or link roads to the new crossing)

It is clear that it is not possible to pin down those variables at this stage. That will become increasingly possible as progress is made in identifying the preferred options for the crossing.

The crossing might be authorised via specific new legislation passed for that purpose or by seeking authorisation under existing transport legislation. Each of these options is discussed briefly below:

8.2 A NEW ACT OF THE SCOTTISH PARLIAMENT

Powers to construct and operate a new Forth crossing might be obtained through an Act of the Scottish Parliament. The advantages of this mechanism are that all necessary powers could be sought in that single vehicle, including what would amount to the planning and roads consents for the crossing, compulsory purchase of land, levying of tolls and other administrative arrangements.

In recent years a number of major transport infrastructure projects have been authorised via private Acts of the Parliament including the Waverley Railway (Scotland) Act and the Edinburgh Tram Acts. Primary legislation was required for these projects because their promoters – in each case a local authority – did not have any general powers to implement these projects and because the powers which were sought were in excess of the general law.

The need to promote a private Act for similar transport projects is expected to be obviated at least in part by the passing of the Transport and Works (Scotland) Bill which is currently before the Scottish Parliament and which should receive Royal Assent early in 2007. This Act will allow for the authorisation of certain projects (including the authorisation of, for example, the imposition of tolls) by way of ministerial order rather than by Act of Parliament. The scope of the Act is, however, restricted to authorisation of rail, tram, guided transport and inland waterway projects and would not be available for use to authorise a new bridge or tunnel crossing of the Forth.

The use of the private Bill procedure would remain an option for the authorisation of a new crossing but not if Transport Scotland is the promoter of that project. In order to take advantage of existing private Bill procedure a new crossing would have to be promoted by, for example, a local authority or a private company (such as tie which is the promoter of the Edinburgh Airport Rail Link Bill).

Should Transport Scotland wish to promote a Bill for the purpose of authorising a new crossing, such a bill would be one which at Westminster would be described as a 'hybrid' bill –promoted by central government in the public interest but affecting the private interests of some individuals and organisations more than others. Examples of Westminster hybrid bills used to authorise the construction of bridges and tunnels include the Dartford-Thurrock Crossing Act 1988, the Severn Bridges Act 1992 and the Channel Tunnel Act 1987.

The Scottish Parliament's standing orders do not currently make provision for hybrid bills and a special procedure would have to be devised for such a bill.

An assessment would have to be made as to whether the advantages of primary legislation – allowing all necessary powers to be dealt with comprehensively – outweigh the possible disadvantages of delay and uncertainty which might flow from untested new procedures.

Such an Act may take between 12 and 18 months to obtain Royal Assent. It would be possible for an aggrieved party to seek to challenge any such Act either during its passage or following Royal Assent in which event significant delays might result.

8.3 MAKING USE OF EXISTING LEGISLATION

There are a variety of existing statutory provisions which could be used to authorise all or part of a new crossing, depending on the nature and extent of the option finally decided upon. The following is for illustrative purposes and is not exhaustive:

Roads (Scotland) Act 1984

This Act could be used to authorise a road bridge or tunnel. The 1984 Act empowers the Scottish Ministers to construct new trunk roads and permits any order made by the Ministers designating a new road as a trunk road to include provisions for bridges over and tunnels under navigable waters. The 1984 Act does not authorise the levying of tolls but does contain provisions concerning the procedure to be adopted if a tolling order is to be made under the New Roads and Street Works Act 1991 which is discussed below.

The definition of a road for the purposes of the 1984 Act includes ‘any bridge (either temporary or permanent) over which or tunnel through which the road passes’. There is also specific provision in s75 of the Act for construction of new bridges and tunnels. Sections 75(1) and (2) of the Act confer the power to make an order for construction of a bridge over or of a tunnel under any specified navigable waters.

Alteration of existing road networks could also be authorised by an order made under the 1984 Act, as could the compulsory acquisition of land for the purposes of constructing the new crossing.

An order made under the 1984 Act would inevitably involve the holding of a public local inquiry and the overall timescale for promotion and making of the order is likely to be around 18 months.

It would be possible for an aggrieved party to seek to challenge an order in legal proceedings – provided those legal proceedings are brought within six weeks of the order being made – in which event significant delays might result.

