Forth Replacement Crossing Study

Report 4: Appraisal Report

Volume 1: Main Report

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Authorisation

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EXECUTIVE SUMMARY

Introduction

Jacobs and Faber Maunsell were commissioned by Transport Scotland to undertake the Strategic Transport Projects Review (STPR) 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 2012-2022. The commission also covers a study of the Forth Replacement Crossing.

This is the fourth of five reports for the Forth Replacement Crossing Study (FRCS). The objective of this report has been to present the appraisal of the proposals against the established project-specific objectives, implementability criteria, and the Government's transport criteria covering environment, safety, the economy, integration, and social inclusion and accessibility, in line with Scottish Transport Appraisal Guidance (STAG).

The report has assessed proposals for a replacement crossing for the existing Forth Road Bridge (FRB) if one is required. The possible need for a replacement is due to the lack of certainty that the existing bridge is going to be available in the future. Also, recent reports from the Forth Estuary Transport Authority (FETA) would suggest that the refurbishment of the existing crossing would have severe impacts on traffic flows across the bridge for a period of between 3 to 4 years.

The level of repair/refurbishment carried out on the FRB would be determined by the role that is ultimately intended for that crossing and the level of investment required to support that role. For example, if the FRB is intended only for use by light vehicles in future then there may be no requirement to replace the main suspension cables. A decision can also be taken on whether the deck should be replaced, thereby removing the need for expensive painting and strengthening of the existing deck structure.

The key point is that once the replacement crossing is open there is flexibility and time to decide how best to refurbish and operate the FRB.

The FRCS is, therefore, primarily concerned with determining the form, function and location for the replacement crossing. Further development of the emerging options for a replacement crossing will be required to determine the role that the existing FRB should play once refurbished. However, this is dependent upon the level of investment that is required to achieve a number of different possible outcomes. Therefore, a final decision may have to be left until further information is forthcoming from, amongst others, the FETA Cable Replacement Study.

However, if the FRB was to be refurbished and re-opened then consideration would have to be given as to how it could be used in combination with the replacement crossing. This report considers how a strategy could operate. The guiding principle of the operation of this combination would be that there should be no more than two lanes available for general traffic in each direction. Additional capacity should be reserved for sustainable modes such as public transport or high occupancy vehicles (HOV).

The report also considers how an operational strategy could be developed in relation to using any new crossing alongside the FRB. It also includes an assessment of the Complementary Measures. These are schemes which could be implemented prior to a replacement crossing being constructed and as part of a new crossing. These measures are also considered in the context of a twin crossing strategy in the event that the FRB is refurbished and brought back into commission.

Pre – Appraisal

Pre-appraisal studies provided a review of previous work undertaken within the commission covering the analysis of problems and opportunities (Report 1), the setting of objectives (Report 2), and provides the key outcomes from the option generation and sifting process (Report 3).

The review of existing and future network conditions found that there would be a requirement for increased maintenance on the FRB in the future regardless of the problems associated with the cables. This maintenance cannot be undertaken without temporary traffic management measures being implemented which would restrict the capacity of the crossing. It is also envisaged that due to the type of maintenance works expected to be undertaken on the FRB in the future it would not be possible to limit these traffic management restrictions to weekends or overnight as is currently the case. The forecast increases in daily traffic crossing the Firth of Forth would lead to a spreading of the peak periods and exacerbate the high levels of congestion experienced during restrictions or closures on the bridge.

A number of environmental constraints were also identified. Study work has found a wide variety of designations, some of which pose more of a constraint on any proposed crossing than others. In the Firth of Forth, the Natura 2000 sites comprising the Firth of Forth Special Protection Area (SPA) (which is also a Ramsar site), the Forth Islands SPA and the River Teith Special Area of Conservation represent the highest level of designation, being international designations, and these would strongly influence any replacement crossing. Other designations such as Scheduled Ancient Monuments and Ancient Woodland are of a national or local significance would also strongly influence any crossing options.

High level expectations for transport network performance on, and in the vicinity of, the Forth Road and Rail Bridges were subsequently defined. These expectations have been used to derive strategic transport planning objectives 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.

Option Generation, Sifting and Development of Options.

A long list of 65 potential options was generated and this 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. Following this process, the approach adopted was to consider the crossing location and whether bridges and/or tunnels would be feasible solutions in following the 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 assessed for its suitability for a tunnel or bridge crossing. The work undertaken confirmed that Corridors A and B did not meet the objectives of the study and, therefore, were rejected. It was concluded that these corridors would not be considered further within the study.

Corridors C, D and E did, however, perform well to varying degrees against the objectives and these were taken forward to the STAG Part 1 Appraisal, with bridge and tunnel options considered for all three corridors.

STAG Part 1 Appraisal

The STAG Part 1 appraisal was undertaken on the basis of the initial alignments developed for Report 3 – Option Generation and Sifting.

The majority of the planning objectives were met by each of the proposals, although it is evident that the degree to which they are met varies across corridors and crossing types.

At this stage the critical issue which emerged relates to the Environment objective and the planning objective “to minimise the impact on people, the natural and cultural heritage of the Forth area”. The bridge proposals in Corridors C and E performed particularly badly in this regard as both the northern and southern landfalls cross, or come very close to, the Forth SPA which may lead to loss of SPA habitat. Both were considered to have major adverse impacts on a European designated site and are unlikely to be permitted when viable alternatives exist that have less or no adverse impact. The bridge in Corridor D was considered to avoid this impact.

STAG indicates that any proposal which fails to meet the Part 1 appraisal test should be rejected. In this case, given the importance of the SPA and the likely impact which these bridge proposals would have on it, it was considered that the bridge proposals in Corridors C and E should be set aside and not carried forward to the STAG Part 2 appraisal.

The outcome of the STAG Part 1 Appraisal was that the following proposals were taken forward for further development:

- Corridor C – tunnel;
- Corridor D – bridge;
- Corridor D – tunnel; and
- Corridor E – tunnel.

Corridor Proposals

The design detail and construction methodology of each of the four remaining proposed crossings has been examined. Also, included under each option is a summary of the network connection details of the new crossing to the existing road network. Attention has been placed on developing technically and operationally robust and efficient solutions for each option.

The tunnel in Corridor C is 8.5 kilometres in length and would be constructed through a combination of Tunnel Boring Machine (TBM) and Sprayed Concrete Lining (SCL) tunnelling techniques. Construction is expected to take 7.5 years with a capital cost estimated to be £2.3 billion, including network connections and Optimism Bias at Quarter 4 2006 prices.

There are two types of bridge options suggested for Corridor D. The first is a suspension bridge with a 1375 metre main span and a 40 metre wide deck. It is estimated that this would take 6 years to construct and is estimated to cost £1.7 billion, including network connections and Optimism Bias at Quarter 4 2006 prices.

The second type of bridge considered in Corridor D is a cable stayed bridge with two main spans of 650 metres and a 40 metre wide deck. This would take around 6 months less to construct than the suspension bridge and would cost an estimated £1.5 billion, including network connections and Optimism Bias at Quarter 4 2006 prices.

The tunnel in Corridor D would be 7.3 kilometres in length and would also be constructed using a combination of TBM and SCL techniques. It is estimated to take 7.5 years to construct and is likely to cost £2.2 billion, including network connections and Optimism Bias in Quarter 4 2006 prices.

Finally the tunnel is Corridor E is also 7.3 kilometres in length and would be constructed using a combination of TBM, SCL and immersed tube techniques. It would take 7.5 years to construct and is likely to cost £2.4 billion, including network connections and Optimism Bias in Quarter 4 2006 prices.

STAG Part 2

Implementability

There are currently a greater number of technical risks for the three tunnel options. This is due to uncertainties in relation to ground conditions. Corridor E Tunnel also has issues associated with the construction of an immersed tube tunnel. There are fewer technical risks with the Bridge in Corridor D.

Environment

The Environmental Appraisal findings show that environmental impacts for most options would generally be similar, typically minor to moderate adverse. However, the main exception to this are impacts on biodiversity where Tunnel E and Bridge D options may have Major to Moderate adverse impacts.

For Corridor E Tunnel this is due to the proposed immersed tube that would disturb sediments and may impact on the Firth of Forth SPA and Forth Islands SPA, which are protected at the European level, as well as other European protected species such as cetaceans. In addition, approach roads at the southern end of Corridor E Tunnel pass through the Dundas Castle Garden and Designed Landscape, which is a national designation.

For Corridor D Bridge there is a significant risk of indirect disturbance to protected species particularly within the Forth Islands SPA but also relating to the Firth of Forth SPA, which may impose significant seasonal constraints during construction, as the Forth Islands SPA protects breeding birds (i.e. spring and summer) whilst the Firth of Forth SPA protects over-wintering birds. In addition, the northern landfall of Corridor D Bridge passes through the St Margaret's Marsh Site of Special Scientific Interest (SSSI), protected at national level, and would involve the loss of some areas of ancient woodland.

Safety

Typically the proposals result in marginal reductions in all accident types in all options. Corridor D Tunnel, Corridor E Tunnel and Corridor D Bridge perform similarly, with accident savings valued at around £220 million. Corridor C Tunnel produces benefits at a slightly lower level of approximately £180 million.

No specific security issues have been identified which would differentiate between the options. The majority of issues can be managed through best practice in relation to bridge and tunnel operations.

Transport Economic Efficiency

In all scenarios analysed above the monetised benefits are greater than the costs. Corridor D Bridge produces the most favourable results, with the lower cost of the cable-stayed variant giving the highest Net Present Value and Benefit to Cost Ratio. The most favourable tunnel option is that of Corridor E. This option produces the highest level of monetised benefits, but at a significantly higher level of cost than Corridor D Bridge. This results in an inferior NPV and BCR. The higher level of benefits is thought to arise as a consequence of the proximity of the southern connections with routes into the city of Edinburgh. This could be considered to be undesirable given current regional and local policies.

A summary of the results is given in the table below.

Monetised Summary of Costs and Benefits (£millions, 2002 values and prices)

Corridor Crossing Type	C Tunnel	D Tunnel	D Cable-Stayed Bridge	D Suspension Bridge	E Tunnel
Present Value of Benefits (PVB)	4,655.6	5,303.1	6,026.1	6,026.1	6,317.1
Present Value of Costs (PVC)	-2087.4	-1967.7	-1,397.3	-1,574.9	-2,172.2
Net Present Value (NPV)	2568.2	3,335.3	4,628.8	4,451.1	4,144.9
Benefit to Cost Ratio (BCR)*	2.23	2.70	4.31	3.83	2.91

* ratio, not monetary value

Economic Activity and Location Impacts

At the national level, the main positive impacts are to be felt on existing businesses. At the regional level, existing businesses and new businesses are forecast to experience positive impacts. At the local level, all the corridors are anticipated to have positive economic development effects with Corridors C and D tending to favour West Lothian while Corridor E tends to favour north and central Edinburgh.

Integration, Accessibility and Social Inclusion

All options perform similarly in relation to Integration. This also applies to the Accessibility and Social Inclusion criteria. This is particularly the case given that a replacement crossing is being compared against a scenario where the FRB does not operate as it does at present.

Twin Crossing Strategy

This assessment provides an overview of the possible operational arrangements for the proposed new crossing(s) of the Firth of Forth if a twin crossing strategy were to be introduced after the existing FRB was refurbished and brought back into use.

The key objective is to develop an operational arrangement, which complies with the requirements of the study brief, current national policies, complements the proposed alignments and allows flexibility during abnormal conditions.

Based on the assessment of 160 different operational arrangements the following two options are recommended:

- **Option OP1:**

  New crossing: Two lanes for any vehicles;
  Existing Crossing: One bus lane and one High Occupancy Vehicle (HOV) lane.

- **Option OP3:**
  New Crossing: One lane for any vehicle and one lane for Bus and HOV;
  Existing Crossing: One lane for any vehicles and one lane for Bus and HOV

If LRT was to be considered as part of a new crossing (bridge option only), them the recommended operational arrangement would be:

- **Option OP1 with LRT:**

  New crossing: Two lanes for any vehicles with a third lane for rail based LRT;
  Existing Crossing: One bus lane and one HOV lane

The final recommendation on operational arrangement can be confirmed after more detailed assessment of all of the above options.

Complementary Measures

Possible Complementary Measures have been identified that would be used to improve the performance of the network on and in the vicinity of the Forth bridges and on any replacement 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 HOV lanes, bus priority measures, park and choose sites, further bus services, additional rail capacity, ferry services, active traffic management and variable tolls.

It is clear however, that the recent debate in the Scottish Parliament may mean that the use of variable tolls is no longer an option available for consideration.

Recommendations

The principal factors for differentiating between the options are Implementability, Environmental Impact, and Economic Efficiency. Other factors are principally altered by the method of operation, or the suite of complementary measures.

Corridor E Tunnel has significant adverse environmental impacts associated with the method of construction which may be difficult to mitigate against. The use of an immersed tube in the middle section under the Forth has been identified as a risk due to the impact that dredging would have on the SPA. Furthermore, there is the possibility that dolerite could be found in the dredged excavation and drill and blasting techniques may be required. Again, this would have an impact on the SPA and sensitive operations in the area such as at Hound Point. The sub-marine interface between the immersed tube and TBM sections is also likely to be technically challenging and presents further risks to budget and programme.

There are also substantial mine workings to the south of Corridor E. During construction of the M9 Spur these have required grouting to a depth of some 60 metres. It is likely that further mine workings will be encountered.

All of these factors have resulted in this option being the most expensive of those examined at £2.4 billion. Although Corridor E Tunnel has the greatest monetised transport benefits of all the options this is mainly due to the proximity of its southern connections to the city of Edinburgh which may not necessarily be an outcome which reflects current policy.

The combination of these factors suggests that this option should not be considered further.

Of the remaining tunnel options (C and D) there is little to choose between them. Both are estimated to take 7.5 years to construct and have similar cost estimates (£2.2 - £2.3 billion). The monetised benefits of D are marginally better than C due to its proximity to the existing cross Forth corridor. The environmental benefits of both are similar and do not impact on the SPA.

The implementability risks are similar for the Corridors C and D tunnel options. This is primarily as a result of the lack of geotechnical information that would allow the ground conditions for tunnelling to be predicted with greater accuracy at this stage. It is envisaged that the alignments of each corridor can be altered to avoid any outcrops of doleritic or other hard rock intrusions once these have been identified. It is noted that geotechnical surveys will be carried out later this summer and into 2008.

When considered as a replacement crossing the tunnel options would not be able to provide the same facilities as a bridge crossing. For example pedestrians and cyclists would not be permitted into the tunnel. It will not be possible to provide a hardshoulder within the tunnel options as a consequence of the TBM diameter constraints.

Corridor D Bridge has fewer risks associated with unknown ground conditions than any of the tunnel options. This is due to the fact that survey information was collected when earlier bridge studies were carried out in the 1990's. The bridge options also have the advantage of being able to be delivered earlier than the tunnels. Estimates of construction programme vary from 5.5 years for the cable stayed option to 6 years with the suspension bridge option. This compares with 7.5 years for all the tunnel options.

The cost of the bridge options, at £1.5 billion for the cable stayed and £1.7 billion for the suspension bridge, is also substantially less than the tunnel options (which range from £2.2 billion to £2.4 billion). This results in the bridge options having the best Benefit Cost Ratio (BCR) of the corridor options. The cable stayed bridge has a BCR of 4.3 and the suspension bridge has a BCR of 3.8.

Environmentally, however, the bridge options do not perform as well as the tunnel options in Corridors C and D. There are likely to be direct impacts on the St Margaret's Marsh SSSI in the north side of the corridor. There may also be indirect disturbance to protected species within both the Forth Islands and the Firth of Forth SPAs. These may impose seasonal constraints during construction. The full scale of these impacts would not be known until such time that an Environmental Impact Assessment has been carried out.

It is clear from the above that the bridge option in Corridor D provides the best overall solution for a replacement crossing. It is cheaper than the tunnel alternatives, it is easier to implement and can therefore, be constructed quicker than the tunnels. There are fewer risks associated with the bridge option.