New Roads and Street Works Act 1991

As mentioned above, this Act would allow the imposition of tolls on any new road or bridge. Where it is proposed to impose tolls on a new special road, the 1991 Act requires that the process for obtaining a toll order should "so far as practicable" be concurrent with the process for making a special roads scheme where the toll order relates to that road.

The timescale for obtaining a tolling order should be similar to that for obtaining the requisite roads order(s) under the 1984 Act. It would be possible for an aggrieved party to seek to challenge an order in legal proceedings in which event significant delays might result. The Skye Bridge was promoted by this route.

Transport and Works (Scotland) Bill

This Bill is discussed above and could, if passed, be used to authorise rail or tram construction on a new bridge or through a new tunnel and could also be used to compulsorily acquire land for those purposes.

The timescale for the making of an order under this Act is expected to be similar to that for a roads or toll orders. It would be possible for an aggrieved party to seek to challenge an order in legal proceedings – provided those are raised within 42 days of the order being made – in which event significant delays might result.

8.4 FUTURE MANAGEMENT OF THE CROSSINGS

There are a number of options available in relation to the management of a new Forth Crossing. The appropriate mechanism or mechanisms will depend to a large extent on the preferred technical option and will be a matter for discussion in light of this. Depending on the option chosen, it may be appropriate to review the existing management structure and to consider replacing it. It has not yet been decided what organisational structure would need to be put in place to manage the crossing(s).

A private or hybrid bill

Provision could be made in new primary legislation for the alteration of the powers of the existing management body (FETA). Primary legislation could also be used to create a new management structure. Legislation could deal with this matter alone or this could be combined with primary legislation dealing with other aspects of any new Forth Crossing.

The Local Government (Scotland) Act 1973

The 1973 Act provides that where arrangements are made for any functions of two or more local authorities to be discharged jointly, then a joint board may be established to discharge those functions.

The Forth Road Bridge Joint Board was dissolved and replaced by FETA by the Forth Transport Authority Order 2002. This Order was made using the powers vested in the Scottish Ministers by Section 69 of the Transport (Scotland) Act 2001. FETA is, in terms of that order, a joint board.

Section 69 of the 2001 Act provides that where a ‘body’ other than a roads authority has responsibility for the maintenance and management of a bridge which has been constructed under statutory authority – and that body’s functions relate solely to the bridge – then the Scottish Ministers can dissolve that body. It also further provides for the transfer of the rights and functions of such a dissolved body to a joint board comprised of local authorities (as was done in the case of FETA).

Section 69(3) further provides that a joint board created in terms of s69 is “*deemed for all purposes to be a joint board within the meaning of the Local Government (Scotland) Act 1973 constituted under this Act”.* It is believed that any joint board created under the 2001 Act is subject to the general provisions concerning joint boards contained in the 1973 Act and is to be treated as though it has been constituted under the 1973 Act.

Section 62C of the 1973 Act provides that any joint board established under the 1973 Act may be dissolved by order of the Scottish Ministers. It is considered that this power provides a realistic option by which FETA could be dissolved, if this was considered to be an appropriate measure, and/or another joint board established.

The Transport (Scotland) Act 2001

As mentioned above, Section 69 of the 2001 Act – which was used to dissolve the Forth Road Bridge Joint Board – empowers the Scottish Ministers to dissolve any “body” whose sole remit is the management and maintenance of a bridge and to transfer that body’s functions to a joint board.

It is not absolutely clear whether the sort of body which may be dissolved using this power includes joint boards which have actually been created under the 2001 Act itself. It can certainly be said to include joint boards created under other legislation given that it was used to dissolve the FRBJB which was constituted by a private Act of 1947.

It appears that s69 of the 2001 Act could be used to constitute a new joint board for the purposes of management of a bridge. It is also at least arguable that dissolution of a joint board such as FETA could be achieved by order made under Section 69 of the 2001 Act. In the particular case of FETA the complication is that there must be doubt about whether FETA's functions relate 'solely' to the bridge – a prerequisite to an order under Section 69. Section 7 of the Forth Estuary Transport Authority Order 2002 also empowers FETA to 'develop, support and fund schemes and measures including roadworks, traffic management and public transport services' to reduce traffic congestion on the bridge or to encourage an increase in the use of public transport across the Firth of Forth.