Of the two types of bridge structure the cable stayed bridge has advantages over the suspension bridge in that it is the cheaper option and can be delivered around 6 months earlier. The use of cable stay techniques would avoid the need for complex foundations on the landfalls therefore, avoiding the methane risk on the southern side. Cable stayed bridges are modern forms of long span crossings and there is therefore, the opportunity to create a vista across the Forth of three different types of bridge construction comprised of the old (Forth Bridge), recent (FRB) and the new (the replacement). The visual impact of this vista is clearly something to be discussed with Architecture and Design Scotland.

1 INTRODUCTION

1.1 BACKGROUND

Jacobs and Faber Maunsell were commissioned by Transport Scotland to undertake the Strategic Transport Projects Review (STPR) 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 2012-2022. The commission also covers a study of the Forth Replacement Crossing and this element of the work is 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 Report 4 of the Forth Replacement Crossing Study (FRCS) and its objective is to present the appraisal of the proposals against the established project-specific objectives, implementability criteria, and the Government's transport criteria covering environment, safety, the economy, integration, and social inclusion and accessibility, in line with Scottish Transport Appraisal Guidance (STAG).

1.2 FEASIBILITY STUDY FOR THE REPLACEMENT (OR AUGMENTATION) OF THE MAIN CABLES OF THE FORTH ROAD BRIDGE

A study is currently being carried out for the Forth Estuary Transport Authority (FETA) to determine the feasibility of replacement or augmentation of the suspension cables. The need for this study is as a consequence of the level of corrosion that was found in the cables. This was summarised in Report 1[1]. The preliminary report of the feasibility study, published in early June 2007, found that the replacement or augmentation of the cables presents significant engineering challenges but is achievable. It identified three possible options for undertaking the work. The preliminary report reviewed the principal construction sequences of the options and estimated the consequent traffic impacts. The contract duration would be between 5.5 and 7 years depending upon the option pursued.

[1] Forth Replacement Crossing Study – Report 1- Assess Existing, and Forecast Future, Conditions of the Transport Network within the Vicinity of the Forth Road and Rail Bridges, Transport Scotland/Jacobs/Faber Maunsell – February 2007

The first option would result in around 50 complete weekend closures of the bridge and 3 separate blocks of 32, 12 and 24 weeks (spread over 4 years) of carriageway closures requiring contra-flow traffic operation. The second option again would have around 50 weekend closures of the bridge and 2 separate blocks of 32 and 24 weeks (spread over 3 years) of carriageway closures requiring contra-flow operation. The third option would possibly be carried out during two separate blocks of 32 and 24 weeks (spread over 3 years) of carriageway closures requiring contra-flow operation.

The report also considered the option of closing the bridge completely to carry out the work. This would require a continuous closure over a period of some 3.5 years with an overall contract duration of 4.5 years.

It is emphasised within the preliminary report that it is an interim report and the traffic restrictions are indicative only being subject to further consideration in the next phase of the work.

However, the impact of these closures and contra–flow working should be viewed in the light of the recent weekend contra-flow operations at the Forth Road Bridge (FRB) for carriageway resurfacing. Delays of between 60 and 90 minutes are being recorded despite the traffic volumes being 30 per cent down on the corresponding weekends in 2006.

As indicated in the preliminary report, it is envisaged that contra-flow working would be required during week days when average traffic flows are higher than the weekend. It follows therefore, that, unless traffic flows can be reduced considerably below current levels, delays to motorists could be significantly greater than those currently measured.

The preliminary report does go on to state that measures such as increased public transport provision and the introduction of High Occupancy Vehicles (HOV) Lanes would need to be introduced to bring demand down to manageable levels. This would be examined in the next phase of the work as would the likely economic impact of the traffic management measures through a survey of businesses.

1.3 COMMISSION OBJECTIVE

The primary objective of the study is to identify the scope, form and function of any potential replacement to the existing FRB. The need for a replacement crossing is for the following two key reasons:

- there is a lack of certainty that the existing bridge is going to be available in the future; and
- the repair/refurbishment of the existing crossing has too severe a set of impacts on the east of Scotland economy if it were to be closed (or even severely restricted) for a period of time as indicated in 1.2 above.

Therefore, this appraisal focuses upon the options for the provision of a replacement crossing should one be required. Once a new crossing is opened then the FRB could be closed for repairs/refurbishment. During the period of closure all traffic would be switched to the replacement crossing.

The level of repair/refurbishment carried out on the FRB would be determined by the role that is ultimately intended for that crossing and the level of investment required to support that role. For example, if the FRB is intended only for use by light vehicles in the future then there may be no requirement to replace the main suspension cables. A decision can also be taken on whether the deck should be replaced thereby removing, the need for expensive painting and strengthening of the existing deck structure.

The key point is that once the replacement crossing is open there is flexibility and time to decide how best to refurbish and operate the FRB.

The FRCS is, therefore, primarily concerned with determining the form, function and location for the replacement crossing. It could then go onto determining the role that the existing FRB should play once refurbished. However, this is dependent upon the level of investment that is required to achieve a number of different possible outcomes. Therefore, a final decision may therefore, have to be left until further information is forthcoming from, amongst others, the FETA Cable Replacement Study.

However, if the FRB was to be refurbished and re-opened then consideration would have to be given as to how it could be used in combination with the Replacement Crossing. This report considers how such a strategy may operate. The guiding principle of the operation of this combination would be that there should be no more than two lanes available for general traffic in each direction. Additional capacity should be reserved for sustainable modes such as public transport or HOV.

An assessment of the complementary measures that could be implemented alongside the development of a replacement crossing is also reported.

1.4 STAG APPRAISAL

STAG is the official appraisal framework developed by Transport Scotland to aid transport planners and decision-makers in the development of transport policies, plans, programmes and projects in Scotland. It is a requirement that all transport projects, for which Transport Scotland support or approval is required, are appraised in accordance with STAG.

The first element of the STAG process is consideration of problems, opportunities, constraints and uncertainties. This is accompanied by the development of SMART planning objectives. After confirmation of the objectives, there is a process of option generation and sifting. These pre-appraisal elements have been presented within Report 1 (Network Performance), Report 2 (Gaps and Shortfalls) and Report 3 (Option Generation and Sifting).

The appraisal of project proposals within STAG has two parts:

- Part 1: this is an initial appraisal and broad assessment of impacts, designed to decide whether a proposal should proceed to the Part Two Appraisal, subject to meeting the planning objectives and fitting with relevant policies; and
- Part 2: this is a detailed appraisal of proposals that have emerged from the Part 1 appraisal, against the Government's transport criteria, including consideration of cost to government, risk and uncertainty, and proposals for monitoring and evaluation.

1.5 STRUCTURE OF REPORT

Following this introductory Chapter, the remainder of this report is set out as follows:

- Chapter Two – Pre-Appraisal (this contains a summary of the first three reports);
- Chapter Three – STAG Part 1 Appraisal of a Replacement Crossing;
- Chapter Four – Corridor Proposals for a Replacement Crossing;
- Chapter Five – STAG Part 2 Appraisal of a Replacement Crossing;
- Chapter Six – Operation of Twin Crossing Strategy;
- Chapter Seven – Assessment of Complementary Measures; and
- Chapter Eight – Summary and Conclusions.

A series of Appendices support the main report, as follows:

- Volume 2 – Supporting Drawings; and
- Volume 3 – Supporting Technical, Economic and Environmental Appendices

2 PRE-APPRAISAL

2.1 INTRODUCTION

This chapter provides a brief review of the pre-appraisal work, as detailed in the first three reports. It covers the analysis of problems and opportunities, the setting of objectives, and provides the key outcomes from the option generation and sifting process.

2.2 EXISTING AND POTENTIAL PROBLEMS

Report 1[2] examines the current and forecast future (2012, 2017 and 2022) condition of the FRB, Forth (Rail) Bridge and their surrounding transport networks. It also considers the likely environmental constraints that may be associated with any replacement crossing.

2.2.1 Forth Road Bridge

In spite of being maintained throughout its lifetime the FRB 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 climate.

Over and above work to address deteriorating strength in the main suspension cables, increasing maintenance is required to preserve the integrity and life of the FRB, including;

- inspection of the main anchorages;
- 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 would require temporary traffic management measures which would restrict the bridge capacity. It would not be possible to limit these to weekends and/or overnight as is currently the case. It is also possible that, if work to arrest deteriorating strength of the main cables is not successful, steps such as a restriction on Heavy Goods Vehicles (HGVs) would need to be phased in.

2.2.2 Forth (Rail) Bridge

The Forth (Rail) 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.

[2] Forth Replacement Crossing Study – Report 1- Assess Existing, and Forecast Future, Conditions of the Transport Network within the Vicinity of the Forth Road and Rail Bridges, Transport Scotland/Jacobs/Faber Maunsell – February 2007

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 (Rail) Bridge has an expected remaining design life of over 100 years and there are no known significant maintenance issues associated with the existing Forth (Rail) Bridge.

2.2.3 Traffic and Network Operation

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

- the FRB 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 would worsen significantly;
- most vehicles crossing the FRB are single occupant cars;
- rail patronage is expected to increase. This increase can be accommodated by current and likely future route enhancements, which would 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 South East Scotland Transport Partnership (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.

2.2.4 Environmental Constraints

The environmental constraints within and around the Firth of Forth have been examined. These would heavily influence the corridor selection for any Forth Replacement Crossing option. Study work has found a wide variety of designations, some of which pose more of a constraint on any proposed crossing than others. In the Firth of Forth the Natura 2000 sites comprising the Firth of Forth Special Protection Area (SPA) (which is also a Ramsar site), the Forth Islands SPA and the River Teith Special Area of Conservation (SAC) represent the highest level of designation, being international designations, and these would strongly influence any replacement crossing. Other designations such as Scheduled Ancient Monuments and Ancient Woodland that are of a national or local significance would also strongly influence any crossing options.

2.2.5 Summary

There would be a requirement for increased maintenance on the FRB in the future regardless of the problems associated with the cables. This maintenance cannot be undertaken without temporary traffic management measures being implemented which would restrict the capacity of the crossing. It is also envisaged that due to the type of maintenance works expected to be undertaken on the FRB in the future it would not be possible to limit these traffic management restrictions to weekends or overnight as is currently the case.

The forecast increases in daily traffic crossing the Firth of Forth would lead to a spreading of the peak periods and exacerbate the high levels of congestion experienced during restrictions or closures on the Bridge.

2.3 PLANNING OBJECTIVES

Report 2[3] focused 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.

2.3.1 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) would 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

[3] Forth Replacement Crossing Study – Report 2 - Determining Network Performance , Transport Scotland/Jacobs/Faber Maunsell – February 2007

- enhance movements of freight by non-road modes.

2.3.2 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.

Details of how these objectives have been interpreted to meet the requirements of STAG (in particularly, Specific, Measurable, Achievable, Relevant and Time-Related) are contained in Appendix A.

2.3.3 Gaps and Shortfalls

It was concluded that without intervention in the transport network over and above that currently planned, the objectives (outlined above) of the FRCS would 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.

2.4 OPTION GENERATION, SIFTING AND DEVELOPMENT

2.4.1 Generation of Options and Initial Sifting

A long list of 65 potential options was generated in Report 3[4] of the study. 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 and this is covered in more detail in Chapter 7 of this report.

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 (Rail) 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 has indicated that 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 (Rail) Bridge. The issue of cross-Forth rail capacity and journey reliability would be considered by the main STPR.

2.4.2 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.

Different forms of tunnel construction were examined. This included bored, immersed tube, cut and cover and mined tunnel. This initial 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. However, as detailed in Chapter four, this assumption had been explored further. Bored tunnelling would not impinge on the various environmental constraints that delineate the banks of the Firth of Forth. Mined and cut and cover tunnelling are considered as supplementary methods to the main bored tunnel crossing.

[4] Forth Replacement Crossing Study – Report 3 – Option Generation and Sifting, Transport Scotland/Jacobs/Faber Maunsell – February 2007

2.4.3 Complementary Measures

Possible Complementary Measures have been identified that would be used to improve the performance of the network on and in the vicinity of the Forth bridges and any replacement 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 HOV lanes, bus priority measures, park and choose sites, further bus services, additional rail capacity, ferry services, active traffic management and variable tolls. It is acknowledged that the recent debate in the Scottish Parliament may mean that the use of variable tolls may no longer be an option.

2.4.4 Options for Consideration

The approach adopted for the purposes of option sifting was to consider the crossing location and whether bridges and/or tunnels would be feasible solutions in 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 assessed for its suitability for a tunnel or bridge crossing.

The five corridors identified for the purposes of the option sifting process are displayed in Figure 2.1 overleaf.

2.4.5 Corridor Sifting Findings

The work undertaken confirmed that Corridors A and B did not meet the objectives of the study and were therefore, rejected. It was concluded that these corridors would not be considered further within the study.

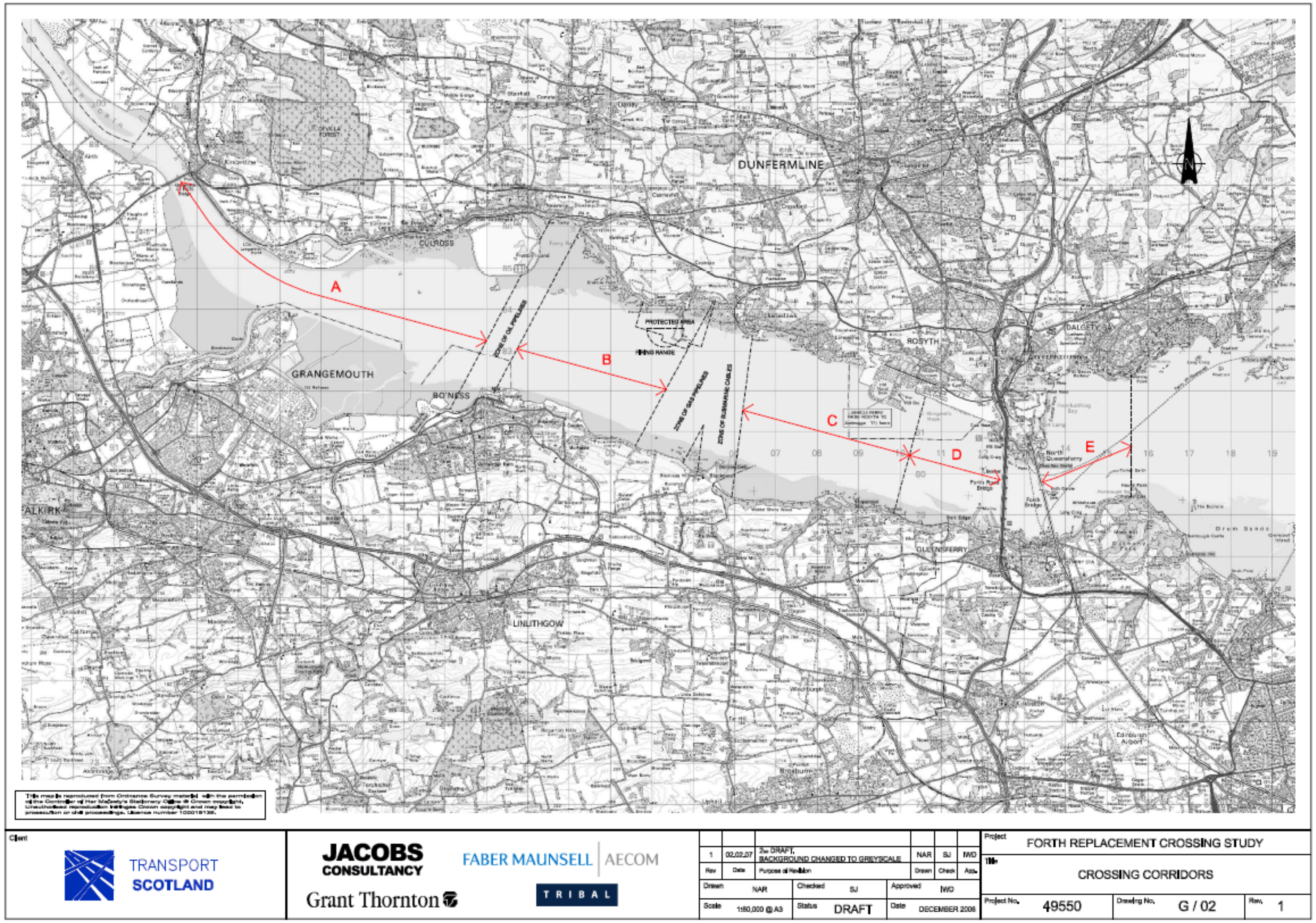
Corridors C, D and E do, however, perform well to varying degrees against the objectives and these were taken forward to the Part 1 Appraisal, with bridge and tunnel options considered for all three corridors.