Transport and Works (Scotland) Bill

It has been suggested that this Bill might also be used to change the management structure of the existing Forth Crossing if combined with a change of use of the existing bridge. This suggestion is based on the proposed power to enable an order for authorisation of a rail or tram line to include provisions for the transfer of powers to operate transport systems (see Schedule 1 to the Bill). One difficulty with this suggestion is that expression 'transport system' may not includes the current bridge but refers, rather, to systems such as railways, trams and guided busways.

considerate is believed that new primary legislation, the 1973 Act and the 2001 Act provide better options for the re-organisation of management structures if this is required.

Table 8.1 – Summary of Options and Timescales

Crossing Option	Legislative options	Comments	Timescale
Toll Road Bridge	Act of the Scottish Parliament Orders under the Roads (Scotland) Act 1984 and NRSWA 1991	Hybrid bill which will require new parliamentary procedure. Obvious option if a road bridge only is chosen.	12 to 18 months 12 to 18 months
New Toll Road Bridge and light rail system using existing bridge.	Act of the Scottish Parliament Combination of orders made under 1984 Act, 1991 Act and TWA.	Attractive because it could deal with all necessary consents via a single process but hybrid bill which will require new parliamentary procedure. Multiplicity of orders makes this a less attractive option. Multiple opportunities for challenge and therefore delay.	12 to 18 months 12 to 18 months
New Tunnel only (imposing toll charges).	Act of the Scottish Parliament Orders under the Roads (Scotland) Act 1984 and NRSWA 1991	Hybrid bill which will require new parliamentary procedure. Obvious option if a tunnel only is chosen.	12 to 18 months 12 to 18 months
New Tunnel (with tolls) and light rail system using existing bridge.	Act of the Scottish Parliament Combination of orders made under the 1984 Act, 1991 Act and TWA.	Attractive because it could deal with all necessary consents via a single process but hybrid bill which will require new parliamentary procedure. Multiplicity of orders makes this a less attractive option. Multiple opportunities for challenge and therefore	12 to 18 months 12 to 18 months

		delay.	
Abolition of FETA	Act of the Scottish Parliament Order under Local Government (Scotland) Act 1973 Order under Transport (Scotland) Act 1991	Could be included in an Act dealing with all other aspects of project. Could be used where remainder of project to be authorised by orders rather than Act of Parliament.	12 to 18 months 2 to 3 months

9 SUMMARY AND CONCLUSIONS

9.1 INTRODUCTION

The Scottish Executive and Transport Scotland are investing more than £3 billion on transport infrastructure projects to 2012, across all modes of transport. This includes providing funding for local authorities and their partners to improve transport.

Scottish Ministers are committed to a Strategic Transport Projects Review (STPR) and Jacobs with Faber Maunsell were commissioned by Transport Scotland to provide technical advice to the study. The STPR commission involves identifying the strengths and weaknesses of the Scottish strategic transport network, identifying gaps between the future demand and capacity of the network, and producing a prioritised list of interventions for the period 2012-22. The commission also covers a study of the Forth Replacement Crossing.

The objective of the study is to generate robust options for a potential replacement Forth Crossing. This report is the third report produced as part of the Forth Replacement Crossing Study and covers the Generation of Options and Sifting.

9.2 CONSTRAINTS MAPPING

A review of the various constraints which exist within and around the Firth of Forth has been carried out. These constraints play an important part in the development of the preferred options and include environmental, physical and urban constraints together with navigation constraints caused by the varied clearances required at different points along the length of the Firth.

The environmental constraints were documented in Report 1 of this study and include the Special Protection Areas, the Ramsar sites and the Sites of Special Scientific Interest. These have been most influential in the constraints mapping and subsequent development of the corridors, as they cover most of the mudflats between Kincardine to the east of Queensferry. There are also a number of Scheduled Ancient Monuments, listed buildings and landscaped gardens particularly on the south shore.

9.3 GENERATION OF OPTIONS AND INITIAL SIFTING

A long list of 65 potential options was generated.

The long list was subjected to an initial sifting process. This was undertaken with a view to reducing the list by eliminating options which did not satisfy the objectives of the study or were not technically feasible. 19 of the original 65 options were rejected, Those rejected included the use of arch bridges and swing bridge options, which could not provide the required spans. Suggestions of bridges or tunnels crossing between Leith/Portobello to either Kirkcaldy or Burntisland were also rejected as these were uneconomic or beyond practical engineering limits.

Options involving ferries and hovercraft were also considered but rejected as they would not provide sufficient capacity on their own. However, such measures may have a complementary role to play as part of an overall strategy for enhancing public transport choice for cross Forth Travel.

A number of options generated by the long list included heavy rail as part of a new bridge crossing or tunnel. Studies undertaken recently, notably the SEStran Integrated Transport Corridor Study (SITCoS), found that sufficient additional cross Forth rail capacity can be provided by enhancing the services using the Forth Bridge to cater for the expected growth in demand until around 2026. This can be done through the introduction of longer train sets (six cars) with accompanying platform extensions and two additional trains in the peak hour. Beyond 2026 Network Rail have indicated that still further capacity can be provided without recourse to a new rail crossing.

It was therefore concluded that future heavy rail capacity should be provided by enhancing the services across the Forth Bridge. This would provide a more cost-effective increase in heavy rail capacity rather than incorporating heavy rail provision into a new Forth Crossing. Previous studies had indicated that the technical requirements to incorporate heavy rail into a new crossing could possibly double its cost. The issue of cross Forth rail capacity and journey reliability should be considered by the main STPR Commission.

9.4 GENERAL DESIGN ISSUES

Before assessing each of the corridors a number of key design issues associated with possible bridge and tunnel crossings were explored. For the bridge options it was considered that the most appropriate structural form for a crossing of this size would be a suspension bridge or a cable stayed bridge.

Using experience and information gathered around the world it was concluded that a suspension bridge would probably take between five and half to six years to construct with a cable stayed bridge possibly taking around six months less.

Different forms of tunnel construction were examined. This included bored, immersed tube, cut and cover and mined tunnel. This review concluded that a bored tunnel utilising a tunnel boring machine (TBM) is the most desirable of the methods as it would avoid the main environmental problems associated with immersed tube tunnelling. Bored tunnelling will not impinge on the various SPAs and SSSIs that delineate the banks of the Forth. Mined and cut and cover tunnelling are considered as supplementary methods to the main bored tunnel crossing.

New European design standards, currently issued for consultation and to be introduced in 2007, dictate that the maximum gradient for new tunnels should be no more than three per cent. This will in turn dictate the length of any tunnel beneath the Firth of Forth. In the corridors examined the lengths of tunnels likely vary between 7km and 10km. Again, using experience and information gathered around the world it is estimated that the construction programme for a tunnelled crossing would be of the order of seven years.

9.5 COMPLEMENTARY MEASURES

Possible Complementary Measures have been identified that will be used to improve the performance of the network on and in the vicinity of the Forth bridges and any new crossing. These measures might be considered interim measures prior to the construction of any Forth Crossing but should also be considered in terms of how they might be maintained as part of the final strategy.

Measures considered for further assessment include high occupancy vehicle lanes, bus priority measures, park and choose sites, further bus services, additional rail capacity, ferry services, active traffic management and variable tolls.

Some initial testing has indicated that many of these measures will have a role to play in a future Forth Replacement Crossing Strategy. These will be examined in more detail in the next stage of the study.

9.6 OPTIONS FOR CONSIDERATION

There is, of course, a possibility that the existing Forth Road Bridge can be repaired without the need for a replacement crossing. Report 2 of this study has demonstrated, however, that this would not provide adequate capacity to meet the study objectives.

At this point in time there is also considerable uncertainty as to the extent of the remedial works associated with refurbishment of the existing bridge and their impact on traffic flows.

In spite of this finding, an option considered during the sifting process was a “No-new crossing” scenario. In this, enhanced public transport (rail and bus) services were introduced together with extensive priority for bus services on both sides of the Forth and High Occupancy Vehicles priority on the M90/A90 southbound approach. In order to maximise the use of the Upper Forth Crossings at Kincardine for vehicular traffic the A985 was upgraded to Dual 2 lane Carriageway standard between Kincardine and the proposed Rosyth Bypass. It should be noted that this scenario is purely indicative of possible interventions and do not represent a commitment by Transport Scotland to implement any of them.