2.5 PROPOSALS RETAINED FOR STAG PART 1 APPRAISAL

The following proposals were retained during the option generation and sifting process and were taken forward for further appraisal at STAG part 1 level:

- Corridor C - West of Rosyth;
  - bridge crossing (suspension with a span of 1800 metres)
  - tunnel
- Corridor D - East of Rosyth/West of Queensferry; and
  - bridge crossing (suspension with a span of 1375 metres or cable stayed with spans of 600 and 650 metres)
  - tunnel
- Corridor E - East of Queensferry.
  - bridge crossing (suspension with a span of 1,650 metres or 1,850 metres)
  - tunnel

Figure 2.1 – Crossing Corridors



3 STAG PART 1 APPRAISAL

3.1 INTRODUCTION

This chapter provides a summary of the key outcomes of the STAG Part 1 appraisal.

3.2 ASSUMPTIONS

The issues with regard to the structural integrity of the existing FRB are well documented and it is recognised that a range of possibilities exist in relation to its future status and use. As outlined in Chapter 1 the objective of this report is to appraise the options for a replacement crossing. Therefore, it is assumed that the existing FRB would no longer be available for any traffic.

The appraisal also took into account other operational assumptions which are detailed below.

Any replacement crossing would comprise, as a minimum, two lanes in each direction to ensure that the crossing would have the potential to offer at least the same level of service as offered at present by the existing crossing. Hard shoulders would also be provided on the bridge crossings. The requirement to have a tunnel bore in excess of 13 metres in diameter would mean using a TBM at the upper end of the range of boring machines currently available. This would be technically challenging to the point of being infeasible and would add considerably to the cost. This diameter would not be sufficient to accommodate two lanes and a hard shoulder. Therefore, standard edge strips would be provided in any tunnel option.

The future of tolls on Scotland's crossings was discussed in the Scottish Parliament in late May 2007 and primary legislation is to be introduced later this year which is planned to lead to the abolition of tolls at the FRB. However, during the course of the appraisal it has been assumed that tolls on the replacement crossing would be set at the same level as those in place at present on the existing FRB.

3.3 DO MINIMUM SCENARIO

STAG advocates that "to facilitate appraisal, it is necessary to develop a "Do-Minimum" scenario which accurately reflects the changes which are committed to occur irrespective of the conclusions of the planning exercise". The purpose of the Do Minimum scenario is to provide a base case against which to assess the proposals. The Do Minimum scenario confirms, or otherwise, the need for interventions beyond committed schemes and enables unbiased assessment of individual proposals.

The Do Minimum scenario has been agreed with Transport Scotland for use on both the main STPR and the FRCS. Therefore, it incorporates many schemes which are clearly outwith the direct influence of the FRCS area. For the record it contains the following schemes:

- M74 completion;
- M9 Spur Extension;
- Finnieston Bridge (Glasgow);
- A68 Northern Dalkeith Bypass;
- Ferrytoll Link Road;
- Second Upper Forth Crossing;
- Alloa – Stirling – Glasgow Rail Service;
- Borders Rail Service;
- M80 Upgrade;
- Aberdeen Western Peripheral Road; and
- M8 Upgrade (M8 Baillieston to Newhouse, Raith Interchange and Adjacent Network Improvements).

The Do Minimum scenario also includes development control-led infrastructure at Heartlands, Pollok and the A90 new interchange at Portlethen.

In addition to the above, it is assumed that the existing crossing is closed to all traffic from 2019. This date is the best estimate of when the existing crossing is likely to close to all traffic assuming that the suspension cables continue to deteriorate at the same rate.

3.4 OPTIONS

The STAG Part 1 appraisal was undertaken on the basis of the initial alignments developed for Report 3 – Option Generation and Sifting. Alignments are shown diagrammatically in the Appendices of Report 3.

3.4.1 Corridor C Bridge

A probable bridge option for this alignment is a suspension bridge with a main span of approximately 1800 metres and side spans of 550 metres. The location of the bridge within Corridor C has been heavily influenced by the boundary of the SPA. In order to minimise any impact on the SPA, the southern landfall would be between the boundary of the SPA and Hopetoun House. At the northern landfall the preferred bridge alignment would pass over the SPA immediately west of Rosyth.

3.4.2 Corridor C Tunnel

The preferred tunnel alignment would link the A823(M) Junction at St. Margaret's Stone to Junction 2 of the M9. It would comprise a tunnel from a point close to Pattiesmuir and under Limekilns, reaching the south shore around Abercorn. The tunnel would then rise to a portal between Duntarvie and Carmelhill. This alignment would involve approximately eight kilometres of twin-bore tunnel.

3.4.3 Corridor D Bridge

A suspension bridge in this corridor would be approximately 2.2 kilometres long with a proposed main span of 1375 metres and two equal side spans of 416 metres. A cable stayed bridge would have two main spans, each in excess of 600 metres, with the central tower supported on Beamer Rock.

3.4.4 Corridor D Tunnel

The tunnel alignment in this corridor would connect the M90 at Junction 1 to Junction 1a of the M9. The alignment would cross the south shore near Port Edgar and then rise to a portal between Dundas Mains and Junction 1a of the M9. A tunnel on this alignment would be approximately seven kilometres in length of which approximately two kilometres may be mined through dolerite, whilst five kilometres would be of bored tunnel construction.

3.4.5 Corridor E Bridge

Two suspension bridge alignments are considered within this corridor.

Alignment 1

The area of relatively little urban development between Inverkeithing and Dalgety Bay forms a natural landfall. The south landfall would be located east of Long Craig Pier. In order to found bridge piers in relatively shallow water a suspension bridge with a main span of approximately 1850 metres, with side spans of approximately 550 metres, would be required.

Alignment 2

It is possible to bridge the potentially narrow crossing between Whitehouse Point and North Queensferry as part of a longer cross Forth route. In order to found the main towers of a bridge on this alignment in relatively shallow water, it would be necessary to provide a suspension bridge with a main span of 1650 metres, with side spans of 500 metres. Approach viaducts would be required to link the bridge to the north landfall. A further bridge would be required across Inner Bay between West Ness and East Ness.

The southern landfall for both bridge proposals in Corridor E have been determined to clear the Hound Point Marine Terminal. However, the presence of the pipelines between Hound Point and Dalmeny imposes complexity to the construction of the south anchorages and approach viaducts.

3.4.6 Corridor E Tunnel

Tunnelling could commence between Junction 2A of the M90 and Balgougie on the north shore. The tunnel would cross the northern shoreline in St. Davids Harbour area. It would then pass to the east of Inch Garvie, making landfall on the south shore at Lone Craig Gate. It would then rise to a portal between Dalmeny and the M9. The length of bored tunnel for this alignment would be approximately 7.5 kilometres. However, if a combined bored / immersed tube solution were used, this may be reduced to approximately 7 kilometres.

3.5 PERFORMANCE AGAINST PLANNING OBJECTIVES

3.5.1 Introduction

A qualitative appraisal of performance against planning objectives has been undertaken for STAG Part 1 appraisal.

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

This objective would only be achieved if additional road space was provided, for the dedicated use of HOVs, public transport or some combination of the two. There would be the potential for maintaining and indeed improving the level of service for cross-Forth transport links irrespective of which corridor the crossing is located within. Should capacity remain the same, this objective would not be met, as the anticipated traffic growth would reduce the level of service available in the future.

Bridge proposals would afford more flexibility to provide the additional road space.

In terms of the location of the crossing, the fact that Corridors D and E are located adjacent to the existing FRB means that the requirement for traffic to divert from current routes is generally low if either of these is being used as a replacement crossing. These proposals would, therefore, provide a higher level of service than Corridor C proposals in this regard.

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

The connections to the strategic transport network associated with the tunnel proposals offer less flexibility than their corresponding bridge proposals due to their portal locations being further inland.

The location of Corridor C, approximately three kilometres upstream from the existing FRB limits its options in terms of connectivity to the existing primary transport network. Infrastructure provision would ensure that a new crossing would connect with the primary transport network. However, the location of this proposal would result in significant diversions and additional mileage. This problem would be more acute in the case of the tunnel on Corridor C than the bridge as with the latter it would be possible to create a connection with the A985 on the north side.

Corridors D and E, being located adjacent to the existing bridge, permits relatively short connections to the network and would offer direct alternatives to the existing FRB which, in turn, would permit reasonable optimisation of the network.

3.5.4 Improve the reliability of journey times for all modes.

The performance of the proposals in relation to this objective is measured by the degree of congestion which may result on the network and also the impact which accidents and unplanned incidents may have on the operation of the network.

For all of the bridge proposals under consideration, a full width hard shoulder would be provided. The tunnel options would have edge strips which would provide refuge for vehicles in the event of a breakdown or other incident. As mentioned previously, this limits each tunnel option to two lane operation, given the practical diameter of the tunnels envisaged.

Although there would be a strong tunnel management regime (which is dealt with in Chapter 4) in place to deal with breakdowns and incidents, it is clear that the reliability of journey times of the tunnel options would not be as great as that for the bridge options.

Other than the benefits of providing a hard shoulder, the ability of a replacement crossing to improve the reliability of journey times is limited unless additional lane provisions are included. It is possible that the hardshoulder could be given over to the running of HOVs and/or public transport. Therefore, the reliability of journey times for these modes would be improved should a bridge be provided.

Since the tunnel proposals could not accommodate additional lanes without additional tunnel bores, the likelihood of tunnels meeting this objective is further limited.

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

This objective focuses on the opportunity to provide dedicated road space for HOVs and/or public transport. In addition, the location of the crossing and its potential to connect with the public transport network is also considered.

Generally, the proposals to replace the existing crossing with a dual two lane carriageway, plus hard shoulders or edge strips in each direction have no impact on increasing travel choices and encouraging modal shift. However, if additional lanes are provided for HOVs and public transport the opportunity would clearly exist to achieve this objective. As outlined above this could be done by allowing the HOVs and/or public transport modes to make use of the hardshoulder provided on the bridge. The limitations associated with the size of tunnel bore would mean that this is unlikely to be achieved for the tunnel proposals.

In terms of the location of each of the proposals, those which are located adjacent to the existing cross Forth public transport routes (Corridors D and E) would provide the greatest opportunity to encourage such modal shift. The opportunities for Corridor C would be less evident.

3.5.6 Improve accessibility and social inclusion.

The key aim of this objective is to improve accessibility to employment, communities, services and other facilities. The aim is also to improve social inclusion through linkage to community regeneration areas, and assess how those suffering social exclusion can access centres of major employment and other services. This objective also aims to avoid community severance.

Unless additional lanes are provided, there is little opportunity to achieve this objective, irrespective of the corridor location. Should additional lanes be provided, some benefit may accrue due to the potential to improve cross-Forth public transport services.

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

The key aim is to minimise the disruption to the network during planned or unplanned maintenance activities.

Other than the provision of a hard shoulder or edge strips, none of the proposals presented would provide significant improvements in relation to minimising the impact of maintenance on the network. Clearly the presence of a hardshoulder on a replacement bridge crossing would provide significant benefits over the current situation which would allow flexibility during periods of maintenance. This would not be the case with tunnels which would not be equipped with hardshoulders.

Some benefits to network operation could be made if additional lanes were constructed. Although these lanes would primarily be for HOVs and public transport, they could be utilised for any vehicle type during periods of maintenance.

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

The key aim is to minimise the impact of the proposal on people, the natural and cultural heritage of the Forth area. This objective relates to possible impacts on designated environmental sites in addition to noise, visual and air quality impacts on the wider community.

In terms of air quality and its impact on the local population, the information available for the STAG Part 1 appraisal meant that it was not possible to differentiate between proposals.

However, in relation to the other aspects of this objective, each of the proposals under consideration have significantly different characteristics and are therefore, reported separately.

Corridor C Bridge

This proposal would directly impact on the SPA, Ramsar and SSSI sites located on the north and south shores of the Firth of Forth. The northern landfall crosses the Firth of Forth SPA at Limekilns, and again in the south near Hopetoun. The southern landfall might be able to avoid loss of the SPA designated habitat, but its close proximity to the SPA may lead to indirect impacts particularly on the important inter tidal area at Blackness Bay. The bridge alignment would directly impact on the landscape as it crosses two designated areas comprising the Forth Shore Area of Great Landscape Value (AGLV) and the Hopetoun House Gardens and Designed Landscape (GDL). The latter area, including Hopetoun House itself, is designated at the national level and would also be subject to cultural heritage impacts from this proposal.

Overall, therefore, this proposal performs poorly against this objective.

Corridor C Tunnel

This proposal would cross under or adjacent to a number of historic buildings and designated environmental sites, but the impact is likely to be negligible. This proposal would avoid direct impact on the Firth of Forth SPA, although there may be indirect impacts. The most significant environmental constraints comprise the GDL at Hopetoun House and AGLVs both in Fife and in West Lothian, which may be directly impacted.

Whilst having the potential to impact the natural and cultural environment, this proposal seeks to minimise this impact by avoiding direct impact on the SPA.

Corridor D Bridge

St Margaret's Marsh SSSI and the Ferry Hills SSSI are both located near the likely centre line of the route corridor, resulting in potential for direct and indirect impacts on these sites. Indirect impacts on the Firth of Forth SPA and Forth Islands SPA are also a possibility. In addition, some areas of ancient woodland and listed buildings may be affected. Significant visual and landscape impacts are likely with this alignment in particular due to its proximity to the existing Road and Rail Bridges.

However, as this proposal avoids direct impact on the SPA, it performs reasonably well against this objective. Nevertheless, the risks of indirect adverse impact remain.

Corridor D Tunnel

This proposal may indirectly impact on the St Margaret's SSSI and the Ferry Hills SSSI and may also have indirect impacts on the Firth of Forth SPA and Forth Islands SPA. Some areas of ancient woodland and listed buildings may be affected by surface infrastructure such as access roads and toll plazas. Overall, however, this proposal would be expected to minimise such impacts.

Corridor E Bridge

This proposal would directly impact on the Firth of Forth SPA on the southern shore and also the northern shore of the Firth of Forth. The bridge proposal crosses the open water of the Firth of Forth which may impact on the SPA qualifying species using the open habitat, in addition to European Protected Species (EPS) such as cetaceans. Carlingnose SSSI lies on the western margin of the route corridor in Fife and may be susceptible to indirect effects. Ancient Woodlands are present in the corridor surrounding connecting roads. There is likely to be significant visual and cultural heritage impact associated with this proposal, which would be located immediately to the east of the Category A listed Forth (Rail) Bridge. In addition, this option would impact directly on the Dalmeny Estate GDL.

The likely significant impacts on the SPA and the GDL result in this proposal failing to meet this objective.

Corridor E Tunnel

This proposal would avoid direct impact on the Firth of Forth SPA, although indirect impacts may depend on the final placement and design of the route. There may be some indirect impact on Carlingnose and Ferry Hill SSSIs, which lie on the western margin of the corridor. In addition, there may be direct impacts on the Dundas Castle GDL. This cannot be fully assessed until the exact alignment of the route is known. In comparison with a bridge on this alignment, visual impacts would be reduced although there may be significant local landscape impacts.

Due to the fact that direct impact on the SPA is avoided, this proposal would be expected to minimise the impact on the natural and cultural environment and, as a consequence, performs reasonably well against this objective.

Summary

The potential for impacts on the Firth of Forth SPA is a critical element in relation to this objective. The bridges on Corridors C and E fail to meet this objective. In addition, it should be noted that development proposals which have a direct adverse impact on a European designated site, such as the SPA, are unlikely to be permitted where viable alternatives exist that have less or no adverse impact. This is the case with this study. The only reason for constructing within the SPA would be for over-riding reasons of public interest and if there were no other alternatives. Neither of these circumstances applies to the bridge options in Corridors C and E. The bridge on Corridor D should avoid this direct adverse impact. However, it is recognised that indirect impacts on the SPAs could still result.

The tunnel proposals generally avoid direct impacts to the SPA and, therefore, perform reasonably well in relation to this objective, although the potential for other adverse impacts, such as on the GDLs, is recognised.

3.5.9 Support sustainable development and economic growth.

Local policies, as detailed within Report Two[5]: Gaps and Shortfalls seek to promote economic development within the local area and improve strategic access to key "growth areas"[6]. Whilst stimulating economic development provides an ultimate goal, within the context of the scope of this study, an objective for reducing cross-Forth peak road based journey time (for all users) and modal shift provides a suitable proxy. Increasing public transport mode share as a proportion of travel would be a measurement of the success of each proposal in achieving this objective.

When operating as a replacement for the existing crossing, the proposals would have limited impact on the objective to support sustainable development unless additional lanes are provided. There would be a significant impact on economic growth as the "do-minimum" scenario would severely constrain the economy of Edinburgh, Fife and East Central Scotland. The location of Corridor C does not serve key employment hubs as well as Corridors D and E, but relative to the "do-minimum" scenario, all corridors would support economic growth.

The replacement crossing proposals would be essential to promote economic growth. Generally, Corridors D and E provide the best performance in this category as a result of their proximity to the existing crossing and increased (in relation to Corridor C proposals) ability to serve existing areas of economic development, but Corridor C would also meet the needs of the area in terms of supporting economic growth.

3.6 OVERALL SUMMARY OF PERFORMANCE AGAINST THE PLANNING OBJECTIVES

The majority of the planning objectives are met by each of the proposals, although it is evident that the degree to which they are met varies across corridors and crossing types.

For the majority of objectives, the tunnel proposals perform slightly less effectively than the corresponding bridge proposals. This is due to network connectivity issues and the limited ability for the possibility of additional lanes to be provided without the requirement for an additional tunnel bore.

Generally, there is a preference for Corridor D and E proposals, over Corridor C proposals, due to their proximity to the existing crossing and primary transport network which minimises diversionary routes, increases flexibility and allows them to better serve developed areas and trip generators.

The only objective not met by all proposals is to minimise the impact on people, the natural and cultural heritage of the Forth area. This is not met by the Corridor C bridge and Corridor E bridge proposals, due to their expected impact on the SPA.

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[5] Forth Replacement Crossing Study – Report 2 - Determining Network Performance , Transport Scotland/Jacobs/Faber Maunsell – November 2006

[6] SEStran Regional Transport Strategy, Draft for Consultation, SEStran, November 2006

3.7 IMPLEMENTABILITY

A review of the implementability of each of the options was undertaken during the STAG Part 1 appraisal process.

It is evident that the implementation and operation of a new / replacement crossing of the Firth of Forth would be a technically challenging project. A number of significant technical risks would require to be identified and addressed, and appropriate mitigation strategies developed.

In terms of financial implementability, a wide range of costs exist for the proposals. However, none of the proposals can be excluded due to the affordability implications.

In terms of public acceptance there has been media coverage which suggests that there is a preference for the tunnel options as opposed to the bridge. However, none of the proposals could be excluded on the basis of public acceptance at this stage.

Given the level of study undertaken to date, it would appear that all of the proposals included in the STAG Part 1 Appraisal are "implementable" and therefore, worthy of further consideration.

3.8 PERFORMANCE AGAINST GOVERNMENT OBJECTIVES

A qualitative appraisal of the overall performance of the various proposals against the Government transport appraisal criteria was undertaken for the STAG Part 1 appraisal. The most significant findings which emerged are detailed below.

When acting as a replacement crossing, all of the proposals would be expected to perform well against the Government objectives when compared against the Do Minimum situation. It is recognised that the ability to provide extra lanes for HOVs and public transport on a bridge crossing would enhance the performance of these proposals when compared to tunnel options. It is clear that the option of providing extra lanes within the tunnel options would not be possible without the construction of a further bore.

None of the proposals exhibit a beneficial or even neutral performance against the environmental objective, and this is particularly the case for the bridges on Corridors C and E. The northern and southern landfalls of the Corridors C and E bridge proposals cross the Forth SPA, which may lead to loss of SPA habitat. These are both considered to be major adverse impacts. As noted above in section 3.5.8 development proposals which have a direct adverse impact on a European designated site, such as the SPA, are unlikely to be permitted where viable alternatives exist that have less or no adverse impact. This is the case with this study. The only reason for constructing within the SPA would be for over-riding reasons of public interest and if there were no other alternatives. Neither of these circumstances applies to the bridge options in Corridors C and E. The bridge on Corridor D should avoid this direct adverse impact.

Furthermore, major negative impacts are anticipated for Corridor E Bridge due to the impact on the setting of the Forth (Rail) Bridge.

In terms of the economy objective, proposals for Corridor C were considered to provide less benefit than proposals for Corridors D and E.

3.9 OVERALL SUMMARY OF APPRAISAL

The purpose of this STAG Part 1 level of appraisal has not been to highlight a preferred option, but to identify which of the proposals perform sufficiently well against the objectives to merit further study.

At this stage the critical issue which has emerged relates to the Environment objective and the planning objective to "*minimise the impact on people, the natural and cultural heritage of the Forth area"*. It is clear that the bridge proposals in Corridors C and E perform particularly badly in this regard. STAG indicates that any proposal which fails to meet the Part 1 appraisal test should be rejected.

Furthermore, the length of main spans in Corridors C and E (between 1650 and 1800 metres) are considerably longer than that in Corridor D (1375 metres). This would have an impact on construction timescales (and cost). The visual impact of a bridge in Corridor E on the setting of the Forth (Rail) Bridge is also clearly an issue.

It is, therefore, clear that the bridge options in Corridor C and E do not offer any advantages over the bridge option in Corridor D but attract impacts as identified above. It is considered that the bridge proposals in Corridors C and E should be set aside and not carried forward to the STAG Part 2 appraisal.

It is also clear from the work undertaken to date that, other than in relation to the Environment objective, the bridge proposals perform to a higher standard than the tunnel proposals.

At this stage of the STAG process, Corridor D bridge proposal appears to generally perform to a higher standard against the majority of the planning objectives and Government objectives than the other proposals considered. However, the tunnel proposals within Corridors C, D and E all have sufficient merit to remain for further scrutiny.

3.10 RECOMMENDATION

The outcome of the STAG Part 1 Appraisal was that the following proposals were taken forward for further development:

- Corridor C – tunnel;
- Corridor D – bridge;
- Corridor D – tunnel; and
- Corridor E – tunnel.

4 Corridor Proposals

4.1 INTRODUCTION

This chapter outlines the four remaining crossing options taken forward from the STAG Part 1 Appraisal, detailing the type and nature of the proposed construction methodology. The four remaining crossing options considered are:

- Corridor C - tunnel;
- Corridor D - bridge;
- Corridor D - tunnel; and
- Corridor E - tunnel.

Where appropriate, the associated drawing number has been included at the start of each section.

It is recognised that the development of network linkages for replacement crossing options would require significant detailed study necessitating detailed traffic, economic and environmental appraisal to ensure the optimum solution is developed. This level of detail is outwith the scope of this study. However, to date an overview of options has been undertaken in order to confirm feasibility and explore key issues and likely costs.

In addition, the operational characteristics of a replacement crossing would have an impact on the junction layouts and any associated network improvements which would be required.

Before considering each of the crossing options in detail a discussion of a number of issues which are common to each of the tunnel options is provided. This relates to:

- Tunnel cross section;
- Hazardous goods in tunnels;
- Incident management;
- Geotechnical information; and
- Scheme development.

4.2 GENERIC TUNNEL CONSIDERATIONS

4.2.1 Tunnel Cross Section

The cross section of the tunnel is defined primarily by the type of tunnelling technique employed. The tunnel is designed to Dual 2 Motorway Standard with two 3.65 metre traffic lanes but does not include a hard shoulder. This, as stated previously, reflects the limitations of the TBM diameter. The extremely high costs associated with the provision of hard shoulders means that there are very few examples of continuous emergency stopping lanes in bored tunnels. A one metre wide verge is required on each side of the carriageway and, when combined with a narrow hard strip, provides sufficient width to allow for traffic to pass a stranded vehicle (or provide access for emergency vehicles) should an incident occur.

Emergency walkways are required on both sides of the carriageway to enable users to move freely along the tunnel in order to reach a place of relative safety in the event of an incident. Unfenced walkways on the verges are raised 75 millimetres from the carriageway. Headroom standards require that an additional clearance of 0.25 metres is maintained above the vehicle envelope of 5.03 metres to provide protection to ‘soft’ equipment and services from high vehicles.

The cost of tunnelling generally increases with the cross sectional area. It is therefore, important to optimise the use of the cross sectional area to include all necessary functional and safety provisions. There is a maximum diameter that current TBM technology would permit in given ground conditions

The cross section area of a sprayed concrete lined (SCL) tunnel is similar to that of a TBM tunnel, however, the method of excavation means that there is significantly more flexibility in the actual shape that can be achieved to suit the traffic envelope and services. Guidelines indicate there would be a requirement for cross passages between the two tunnel bores to provide an emergency escape route for tunnel users in the event of an incident. Alternative emergency escape solutions could be provided utilising a void below the road deck. However, for both TBM and SCL tunnels this would increase tunnel diameter. In an immersed tube tunnel, flexibility in shape is readily achieved as the shape of the unit can be fabricated to suit the requirements. The immersed tunnel unit is divided into different cells, to be used for traffic and services and for ballast purposes. It should be noted that the cross section of a cut and cover tunnel is similar to an immersed tube where the shape can be varied to suit requirements. Further details of each tunnelling technique can be found in Appendix B.

Figure 4.1 below shows a typical cross section for a bored TBM tunnel. A typical cross section of a mined SCL is shown in Figure 4.2 and Figure 4.3 shows a typical cross section of an immersed tube tunnel.

Figure 4.1 – Typical Cross Section for a Bored TBM tunnel

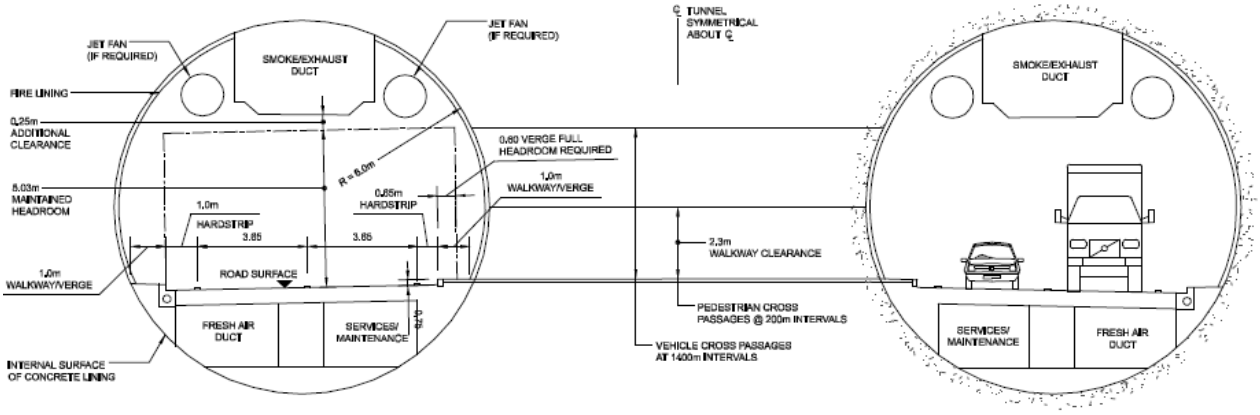


Figure 4.2 – Typical Cross Section for a Mined SCL Tunnel.

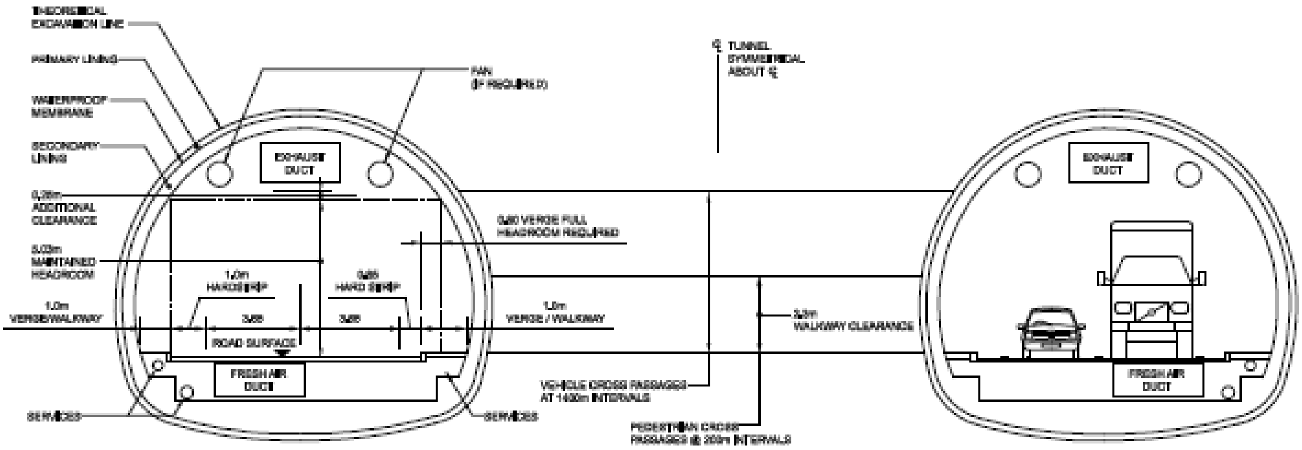
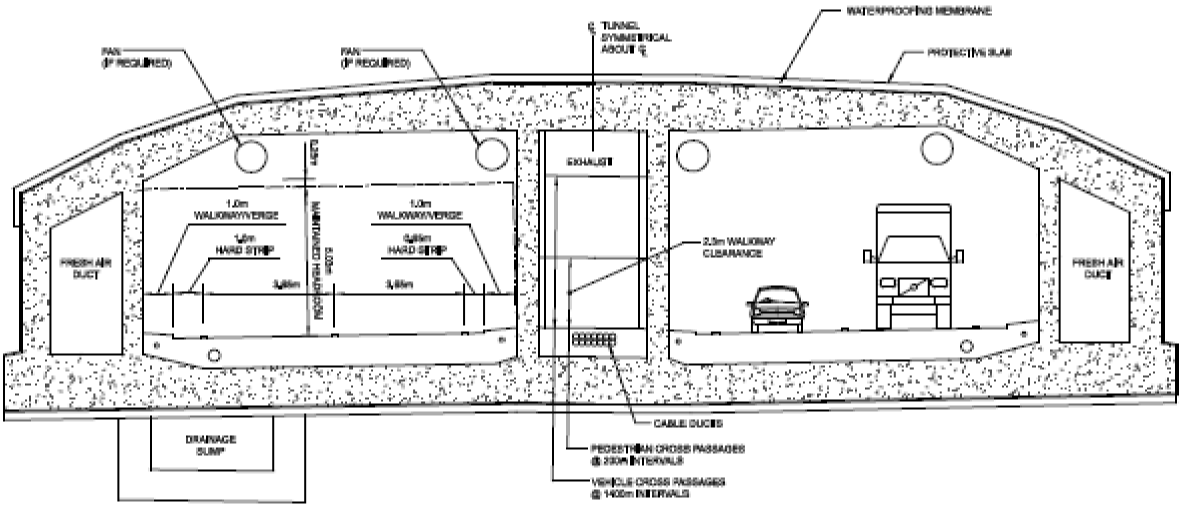


Figure 4.3 – Typical Cross Section for an Immersed Tube Tunnel



4.2.2 Hazardous Goods in Tunnels

The passage of hazardous goods through the tunnel is subject to restrictions as outlined in the British Toll Tunnels Dangerous Traffic List of Restrictions booklet which is currently in its thirteenth edition. The basis of this list is the restructured 2005 European Agreement concerning the international Carriage of Dangerous Goods by Road, (ADR) as amended by the Report of the Committee of Experts meeting in December 2004.