The Transport Model for Scotland (TMfS) was used to examine the impacts of this No-new crossing scenario and found that it is likely to result in changes to travel patterns and choices throughout the study area in 2022. There is likely to be an increase of up to one third in the number of southbound trips made by public transport in the morning peak hour. It is also possible that southbound peak hour traffic on the Forth Road Bridge could reduce by up to one third in the morning peak.

However one key finding arising from scenario is the fact that there is expected to be a reduction of up to 33 per cent in the number of people making journeys between Fife and Edinburgh/Lothians. These journeys are being made instead to other destinations such as the Falkirk/Stirling areas or are remaining within Fife. Although the wider economic impacts of this have not been assessed it is clear that, given the synergy that currently exists between Fife and Edinburgh/Lothians that there will be substantial economic impacts as a consequence of this scenario

Turning to the possible options for a new crossing, following the initial sifting and constraints mapping it was considered appropriate to apply a hierarchical approach to the appraisal to ensure that the major issues were dealt with adequately before focussing on the more detailed issues.

The approach adopted for the purposes of this report was to consider the crossing location and whether bridges and/or tunnels were feasible solutions at each. All other issues will be considered in future reports once a clear view on these primary issues has been established.

The remainder of this report therefore considers bridge and tunnel options in the five remaining corridors

- A – Grangemouth (West of Bo'ness);
- B – East of Bo'ness;
- C – West of Rosyth;
- D - East of Rosyth/West of Queensferry; and
- E – East of Queensferry.

Each corridor has been assessed for its suitability for a tunnel or bridge crossing.

9.7 CORRIDOR SIFTING CONCLUSION

The sifting carried out within this report is undertaken in order to establish which options are unlikely to meet the study objectives. It is equivalent to the pre-appraisal phase of the STAG process. Any options passing this sifting exercise will then be subjected to a Part 1 appraisal during the next work package.

It is clear from the work undertaken that Corridors A and B do not meet the objectives of the study and should therefore be rejected. It is concluded that these corridors should not be considered further within the study.

Corridors C, D and E do, however, perform well to varying degrees against the objectives and it is considered that these should therefore be taken forward to the Part 1 Appraisal.

9.8 PROCUREMENT AND FINANCE

An initial assessment of the options to procure, fund and deliver a Forth Replacement Crossing has been undertaken. There are a range of alternatives available for both the procurement and the funding. At this stage it is not possible to determine the optimal procurement and funding route for the new crossing. This will only become clearer after the detailed Stage 2 qualitative and quantitative analysis required which will highlight the relative costs and risks associated with each procurement and funding option.

It is still too early in the overall project development to be definitive on procurement and finance options. As the project develops factors may emerge that may require a change or refinement of the procurement and funding strategy. However, from the initial assessment of the crossing options it is clear that there is nothing being identified which would preclude or materially impact on the procurement and funding options identified at this stage. In summary the main findings to date are as follows:

- The project clearly demonstrates the attributes for consideration to be implemented as a PPP;
- The risk differentials between the technical options identified at this stage are not material in terms of the ability to develop the procurement options identified;
- It is likely that the PPP options would take a form of a DBFO type structure;
- The eventual form of the PPP will be dependant on the ownership of key risks such as demand, programme and existing bridge condition; and
- Tolling policy and PPP concession length will have a significant impact on the overall affordability of the project.

9.9 LEGISLATIVE ISSUES

A variety of statutory mechanisms have been reviewed by which, alone or in combination, the Scottish Ministers will be able to secure the necessary legal authority to construct a Forth Replacement Crossing. In a similar manner to the procurement and finance issues, it is not possible to be defintive at this stage about the best way forward until the following have been resolved:

- the identity of the promoter of the project;
- the type of crossing involved;
- the other parties who may be involved in the construction and operation of the crossing;
- the timing of the project; and
- the extent of the project (for example whether it involves the existing bridge and/or link roads to the new crossing).

As the project progresses and these issues become resolved then a clear picture of an appropriate legislative route should appear.

9.10 NEXT STEPS

The recommendation from this report is that Corridors C, D and E should be taken forward for a Part 1 STAG appraisal. Both bridge and tunnel options should be considered in these corridors. This will be done as part of the next package of work. This work will examine how public transport modes can be incorporated into the new crossing.