The classes of dangerous goods according to the ADR are the following:

Class 1: Explosive substances and articles;

Class 2: Gases, compressed, liquefied or refrigerant;

Class 3: Flammable liquids;

Class 4.1: Flammable solids, self-reactive substances and solid desensitised explosives;

Class 4.2: Substances liable to spontaneous combustion;

Class 4.3: Substances which in contact with water emit flammable gases;

Class 5.1: Oxidising substances;

Class 5.2: Organic peroxides;

Class 6.1: Toxic substances;

Class 6.2: Infectious substances;

Class 7: Radioactive material;

Class 8: Corrosive substances;

Class 9: Miscellaneous dangerous substances and articles.

Larger loads and tankers carrying hazardous goods are generally prohibited from tunnels but permitted access would depend on the substance being carried. Some vehicles would be allowed access under escort. To gain approval for carriage of hazardous goods through the tunnel, the consignor of any goods, substances or articles on the list of restrictions must submit to the Tunnel Manager a written declaration as to the nature and quantity of such goods. Similarly, for an empty petrol or other tanker, a declaration is required as to the nature of the substance last carried if it has not been cleaned since that loaded journey. Permission may be granted for passage through the tunnel at a prescribed off peak time when the tunnel can be closed to the public following notification to the public of the temporary tunnel closure.

These constraints, whilst of a detailed operational nature, illustrate some of the issues that may be associated with tunnels.

4.2.3 Incident Management

The management of an incident in the tunnel is controlled by the Tunnel Control Centre (TCC). This is likely to be located within the toll plaza complex, if there is one. The centre is responsible for monitoring the tunnel at all times, traffic management, traffic information communication and signal control. The automatic incident detection system, CCTV Alert, is used to feed information to the operator in the TCC identifying the nature, cause and severity of incidents that occur. CCTV Alert can automatically detect a vehicle stopping in the tunnel in the event of a breakdown or accident and it also detects fire. Typical response time should be approximately five minutes but would depend upon its location within a tunnel of this length.

Breakdowns

As per normal practice in tunnels of this length, recovery vehicles are located at each side of the tunnel adjacent to the portal and once the incident is detected by the TCC, a recovery vehicle is dispatched to the traffic incident. The driver of the broken down vehicle is instructed via radio or public announcement to remain in their vehicle pending recovery. Traffic in the tunnel should be able to negotiate the stranded vehicle without causing serious congestion behind. However, it is noted that the reduced width of the cross section would require vehicles to pull onto the hard strip.

Traffic Accidents

A minor accident is managed in the same way as a breakdown. However, in this instance two or more recovery vehicles may need to be dispatched to deal with the stricken vehicles. In the event of a serious accident where debris blocks the tunnel and traffic backs up behind the incident, a recovery vehicle from the opposite end of the tunnel can use the vehicle crossover outside the portal or vehicular cross passages within the tunnel to enter the incident tunnel. The emergency services enter in a similar manner. Variable Message Signs (VMS) and lane closure indicators are activated by the TCC to warn tunnel users about an incident and, if necessary, the incident tunnel is closed and alternative traffic management plans are implemented. These could include the introduction of a temporary contra-flow system in the non-incident bore or complete diversion elsewhere on the trunk road network. The role of the FRB in any future network should be considered in this respect.

Fire

Access for the emergency services is provided in a number of ways depending on the circumstances. They can drive down the affected bore directly to the incident if there is no traffic blocking the route. Alternatively, if the route is blocked, the non-affected bore can be closed to traffic and the emergency services can use the crossovers at each portal to access the non-affected bore. From there access to the incident is via the nearest pedestrian cross passage on foot or they can use the nearest vehicle cross passage to drive directly to the incident bringing all the necessary heavy equipment with them. If vehicular access is not possible or desirable, emergency access points are located in the ventilation shafts on each shoreline, which provide access on foot via stairs and lifts.

4.2.4 Geotechnical Information

Previous geotechnical studies have focussed on data collection in Corridor D where a bridge option had been promoted. As would be expected, these studies are useful in understanding the overall context but provide no information sufficient to advise the specific constructability and risk issues related to tunnelling.

For all the proposed tunnel corridors therefore, there is no detailed site specific or generic data that informs the designers of hazards to be avoided in setting tunnel alignments. Further extensive site investigations would be needed to address specific perceived risks.

4.2.5 General Tunnel Construction Issues

An overview of the key risks associated with tunnelling under the Firth of Forth is included in Section 5.11 and is covered in more detail in Appendix B. Tunnel construction issues that are specific to each corridor are covered under the individual corridor section but the major construction issues that are relevant to all corridors are summarised below.

There is only very limited geotechnical information available but interpolation of this data suggests that dolerite may be encountered under the Firth of Forth in any of the three corridors. Detailed geotechnical investigations are required to identify the locations of dolerite and the alignment of the TBM tunnel necessary to avoid them. However, if a significant band of dolerite or other hard material was anticipated along the alignment of a proposed tunnel that could not be avoided, then it is likely that it would need to be excavated from the surface by constructing a caisson or cofferdam and mining through the dolerite by drill and blast, or other techniques.

A TBM is the only practicable method for tunnelling under the Firth of Forth due to the presence of the soft river sediments and glacial deposits with high hydrostatic pressure. However, it is possible that a tunnel would encounter unexpected obstructions in the glacial deposits such as large boulders or trees, volcanic sills or dykes and doleritic intrusions. A large diameter TBM designed for soft sediments is unlikely to be able to excavate through the hard obstructions. Intervention may be required at the cutting head which would mean extensive ground treatment or compressed air being used.

Construction of cross passages under the Forth also represents a significant challenge. Mining in soft sediments under high hydrostatic pressure presents difficulties as the face of the excavation is unsupported during construction. Ground stabilisation techniques such as ground treatment or freezing would be required.

There is a significant chance of encountering old mine workings on the southern side of the Firth of Forth which would need to be grouted prior to construction.

The disposal of large quantities of excavated spoil may have an adverse environmental impact. It is anticipated that approximately two million cubic metres of spoil would be generated from the tunnels. This is equivalent to approximately four million tonnes or over 140,000 truck movements if all spoil is removed by road.

4.2.6 Scheme Development from Report 3 to Report 4

Report 3 suggested that TBM driven tunnels for all corridors would be taken from the southern portal to the northern portal or to a point of connection to an immersed tube tunnel. In Report 4 it has been assumed that the tunnels between the portal and the vent shaft located near the shore line would be constructed using an open face SCL method for reasons described as follows.

The programme for the construction of the TBM driven tunnels would be led by the procurement of a bespoke machine. The specification of this machine would need to incorporate facilities to manage all the anticipated risks and be large enough to incorporate the required internal tunnel section. It is assumed that the design of the internal space would be concluded by the time that the contract is let. However, this may not be the case and would depend upon the procurement route adopted by the client. Typically, a machine of this type would take one year to be delivered to site and a further two months to be assembled, tested and commissioned. In parallel, sufficient stock of the precast concrete lining segments would be required to allow reasonable advancement of the tunnel. Therefore, there could be a 14 month lead time to the start of tunnelling if a TBM is used. Adopting the SCL method on the approaches where less sophisticated and more readily available plant is used, means that tunnelling can commence earlier than otherwise planned.

The unit costs for constructing an SCL tunnel are less than those of a TBM tunnel. By adopting this approach it is suggested that an overall reduction in cost could be achieved. A detailed programme would need to be developed to support the assumed cost savings. Also, a detailed site investigation is required to demonstrate that the open face method is constructible and safe. Amendments to the location of ventilation shafts may be required if significant and unmanageable water ingress is predicted.

4.3 CORRIDOR C TUNNEL

4.3.1 Introduction

The proposed tunnel in Corridor C is a twin bore tunnel (one tunnel in each direction) approximately 8.5 kilometres long with ventilation shafts located on both banks of the Firth of Forth. A mined SCL tunnel is proposed from the portals to the ventilation shafts. A bored tunnel using a TBM is proposed under the Firth of Forth between the ventilation shafts.

4.3.2 Alignment (drawing number 49550/T/TC1/01)

The horizontal alignment of Corridor C Tunnel is driven by a number of factors including, but not limited to, the location of the portals (and any toll plaza on the south side), the need for ventilation shafts on both shorelines, the required connections to the road network and their performance against the objectives of the FRCS. In choosing the location of the portals and ventilation shafts, it was noted that a large construction compound would be required there with sufficient space and access for a construction project of this size.

The northern portal is located north-west of Rosyth with an approach ramp linking the tunnel with junction 2 of the M90. The northern ventilation shaft is located near the remains of Rosyth Church.

It was concluded that the southern portal and any toll plaza should face east to achieve better connections with the road network. The northern side of the M9 was considered but the gradient of the tunnel in this configuration was prohibitive and with the proximity of Duntarvie Castle, there was insufficient space for a toll plaza and road connections. The chosen location is directly to the south of the M9 adjacent to the disused Craigton Quarry. The ventilation shaft is located to the south of Wester Shore Wood.

The vertical alignment is derived from maintaining a minimum of two diameters (approximately 24 metres) of cover above the TBM tunnel under the Firth of Forth. The depth of the river and the need to rise to make the road network connections mean that the vertical alignment is maintained at 3 per cent, which is the recommended maximum.

4.3.3 Specific Tunnel Construction Issues

The choice of the most appropriate tunnelling technique to be used is driven primarily by the predicted ground conditions and the suitability of each technique to meet the demands of those conditions. The limited geotechnical information available suggests that the bedrock is close to the ground surface on the shorelines but falls significantly when below the Firth of Forth. Considerable depths of soft alluvial river sediments and glacial deposits are expected directly under the crossing. The tunnel construction must negotiate a mixture of limestone, shale, sandstone and coal measures on the shore lines. Although there are no specific outcrops in the river on this alignment to indicate the presence of dolerite, the dolerite under Blackness Castle indicates that outcrops are in the general vicinity and its presence should not be ruled out. It is likely that high groundwater pressures would be encountered in the river sediments. In addition, there is a significant chance of encountering old mine workings in the area to the south of Wester Shore Wood where the ventilation stack and construction compound is proposed (see drawing number 49550/T/GC1/01)

A mined SCL tunnel is proposed between the portals and the ventilation shafts at the river banks. This technique has been used extensively elsewhere for mining through similar materials as anticipated on the banks of the Forth. However, it should be noted that the suitability of this technique is dependent on the competency of the rock which needs to be confirmed by a detailed site investigation at a later date. Notwithstanding this fact, the use of SCL offers cost savings over other forms of tunnelling. It also helps to speed up progress during construction, as other worksites can be set up at the ventilation shaft locations which can then be used as reception and launch chambers for the TBM drive under the crossing. Potential construction sites are shown on Drawing No. 49550/T/GC1/01.

The northern approach ramp may require open cut retaining walls or a short cut and cover tunnel section to avoid disruption to the property at Blackhall on the north-western corner of the site. A cutting would be required on the southern side to accommodate any toll plaza. Conventional approach ramps can be used to interface with the mined tunnel. Generally, a SCL tunnel requires a minimum of five to ten metres of cover depending on the quality of the overlying material. Where excavation for the approach ramps and toll plaza is in rock, the sides can be cut at a steep angle or otherwise retaining walls can be constructed so that the land take is minimised.

Construction and operation costs for Corridor C Tunnel are detailed in Section 5.10.

4.3.4 Network Connections

Northern Side of the Firth of Forth

The tunnel would emerge at a depth of approximately 15 metres on the north side of the Firth of Forth, approximately 1.2 kilometres west of the existing roundabout which forms the junction of the B980/A823/A823(M). The alignment of the road bears north east at a gradient of between two and three per cent. The existing railway line is in cutting at this location so would be bridged prior to the new junction. The existing roundabout would be amended to form a new grade separated junction with the A823(M). It is likely that lane provision on the A823(M), would be increased to the west of Junction 2 of the M90 (Masterton interchange).

The new junction of the tunnel alignment and the A823(M) near Pitreavie can also be amended to provide connection to the proposed Rosyth Bypass, if required.

Additionally, it is likely that the capacity of certain movements to/from the A823(M) and the interchange would require to be improved.

Also, it is expected that the M90 would be widened to 3 lanes in each direction between Masterton and Junction 2a/3 at Halbeath. This additional capacity could be used to provide an HOV and/or public transport priority lane between Halbeath and the Forth Bridgehead. It is likely that reconstruction of the M90 road pavement will be required as early as 2009 between Halbeath and Masterton junctions. There may be an opportunity to undertake the widening as part of this work if that proved to be cost effective.

While the tunnel has been assessed as a replacement for the existing FRB, the network connections can be developed to permit the efficient operation of a twin crossing strategy if so desired.

Southern Side of the Firth of Forth

Due to the topography and gradient/alignment restrictions within the tunnel, it is necessary to extend the tunnel such that the exit would be located south of the M9, approximately 1 kilometre west of the B9080 at Winchburgh. A major new motorway junction would be required at this location to ensure free flowing traffic from the M9 gains access to the tunnel alignment. It is anticipated that the major movement would be between the tunnel and M9 Edinburgh, therefore, the junction design would require to reflect this major traffic flow.

In addition, due to the proximity of Junction 1a on the M9, it is anticipated that the new junction would be linked with a remodelled Junction 1a to ensure all necessary free flowing movements are provided.

Access from the local road network to the tunnel for non-motorway traffic would be provided at this junction.

It is also recognised that a route to the proposed tunnel would need to be provided for traffic on the A90 Queensferry Road. In order to facilitate this movement the junction of the M9 Spur extension (under construction) and the A90 would require to be upgraded to provide all possible free flow movements.

4.4 CORRIDOR D BRIDGE

4.4.1 Suspension Bridge Cross Section and Alignment (drawing number 49550/B/SD1/01)

The suitability and form of any bridge would depend on several design issues relating to constraints which were outlined in Report 3. Both suspension bridges and cable stayed bridges would be able to accommodate these constraints and each are now detailed below. This section summarises the principal design and construction issues developed for the STAG Appraisal. Further detail of this work can be found in Appendix C of this report.

A cross section for a Dual 2 lane Motorway standard has been developed and is discussed below. An alternative cross section which includes a corridor for segregated Light Rail has also been developed and this is discussed in Chapter 7 Complementary Measures.

4.4.2 Dual 2 Motorway Standard (Refer to Figure 4.3 and drawing number 49550/B/SD1/03)

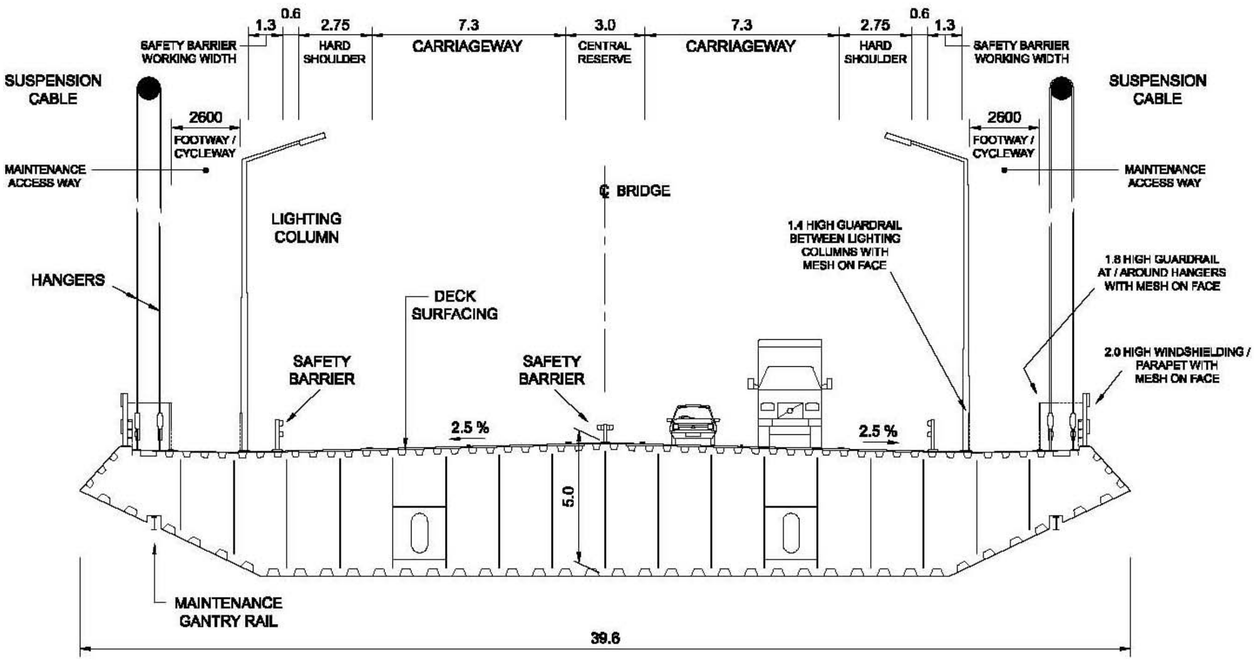
It has been assumed that the crossing is designated as an urban motorway with a maximum speed of 50mph, similar to the existing FRB. Since the bridge is to act as a replacement crossing, provision is made for pedestrians and cyclists to cross the bridge.

Current road design standards lead to the following minimum criteria:

- Lane widths to be 3.65 metres and each carriageway to be 7.3 metres wide.
- Hard shoulders to be 2.75 metres wide.
- Central Reserve to be 3 metres total width.
- Safety barriers at the edge of the carriageway with a working width allowance of 1.3m clearance to the nearest face of the lighting columns.
- An access way with a minimum width of 2.6 metres would be provided between the lighting columns and the structural hangers. This access way would also act as a combined footway/ cycleway. Guard rails would be provided each side of the access way. The rails around the hangers would be provided with anti-climb mesh to prevent vandalism to the hangers and would be boxed around the hangers. The access way would allow routine inspection and maintenance work to be carried out without the need for carriageway restrictions or hard shoulder closures.
- Wind-shielding 2 metres in height would be provided with parapets at the edge of the bridge.

The resulting full width of bridge deck is approximately 40 metres.

Figure 4.3: Deck Cross section for Dual 2 Motorway Standard



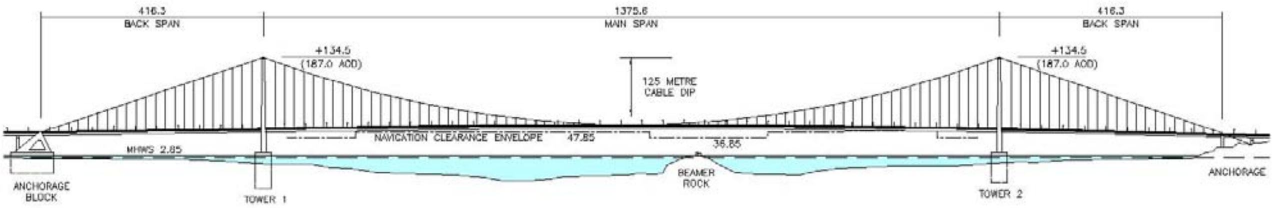
The design standards adopted (Urban 50 mile per hour speed limits) result in a hardshoulder width of 2.75 metres. However, it should be noted that should it be required to operate a bus or HOV lane on the hardshoulder (see Chapter 7) then a wider section of 3.3 metres would be necessary.

4.4.3 Suspension Bridge Alignment (Refer to Figure 4.4 and drawing number 49550/B/SD1/01)

Two main options for a suspension bridge in Corridor D have been developed. The two options have different lengths of main span. For reasons of proximity to the shipping channels, the most likely option to be taken forward would be a 1375 metre main span option similar to that proposed in Report 3. For a comparison of costs, a bridge with a reduced main span of 1200 metres has also been considered (details of which are contained in Appendix C).

The 1375 metres main span bridge would run from the northern end of a possible toll plaza between Linn Mill and South Queensferry, over Beamer Rock to Cult Ness headland between St Margaret's Hope House and the Queensferry Lodge Hotel. The overall length of the bridge would be approximately 2.2 kilometres. The vertical alignment of the bridge provides a minimum vertical clearance of 45 metres above mean high water spring tide level which is the same as that provided by the existing FRB.

Figure 4.4: Suspension Bridge Option



4.4.4 Suspension Bridge Structural Issues

Deck Girder and Bridge Articulation

The deck girder, as well as providing the running surface for traffic, also participates in distributing live loads along the length of the bridge to several hangers.

It is current best practice for suspension bridges to make the bridge deck continuous through the towers. This has a disadvantage in that it concentrates the deck movements at the movement joints at each end of the bridge. The approximate average tonnage for the deck is 16.4 tonnes per metre along the length of the bridge.

Buffers would be provided at each end of the bridge deck in order to limit longitudinal movements arising from wind and traffic loads. At the centre of the main span, the deck and main cables would be linked to reduce differential movement and bending of the short hangers at the centre of the main span.

Main Cables

The main cables would be approximately 34.5 metres apart, and be supported on steel saddles on top of the main towers.

There are two main methods of erecting the main cables – Aerial Spinning (AS) and Preformed Parallel Wire Strands (PPWS). Details of both these techniques are covered in Appendix C.

The advantages and disadvantages of each technique have been considered. With PPWS cables, the quality of the overall cable construction is more assured and uses less labour on site. However, for the large size of cables under consideration AS cables appear to be slightly more economical. Therefore, it is suggested that both systems be considered in parallel to a more detailed stage.

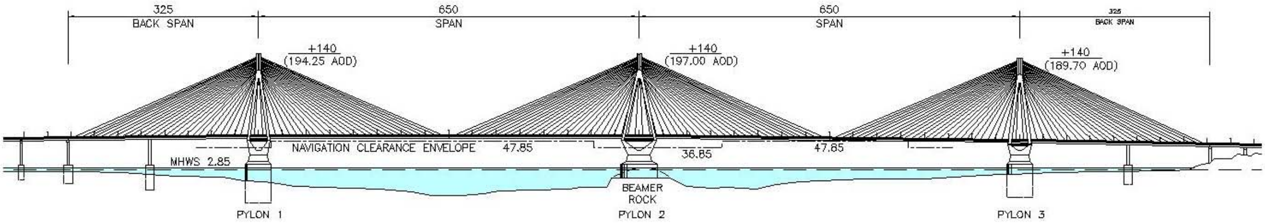
Hangers and Cable Bands

Hangers are typically fabricated from locked coil wire rope or Preformed Parallel Wire Strands enclosed within a High Density Polyethylene (HDPE) sheathing which would provide corrosion protection and reduce the drag coefficient in wind. For both systems, the cable would be compacted and wrapped in galvanised wire.

4.4.5 Cable stayed Bridge Option (Refer to Figure 4.5 and drawing number 49550/B/CD1/01)

The cable stayed bridge option would consist of two main spans of 650 metres with equal back spans of 325 metres. The central pylon would be founded on Beamer Rock. The alignment would be similar to the suspension bridge. The vertical alignment of the bridge provides a minimum vertical clearance of 45 metres above mean high water spring tide level with its crest over the pylon at Beamer Rock.

Figure 4.5: Cable Stayed Option



Deck Girder and Bridge Articulation

The construction of the deck would be similar to the suspension bridge.

Cable Stays

In the design of cable stays, access must be provided for inspection of the full length of the cable and its anchorages.

Various types of cable stay have been used in the past and the following have been considered for use on the bridge option:

- cables from Parallel Wires or Strands; and
- locked Coil Ropes.

Locked coil ropes perform less well under fatigue, shipping and handling and durability when compared to parallel wire strands, hence for the purposes of this study, it has been assumed that parallel wire strand cables would be used.

Construction Programme

Outline construction programmes for the suspension and cable stayed bridges have been developed. Refer to Section 5.4.1 for more detail.

Construction and operating costs for Corridor D Bridge are detailed in Section 5.10.

4.4.6 Network Connections

Northern Side of the Firth of Forth

The bridge connects to viaduct at the northern shore of the Firth of Forth which ends at the B981/B980 roundabout near Jamestown. It connects to the M90, which, it is anticipated, would be upgraded to 3 lanes to a point close to Junction 2a/3. As noted in Section 4.3.4, this widening could be carried out in conjunction with the planned reconstruction of the M90 road pavement between Halbeath and Masterton.

A major re-modelling of the existing Ferry Toll junction would be required to provide the range of movements necessary to suit the operational characteristics of the network.

The available corridor is narrow, therefore, it is anticipated that the new interchange would be complex and much of it would be on structure.

In addition, it is anticipated that the widening of the A90 to the north of the bridge, would facilitate a remodelling of Masterton Interchange (Junction 2) to improve the operational characteristics and safety of this junction.

Feasibility work confirms that a full range of movements would be possible to ensure maximum flexibility for the operation of two crossings, should this be required.

Southern Side of the Firth of Forth

The proposed bridge lies to the west of the existing FRB starting from a point 200 metres west of South Queensferry. The alignment accommodates Inchgarvie House with a toll plaza, should it be required, located on the south side of the Firth of Forth at the entrance to the bridge. The road alignment to the south of the proposed bridge would continue in a generally southerly direction to interchange with the M9 approximately 1 kilometre west of the existing Junction 1a. This would be a similar location to the junction for Corridor D tunnel. The new junction would be combined with the existing Junction 1a and would cater for all necessary movements, in particular the anticipated heavy flow from the M9 (East) would require to be considered.

A new grade separated interchange with the existing A904 would be provided and the existing A904 would be re-aligned and up-graded from the junction with the A90 (Echline). This linkage provides access to the local road network and South Queensferry area. A number of local access roads would need to be re-aligned to accommodate this arrangement.

Again, if required, the layout can be developed to provide maximum flexibility for the operation of two crossings.

4.5 CORRIDOR D TUNNEL

4.5.1 Introduction

The proposed tunnel on Alignment D is a twin bore tunnel (one tunnel in each direction) approximately 7.3 kilometres long with ventilation shafts located on both banks of the Firth of Forth. A mined SCL tunnel is proposed from the portals to the ventilation shafts. A bored tunnel using a TBM is proposed under the Forth between the ventilation shafts.

4.5.2 Alignment (drawing number 49550/T/TD/01)

The horizontal alignment of the tunnel is driven by a number of factors. These include, but are not limited to, the location of the portals (and any toll plaza on the south side), the need for ventilation shafts on both shorelines and the required connections to the road network including their performance against the objectives of the FRCS.

On the north, the site to the west of St. Margaret's Marsh has been safeguarded for construction and operation of a new Forth crossing as part of the Rosyth Dock Development Plan. The alignment goes through this site to enable a ventilation shaft and construction compound to be located there. The northern portal is located immediately to the south of Admiralty Road on the eastern side of the A90.

On the south side, the portal and any toll plaza are located north of Humbie Reservoir. Disruption to this is minimised by completely avoiding the covered reservoir and providing a single crossing of the open reservoir at its narrowest point. A number of properties close to the tunnel portal area are also avoided. The ventilation shaft is located to the west of Queensferry.

The vertical alignment is derived from maintaining a minimum of two diameters of cover above the TBM tunnel under the Firth of Forth. A key feature of the crossing is the deep river channels adjacent to Beamer Rock. These extend to depths of approximately 30 metres below sea level. Therefore, the tunnel crown would be approximately 20-25 metres below riverbed level across the river. The carriageway profile must rise to meet network connections at the A90 and M9, these connections are in the order of 60 metres above sea level. In order to achieve this on the southern side it is not possible to maintain the recommended three per cent maximum gradient. To keep any toll plaza on the northern side of the M9, and reduce the amount of land take and road links required, an increase in the tunnel gradient to four per cent is proposed. Due to the limited space available in this instance, the toll plaza, if required, must be located in a cutting approximately 5-10 metres below the surrounding ground.

The increase in tunnel gradient above three per cent may require additional safety measures in accordance with the EU Road Tunnel Safety Regulations 2007 Consultation Draft. These measures would be decided on the basis of a risk analysis but could include enhanced ventilation requirements, a reduction in design speed and/or traffic volume to reduce risk of congestion or controlling the number and type of HGVs in the tunnel. At this stage of the design process, it is difficult to assess the cost impact of the increased gradient, however, at four per cent it is not expected be prohibitive.

4.5.3 Specific Tunnel Construction Issues

The choice of the most appropriate tunnelling technique to be used is driven primarily by the predicted ground conditions and the suitability of each technique to meet the demands of those conditions. The limited geotechnical information available suggests that the bedrock is close to the ground surface on the shorelines but falls significantly when below the Firth of Forth. Considerable depths of soft alluvial river sediments and glacial deposits are expected to be encountered. Outcrops in the Forth such as Beamer Rock demonstrate that there are dolerite intrusions in the area. It is likely that high groundwater pressures would be encountered in the river sediments. The tunnel must negotiate a mixture of sandstone, shale and coal measures on the southern bank and predominantly sandstone and dolerite on the northern bank.

A mined SCL tunnel is proposed between the portals and the ventilation shafts at the river banks. This technique has been used extensively elsewhere for mining through similar materials as are anticipated on the banks of the Forth. However, it should be noted that the suitability of this technique is dependent on the competency of the rock which needs to be confirmed by a detailed site investigation at a later date. Notwithstanding this fact, the use of SCL offers cost savings over other forms of tunnelling. It also helps to speed up progress during construction, as other worksites can be set up at the ventilation shaft locations which can then be used as reception and launch chambers for the TBM drive under the crossing. Potential construction sites are shown on Drawing Number 49550/ T/GD1/01.

A large cutting is required on the southern side to accommodate the toll plaza should one be provided. The resulting environmental impact may be offset by the fact that the any toll plaza would be hidden from view. Conventional approach ramps can be used to interface with the mined tunnel. A SCL tunnel generally requires a minimum of 5-10 metres of cover depending on the quality of the overlying material. Where excavation for the approach ramps and toll plaza is in rock, the sides can be cut steep or otherwise retaining walls can be constructed so that the land take is minimised.

Construction and operating costs for Corridor D Tunnel are detailed in Section 5.10.

4.5.4 Network Connections

Northern Side of the Firth of Forth

The tunnel emerges on the northern side of the Forth in the vicinity of Junction 1 of the M90, Admiralty Interchange. A new major grade separated interchange would be provided to link with Masterton junction (Junction 2) and in turn would provide linkage with the local road network connecting with the A823 (M) and the A921.

The final layout of the new junction would be heavily influenced by the operational characteristics of the network and a feasible solution has been developed which would provide for access to the proposed tunnel as a replacement for the existing FRB. Feasibility work confirms that a full range of movements would be possible to ensure maximum flexibility for the operation of two crossings, should this be required.

The M90 would to be widened to 3 lanes, to the south of junction 2a/3 for approximately 2 kilometres to offer improved weaving lengths and operational flexibility. As noted in Section 4.3.4, this widening could be carried out in conjunction with the planned reconstruction of the M90 road pavement between Halbeath and Masterton.

Southern Side of the Forth

The tunnel entrance would be located in fields 1 kilometre north of the Humbie Reservoir. Access from the M9 to the tunnel plaza would be provided by means of a new interchange with the M9 approximately 1 kilometre west of the existing Junction 1a with the M9 Spur. Due to the proximity of the junction, it is likely that the new interchange would incorporate an amended Junction 1a to provide free flow in all directions.

Access to the local road network would be provided at this junction.

As is the case for both Corridor C Tunnel and Corridor D Bridge, the junction of the A90 and new M9 spur would require to be upgraded to provide all movements in a free flow manner.

A junction solution could also be developed which would permit the operation of a twin crossing strategy if required.

4.6 CORRIDOR E TUNNEL

4.6.1 Introduction

The proposed tunnel in Corridor E is a twin tube tunnel (one tunnel in each direction) approximately 7.3 kilometres long with ventilation shafts located on both banks of the Firth of Forth. A mined SCL tunnel is proposed from the portals to the ventilation shafts with a short section of cut and cover tunnel at the southern portal. An immersed tube tunnel is proposed for approximately 1.7 kilometres in the deep river channel with a bored TBM tunnel linking the immersed tube to the ventilation shafts.

4.6.2 Alignment (drawing number 49550/T/TE/01)

The horizontal alignment of the tunnel is constrained by a number of factors including but not limited to the location of the portals (and any toll plaza on the south side), the need for ventilation shafts on both shorelines and the required connections to the road network and their performance against the objectives of the FRCS.

The northern portal is located immediately north of the A921. The site proposed for the ventilation shaft north of Inverkeithing Bay is steep and not an ideal location but due to environmental constraints, no alternative sites are considered practical.

The southern portal and any toll plaza are located to the south of the A90, to the west of Dalmeny oil storage depot. The ventilation shaft is located south of the B924 near Dalmeny Park.

Due to the depth of the Firth of Forth in this corridor and the cover required above a TBM, the gradient of a fully bored TBM tunnel in this corridor would have been too steep to effectively connect with the road network in the south. An immersed tube tunnel requires only approximately five metres of cover at the river bed. Locating the portal and possible toll plaza on the northern side of the A90 was investigated but the gradient was prohibitive. A 3.3 per cent gradient has been achieved on the southern approach to the immersed tube, while the recommended maximum of three per cent has been maintained on the northern side.

The increase in tunnel gradient above three per cent may require additional safety measures in accordance with the EU Road Tunnel Safety Regulations 2007 Consultation Draft. Further refinement of the alignment at detailed design stage should ensure that the gradient stays close to three per cent.

4.6.3 Tunnel Construction Issues

Construction of the immersed tube section of the tunnel provides a number of challenges. A suitable casting basin must be found for construction of the units. A possible site has been identified near the Rosyth Dockyard. However, extensive modifications would be required to transform it into a suitable dry dock. Potential construction sites are shown on Drawing Number 49950/T/GE1/01.

Construction of the immersed tube requires significant dredging and disturbance of the sediments along and adjacent to the alignment. As the Firth of Forth has a long history of industrial and commercial operations upstream of the crossing there may be trapped pollutants within the existing sediments. The dredging operation may release pollutants in a relatively short period and, therefore, in a concentrated form which would have a negative environmental impact.

Outcrops in the area such as Inch Garvie demonstrate that there are doleritic intrusions in the vicinity of this tunnel alignment. Where it is not possible for the alignment to avoid these areas, the rock would need to be dredged by drill and blast techniques to create the required bed profile for the immersed tube.

The interface between the immersed tube and TBM tunnels is likely to require the construction of a large caisson or cofferdam to provide a dry working area for construction of the connection. A "soft eye" is required in the wall of the cofferdam so that the TBM can breakthrough it into the connection area. A significant amount of dredging would be required to obtain the required depth to meet the bored tunnel. Removal of rock at this location would require drilling and blasting. An insitu connection unit is required to be constructed within the cofferdam to transition from the circular shape of the TBM to the rectangular cross section of the immersed tube.

On the south side, there have been significant mine workings around the tunnel portal and any toll plaza. The area has been grouted recently to a depth of approximately 60 metres prior to the construction of the M9 spur extension. The BP Kinneil to Dalmeny oil pipeline runs directly adjacent to the proposed portal and would almost certainly need to be diverted or protected prior to construction.

A mined SCL tunnel is proposed between the portals and the ventilation shafts at the river banks. The use of this technique would need to be confirmed by a detailed site investigation, however, it offers cost savings if used. It also offers the opportunity of simultaneous construction of all sections of the tunnel if other worksites are set up at the ventilation shafts and used as reception and launch chambers for TBMs, while fabrication, dredging and placement of the immersed tube tunnel can occur independently.

Construction and operating costs for Corridor E Tunnel are detailed in Section 5.10.

4.6.4 Network Connections

Northern Side of the Forth

Connection to the strategic road network on the northern side of the Forth would be created by means of a new junction with the A90 located approximately 1km north of Masterton Interchange (Junction 2). To ensure safe and efficient operation of the network, Masterton Interchange would be remodelled and linked with the new junction.

Again it has been assumed that the M90 would be widened to 3 lanes to the south of junction 2a/3 for approximately 2 kilometres. As noted in Section 4.3.4, this widening could be carried out in conjunction with the planned reconstruction of the M90 road pavement between Halbeath and Masterton. The new junction with the M90 provides all movements utilising free flowing loops, slip roads and link roads. Linkage between the tunnel and the local road network is provided by a connector road joining at the A823(M).

Again, if required a twin crossing strategy could be developed at this location.

Southern Side of the Forth

At the southern end, the tunnel would emerge to the south of the A90 and to the west of the existing A8000. A complex arrangement of direct connections and loops would be required to ensure access to the tunnel from all areas.

The M9 Spur Extension would require to be realigned vertically to provide access to the tunnel by a new junction centred on the location of the former Humbie Roundabout at the junction of the B800 and the A8000. Free flowing links would lead to and from the tunnel alignment near the toll plaza if one were required.

The existing loop junction 1a of the M9 would be upgraded to provide 2 way connections onto the M9 Spur and slip roads provided on the eastbound exit and westbound entrance to the M9.

The junction of the M9 Spur extension with the A90 would require to be modified to provide access to the tunnel from the A90 (Edinburgh).

Non-motorway traffic would access and egress the tunnel from the A8000, and slip roads would be constructed to allow vehicles to make this manoeuvre.

Again the layout can be developed to permit a twin crossing strategy to be taken forward.

4.7 SUMMARY

This chapter has reviewed the construction details and methodology proposed for each of the remaining corridor options. It has also considered the need for the associated construction compounds needed for a project of this size, their location and temporary impact on surrounding land uses.

Included within each corridor is a short summary of the network connections proposed to link the replacement crossing to the existing road network.

5 STAG PART 2 APPRAISAL

5.1 INTRODUCTION

The STAG Part 2 Appraisal provides detailed quantified appraisal against the government's transport appraisal objectives. Volume 2 of the report contains technical appendices providing full detail of the appraisal against each of the objectives.

5.2 ASSUMPTIONS

Within the STAG Part 2 appraisal, the performance of the crossing options has been tested using the Traffic Model for Scotland (TMfS).

At this stage of the exercise the objective is to find the most suitable option for a Replacement Crossing. As explained in earlier chapters this would take the form of a like for like replacement with the existing dual two lane facility – the FRB. A new bridge crossing would likely have hard shoulders provided and a new tunnel would include edge strips. However, these additional features are not represented in the modelled representation within TMfS and, therefore, the bridge and tunnel options are treated similarly. Any distinctions in operational performance arising from this difference are commented upon in a qualitative manner.

The modelling of the Do Minimum situation assumes that the FRB would be closed to all traffic from 2019. The Do Something situation assumes that a replacement crossing would be in place. No complementary measures have been assumed to be present at this stage.

5.3 PERFORMANCE AGAINST PLANNING OBJECTIVES

Chapter 3 of this report provided an analysis of performance against planning objectives, in line with STAG Part 1. STAG Part 2 appraisal requires a refresh of performance against planning objectives in the light of option development, and outcomes of the modelling process.

The modelling process does not currently fully capture the anticipated operational characteristics of the long term strategy for the crossing(s), with respect to public transport priority, and the amount of road space available to Single Occupancy Vehicle (SOV). However, this would be undertaken once the outcome of the long term use of the FRB is better understood.

5.4 IMPLEMENTABILITY

5.4.1 Technical Implementability

The focus of the option development work undertaken since the STAG Part 1 appraisal has been to confirm the most efficient and technically robust options for each alignment and crossing type.

Corridor C Tunnel

A construction programme for Corridor C has been carried out which indicates that tunnel construction would take approximately 7.5 years. An outline sequence of works for this option is contained in Appendix B.

The proposed programme depends on a number of key factors. The rate of construction depends on the number of TBM's used. For the purposes of this study it is assumed that two TBMs would be used. Furthermore, the rate of tunnelling would be affected by the ground conditions encountered. As discussed in the Section 5.11 and 4.2 it is difficult to analyse the likely rate of progress at this stage, as there is limited ground information available. Should unexpected ground conditions be encountered, such as dolerite intrusions, then an impact to the programme could be significant.

In addition to key project risks, there are a range of issues that may benefit from refinement at a later stage. In particular, the interface between the two tunnelling drives at the ventilation shafts. Considerable time savings may be achieved as part of construction optimisation at a later stage.

Corridor D Bridge

Outline construction programmes for the suspension and cable stayed bridges have been developed. Initially, it was assumed that environmental impacts would not lead to any changes to the programme. On this basis it was estimated that the suspension bridge programme would be approximately 6 years and the cable stayed bridge programme approximately 5.5 years.

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. For the construction of a cable stayed bridge, after the main pylons have been constructed there is scope to erect the cable stays and deck from the three main pylons concurrently. This offers a reduction in the programme as noted above.

These programmes were reviewed against the specific environmental constraints arising from summer breeding birds located on Long Craig Island and wintering birds located on the SPAs at Port Edgar and the north intertidal zone. It was assumed that work up to the bridge deck level in the vicinity of Long Craig Island would be interrupted for 2 summer months each applicable year. In addition, for the SPAs, two scenarios were investigated: one in which construction work up to the underside of the bridge deck in the vicinity of the SPA would be interrupted for 2 winter months every second year and one in which the construction work would be interrupted for 5 months every third year. As a consequence the construction programme for the suspension bridge would be increased by a maximum of eight months and the cable stayed bridge a maximum of ten months.

These programmes are presented in detail in Appendix C.

Preliminary ground investigation has been carried out in the vicinity of the bridge at corridor D for both suspension and cable stayed bridge options. Therefore, preliminary information regarding depths to rock level has been available for this study. Further site investigation would be required for the detailed design.

For long span bridge construction one of the biggest risks to the programme is the weather. This particularly affects the main cable erection. The effects of delay have been allowed for in the derivation of the costs as a major risk element. Other delay elements include, amongst others, extra time for excavation of more material to reach rock level, bad weather affecting main cable, deck erection and main tower erection and problems associated with drilling and tunnelling for the suspension bridge anchorages.

The construction of both forms of bridge would entail the prefabrication of large deck panels off site. These sections would be towed on barges to the bridge site and lifted into place.

Whilst being technically challenging, this option has fewer technical uncertainties associated with it than any of the tunnel options.

Corridor D Tunnel

The construction sequence for Corridor D is largely consistent with that for Corridor C. Both tunnel proposals involve the implementation of different tunnelling techniques, for the crossing and the approach sections.

At 7.3 kilometres, the overall length of Corridor D is approximately 1.2 kilometres shorter than Corridor C. This suggests that there could be time savings associated with this option. However, because of the likelihood of encountering doleritic intrusions around Beamer rock and the need to potentially intervene from the surface, this is likely to extend the programme. It is assumed that the net effect would be an overall construction programme similar to that of Corridor C, i.e. approximately 7.5 years.

Corridor E Tunnel

The construction of this tunnel varies significantly from the other two proposals because of its use of an immersed tube tunnel for the deepest section within the Firth of Forth.

Unlike the other tunnelling techniques this approach requires the prefabrication of sections at a nearby casting yard, followed by the floating of the sections into line before lowering them into place.

Whilst the use of this method of construction has many advantages, such as the avoidance of technically challenging cross passages, these advantages are offset by the additional environmental constraints that may be placed upon this method. In addition, the construction of the immersed tube option requires large cofferdams to be constructed in situ, and the need for more complex transition units. Collectively it has been assumed that the net effect of all of these factors would result in an overall construction programme similar to that of the other two corridors, i.e. approximately 7.5 years.

A more detailed overview of technical risk is provided in section 5.11.

5.4.2 Operational Implementability

At the present stage, the final operational characteristics have yet to be determined. As per the STAG Part 1 appraisal, it is considered that all options can be satisfactorily operated. Specific consideration (common to all current options) would be required of the possible suite of complementary measures and any potential twin crossing operational strategy.

5.4.3 Affordability

As per the STAG Part 1 appraisal, all options are considered to have similar Implementability profiles in relation to affordability.

5.4.4 Public Acceptance

The tunnel options are currently receiving public support in the form of recent announcements made by the West Lothian and City of Edinburgh Councils.

5.5 ENVIRONMENT

5.5.1 Introduction

The following sections describe the likely environmental effects of each option in relation to the nine environmental sub-objectives identified in the STAG methodology. In each case the significance of environmental impacts have been assessed on a seven point scale from Major positive to Major negative. It should be noted that where impacts are referred to as "significant" this indicates that the level of impact is either Major or Moderate.

5.5.2 Noise and Vibration

Introduction

STAG recommends that the noise appraisal follows the approach set out in WebTAG Unit 3.3.2 (1) [7]. The STAG appraisal considers operational noise only, and is based on changes in traffic flows. The appraisal aims to estimate the change in the population annoyed by noise for a do-minimum strategy compared with the proposed options. The approach is to estimate the total number of people exposed to different

[7] WebTag 'Transport Analysis Guidance' Website: http://www.webtag.org.uk/ . Department for Transport. Update February 2007.

noise levels and, using the annoyance response relationship data provided in WebTAG, calculate the change in the number of people likely to be 'annoyed'.

As a further requirement of WebTAG, introduced in February 2006, an assessment of the noise impacts in monetary terms has also been undertaken. This approach relates the predicted noise change due to the scheme to a monetary valuation (based on 2002 property prices).

A method for assessing vibration is not included within either WebTAG or STAG.

Key Issues

A number of properties and communities lie adjacent to the routes of the road network tie ins leading to the options. These include residential and other sensitive properties. However, it is noted that a number of properties located close to the northern and southern bridgeheads of the existing Forth Road Bridge will already experience significant impacts from noise generated by north and south-bound traffic on the bridge.

The majority of new road network connections proposed south of the Firth Forth are located away from communities. However, there are individual properties close to the proposed roads that may be affected by traffic generated noise. On the southern shore the road network tie ins run primarily through agricultural land to the south east and south west of South Queensferry.

On the northern shore in Fife, the road network connections could impact on a number of communities.

- The network connection for Option C tunnel runs to the north of Rosyth;
- The network connection for Option D tunnel runs through an area of land sandwiched between the north eastern fringes of Rosyth and north western fringes of Inverkeithing;
- The network connection for Option D bridge joins the existing carriageway north of the existing northern bridgehead; and
- The network connection for Option E tunnel crosses agricultural land to the north east of Dalgety Bay.

Closure of the existing FRB may also have the potential to affect a greater number of receptors in suburban and urban districts of Edinburgh and Dunfermline.

Appraisal Outcome

Construction noise varies considerably during any building project. Properties within 50 to 100m of such works can be disturbed. The character of construction noise varies during the project depending on the activities being undertaken. For changes to existing road infrastructure and construction of new overground roads, initial phases can involve road breaking, earth moving followed by planing. These activities can produce high levels of noise and vibration but would be of limited duration. Rolling and compaction can also be noisy but finishing phases of paving and signage erection tend to be low noise operations. Predicted construction noise is likely to exceed 75 LAeq,12hr[8]. Major negative short term impacts are therefore, predicted to occur at locations in close proximity to construction works.

Traffic modelling indicates that once operational, all the options would experience a significant increase in road traffic and consequently traffic related noise. Increases and decreases in traffic flows are predicted to occur across a large area and consequently a large number of receptors are likely to be affected, both positively where traffic flows are predicted to be reduced and negatively where traffic flows are predicted to increase.

Summary

The traffic predictions indicate that operation of all the options has the potential to cause significant changes in road traffic noise, not only on local routes, but also much further afield. From the traffic predictions, a number of existing roads in West Lothian, Falkirk, City of Edinburgh and Fife have been identified that will experience a change in traffic flow of:

- Less than -20%; and
- Greater than +25%.

In some areas reductions in traffic flows are predicted resulting in reduced noise levels. However, overall, all options are considered to have significant negative impacts. Operational noise impacts would be experienced across a wide area for all the options. The magnitude of the impact is dependent on the proximity of the receptor to the source of noise i.e. the closer the receptor to the source of noise, the greater the impact magnitude. Table 5.1 below summarises this assessment.

[8] 75 LAeq,12hr = 75 (decibels – standard unit of noise) the equivalent continuous sound level - This unit relates to the equivalent level of continuous sound for a specific time period, eg 12 hour. It contains all the sound energy of the varying sound levels over the same time period, and expresses it as a continuous sound level over that period. The unit is used for assessing traffic noise in most parts of the world and for assessing construction noise/railway noise/aircraft noise/industrial noise /community noise in U.K.

Table 5.1 - Summary of Assessment

Proposal	Overall Temporary Effects	Overall Permanent Effects
Corridor C - Tunnel	Minor to Major Negative	Minor to Major Negative
Corridor D - Bridge	Minor to Major Negative	Minor to Major Negative
Corridor D - Tunnel	Minor to Major Negative	Minor to Major Negative
Corridor E - Tunnel	Minor to Major Negative	Minor to Major Negative

5.5.3 Global and Local Air Quality

Introduction

The global and local air quality assessment consists of two parts, a strategic level assessment and a local level assessment. The strategic level assessment considers emissions of pollutants over the whole study area and the local level assessment considers the impact of the scheme on concentrations of pollutants at a local level. The strategic level assessment, presented below, considers emissions of carbon dioxide, a greenhouse gas, which may impact on a global scale.

Strategic Level Assessment

Total annual emissions of nitrogen dioxide (NO2) (as total nitrogen oxides (NOX)), fine particulate matter (PM10) and carbon dioxide (CO2) have been calculated for five scenarios; a do-minimum scenario and do-something scenarios for each corridor, all for 2017. Due to the wide area that could be affected by changes in traffic flow, and therefore, changes in emissions, all road links within an area of 1200 square kilometres, centre on the existing crossing, have been assessed.

The results are presented in Table 5.2 below. The percentage impact of each corridor when compared to the do-minimum is shown in brackets, minus represents a reduction against the do-minimum.

Table 5.2: Annual Emissions of NO2, PM10 and CO2, 2017

Pollutant	Do-Minimum	C Tunnel	D Bridge	D Tunnel	E Tunnel
NO_2 (as NO_X) (tonnes per year)	2,945	2,881 **(-2.1%)**	2,850 **(-3.2%)**	2,887 **(-2.0%)**	2,938 **(-0.2%)**
PM_{10} (kilograms per year)	80,634	80,287 **(-0.4%)**	80,342 **(-0.4%)**	81,281 **(0.8%)**	82,685 **(2.5%)**
CO_2 (kilo Tonnes per year)	1,043	1,026 **(-1.6%)**	1,020 **(-2.2%)**	1,031 **(-1.1%)**	1,056 **(1.2%)**

A reduction in total annual emissions of all three pollutants was predicted for the C Tunnel and D Bridge Corridors. For D Tunnel, reductions in NO_2 and CO_2 were predicted, but an increase in emissions of PM10 was predicted. For E Tunnel, increases in emissions of CO_2 and PM10 were predicted, and a small decrease in NO_2.

The greatest decrease in CO_2 emissions, and hence beneficial impact, was predicted for D Bridge. A 2.2% decrease was predicted (22,721 tonnes/year). For E Tunnel a 1.2% increase in CO_2 emissions was predicted (12,922 tonnes/year).

Summary

The Strategic level assessment predicts overall beneficial (or positive) impacts for C Tunnel, D Bridge and D Tunnel, and overall detrimental (or negative) impacts for E Tunnel. However, it should be noted that these results have not been informed by a local level assessment.

5.5.4 Water Quality, Drainage, Flood Defence

Introduction

For the purpose of this study, the water environment includes water quality, drainage and flooding. A baseline desk study has been undertaken and surface waterbodies located within a 500 metre wide corridor around each proposal have been identified. Where such information has been available, the desk study has incorporated the following:

- identification of the locations and characteristics of principal water bodies in the area;

- details of river classifications from Scottish Environment Protection Agency (SEPA) for relevant waterbodies. Classifications reflect the status of the watercourse in terms of chemical and biological properties, aesthetic quality and toxicity assessment; and

- details of the reporting categories assigned to the surface waterbodies within each corridor, as determined by the Characterisation and Impact Analysis undertaken by SEPA required by Article 5 of the Water Framework Directive (WFD);

It should be noted that no water quality monitoring was undertaken as part of this assessment.

Appraisal Outcomes

This section considers the potential effects of the construction and operation of a replacement Forth crossing. It should be noted that all impacts have been assessed taking into account the mitigation described in Appendix D.

Construction and operation activities are broadly similar for each option. Consequently, the majority of effects, whether temporary (construction) or permanent (operation), are common to all of the options. Construction activities would include:

- site clearance and demolition activities;

- earthworks, including the construction of embankments and cuttings;

- road upgrades including widening, re-profiling and junction alterations;

- construction of new roads linking the crossing to the existing network;

- construction of the toll plaza (if required) and associated facilities; and

- tunnel or bridge construction.

Potential impacts common to all options are set out below, unless otherwise indicated. Temporary and permanent impacts include:

- potential mobilisation of pollutants or sediments by surface runoff during construction, particularly where works take place within the vicinity of surface waters;

- surface runoff that could form a pathway allowing contaminants to enter nearby watercourses, where construction activities take place on or close to areas of contaminated ground;

- re-alignment or culverting of watercourses leading to reductions in water quality;

- culvert construction that could damage the banks or beds of the watercourses and have secondary indirect impacts on riparian or aquatic ecosystems;

- tunnelling in corridors C and D, and bridge construction in Corridor D would have a negligible effect on the hydrology of the Firth of Forth;
- tunnelling in Corridor E would have a significant negative impact on the hydrology of the Firth of Forth as a result of displaced sediments and increased turbidity;
- contaminated surface runoff containing fuels, oils, lubricants, salt or grit could enter carriageway drainage systems and then be discharged to watercourses;
- increase in the volume of surface runoff due to the introduction of impermeable surfaces;
- poorly designed or blocked culverts could lead to localised flooding; and
- culverted watercourses could experience a reduction in water quality meaning those watercourses identified as being at risk of not achieving the objectives of the WFD may not achieve "good status" by 2015[9].

The surface waters potentially affected by all corridors are detailed within Appendix D.

The most significant negative effects of **Corridor C Tunnel** are associated with the culverting or re-aligning of surface waters which could prevent waterbodies achieving the objectives of WFD. As well as potential damage to the banks and/or bed of affected watercourses during the construction of culverts, in the long term there would be reductions in water quality and secondary indirect impacts on the riparian or aquatic ecosystems. Compensatory mitigation, such as ecological improvements of other sections of the affected surface water could offset negative impacts. All other temporary and permanent impacts, in particular those related to the potential contamination of surface runoff, handling site drainage and potential for flooding could be adequately mitigated through the adoption of the mitigation outlined in Appendix D. On this basis the overall temporary and permanent effects of Corridor C tunnel are assessed to be minor negative to neutral.

The impacts of new and upgraded roads on watercourses are likely to be the most significant effects of **Corridor D Bridge**. Culverting of surface waters could prevent them from achieving the objectives of the WFD by 2015. Mitigation would include measures to offset this impact by improvements to other stretches of the affected surface waters. Impacts relating to drainage and flooding can be adequately mitigated by adoption of the mitigation measures outlined in Appendix D. On this basis the overall temporary and permanent effects of Corridor D Bridge are assessed to be minor negative to neutral.

[9] See article 4(1) of "Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy" which requires that member states protect, enhance and restore all bodies of surface water with the aim of achieving good surface water status by 2015. This is translated into Scots law by the Water Environment and Water Services (Scotland Act) 2003 (the WEWS Act 2003).

The impacts of **Corridor D Tunnel** on drainage and flooding can be adequately mitigated by the measures described in Appendix D. However, the construction of a bridge over Humbie Reservoir and culverts associated with new roads could have negative effects on water quality. The cumulative effects of the bridge and culverts is such that the overall temporary effects of this option have been assessed as minor to moderate negative and permanent effects minor negative to neutral.

The most significant negative effects of **Corridor E Tunnel** relate to the displacement of sediments on the bed of the Firth of Forth and the resultant increase in turbidity as well as the potential culverting of surface waters on the northern shore. The majority of impacts can be mitigated through the adoption of mitigation measures described in Appendix D. However, as a result of the significant negative effects on water quality within the Firth of Forth the overall temporary effects have been assessed as minor to moderate negative and the permanent effects as minor negative to neutral.

Summary

The overall temporary and permanent effects of Corridor C Tunnel and D Bridge can be effectively mitigated by adherence to legislation and the adoption of best practice such as Sustainable Urban Drainage Systems (SUDS) and SEPA Pollution Prevention Guideline (PPGs). If such legislation and best practice is adhered to then impacts on the water environment are neutral. Effects resulting from culverting or re-alignment of watercourses would require compensatory mitigation to offset potential negative impacts on water quality. However, it is noted that under the WFD surface waters take the overall quality of the poorest stretch within them meaning that affected watercourses may not achieve the Directive’s targets by 2015.

The overall temporary effects of Corridor D and E tunnel have been assessed as minor to moderate negative and permanent effects as minor negative to neutral.

Within Corridor D the road network linkages and upgrades require a greater number of surface waters to be culverted or re-aligned, and in the case of the Humbie Reservoir bridged. On this basis temporary effects have been assessed as minor to moderate negative.

In terms of surface water quality, construction of the immersed tube tunnel in Corridor E would have a significant negative impact on the Firth of Forth. Dredging, drilling and blasting will displace large volumes of sediment from the bed of the Firth of Forth and cause increased turbidity. The permanent effects of both corridors D and E tunnel has been assessed as minor negative to neutral.

Table 5.3 below summarises the findings of the assessment regarding water environment issues.

Table 5.3: Summary of Assessment

Option	Overall Temporary Effects	Overall Permanent Effects
Corridor C - Tunnel	Minor Negative to Neutral	Minor Negative to Neutral
Corridor D - Bridge	Minor Negative to Neutral	Minor Negative to Neutral
Corridor D - Tunnel	Minor to Moderate Negative	Minor Negative to Neutral
Corridor E - Tunnel	Minor to Moderate Negative	Minor Negative to Neutral

Further details regarding the assessment of Water Quality, Drainage and Flood Defence are provided in Appendix D.

5.5.5 Geology

Introduction

Baseline geological and groundwater information was obtained by means of a desk study review of currently available information. No fieldwork was carried out to confirm the findings of the desk study. An appraisal of contaminated land issues is included in Section 5.5.9, Agriculture and Soils.

The local geology and groundwater regime was determined from geological and hydrogeological maps published by the British Geological Survey (BGS), borehole records held by the BGS, previously published reports, and relevant Geological Memoirs. Information on the presence of any SSSIs of geological interest was obtained from SNH, while Fife Council and the Edinburgh Geology Society were consulted on the presence of any Regionally Important Geological Sites (RIGS) on each side of the Firth of Forth.

Potential impacts relating to geology include damage to areas designated for their geological interest, effects on active or potential mineral extraction activities including sterilisation of reserves, and loss of deposits of limited extent or of ecological or other value, e.g. significant areas of peat. Impacts on groundwater quality or flow regime which affect the resource potential, for human use, ecology or river baseflows would be of concern.

Key Issues for Geology are discussed in Appendix D.

Appraisal Outcomes

The potential impact on the local geology and groundwater regime has been considered for each crossing option. No designated or non-designated sites of geological interest are predicted to be affected by any of the options and the types of bedrock and superficial strata affected by each option are widespread in the area. No specific geological deposits with ecological or other value, e.g. significant peat deposits, are identified in the vicinity of the options. Tunnel C is likely to sterilise more oil shale reserves than the other options, but it is unlikely that oil shale working will become economically viable in the future. Therefore, it is considered that there are no discernible differences between the options with respect to geology.

Shallow groundwater in the vicinity of each option is not considered to have significant resource potential or sustain sites of ecological interest or surface water baseflows and it is, therefore, not a consideration in comparing the options. Deeper groundwater in the bedrock strata is not predicted to be significantly affected by any of the crossing options, although each tunnel option, especially if mine stabilisation is required, may create very localised changes in the groundwater regime. Tunnel C has the greatest potential for such a change, being in an area of more extensive mine workings.

Summary

The appraisal has shown that no significant impacts on the local geology and groundwater regime are predicted and ,therefore, these aspects are not an important consideration in option selection. The bridge option is very slightly advantageous in this regard as it has less potential for locally altering the deep groundwater regime.

5.5.6 Biodiversity

Introduction

The following section discusses the over-riding biodiversity issues associated with the four crossing options of the Firth of Forth, followed by a discussion of potential impacts and broad mitigation measures. The Appraisal Summary Tables (ASTs) present an assessment of impacts after consideration of mitigation. The key issues are set out in a hierarchical order, dealing with protected sites in the first instance, followed by protected species. In both cases, the hierarchy is descending from European (international) importance - UK (national) – local/regional.

The baseline data has been collated from many sources and aims to present an overview of the main issues to inform the decision making process for route selection.

Details regarding the key issues in relation to Biodiversity are provided in Appendix D

Appraisal Outcomes

For the purpose of this route appraisal, the zone of influence for potential terrestrial and intertidal impacts is defined as 500 metres to either side of the likely route, and 500 metres from the edge of the cut and fill for the tunnel exits. In the terrestrial corridor, impacts will decrease with increasing distance; however, wetland habitats are likely to be more vulnerable to impact. The zone of influence for the Firth of Forth is more difficult to define at this stage, so the study considers the broader context of the mid-Firth of Forth for the estuarine environment.

Access to land was not possible to facilitate detailed surveys. A walk over survey was carried out from roads and paths to update the Phase 1 Assessment and an otter survey of the shore lines was undertaken together with some sampling of watercourses for otter signs when possible from land with public access.

Generic Impacts

Many impacts would be shared between two or more corridors and hence are of limited value to discriminate between options. However, it should be noted that the assessment scoring in the ASTs is not a comparative method, it judges the impact of each option individually.

The bored tunnels of C, D and E share impacts from activities associated with the tunnelling, disposal of the spoil and provision of tunnel shafts and construction entrances. The generic effects are indirect, related to noise, visual disturbance, dust, water run off and increased sediment loads into water courses. The mitigation of these impacts would be uniform, following SEPA's Pollution Prevention Guidelines and following of a code of construction practice. However, the ecological receptors present, as well as their sensitivity varies between options. This is discussed further in the text for each option, as are the impacts of the immersed tube construction method proposed for tunnel E.

Detailed discussion of the impacts on international, national and local issues for each of the corridor options are described in Appendix D.

Summary

Tunnel options C and D have the potential for indirect impacts on the Firth of Forth SPA. Impacts associated with portals and construction sites adjacent to the SPA could cause disturbance and possibly affect the estuarine environment, although the latter can be controlled by good construction practices.

Tunnel E has potential for a greater impact on the SPAs within the Firth of Forth. The immersed tube method that is necessary to overcome geological formations and to ensure that the tunnel conforms to gradient constraints will cause considerable disruption to the natural sedimentation processes by dredging and blasting. This has potential implications for open water birds and shore birds of the Firth of Forth SPA, the breeding terns of the Forth Islands SPA and migrating salmon and lamprey associated with the River Teith SAC. Additionally, cetaceans and other protected species (such as basking sharks and seals) may be disturbed and there may be far reaching impacts from disturbed sediments smothering eelgrass beds, which are an important habitat feature of the Firth of Forth. It is worth noting that a number of these species are specifically protected by the Nature Conservation (Scotland) Act 2004, particularly from "reckless" harm. Therefore, as with the SPAs, mitigation comprising seasonal constraints may be imposed during construction works, including blasting and movement of sediments in order to avoid such harm occurring.

Bridge D also has potential for construction disturbance and other indirect impacts on the Firth of Forth SPA, the migrating salmon and lamprey associated with the River Teith SAC, and the breeding tern populations of the Forth Islands SPA. The latter is particularly notable due to the importance of Long Craig Island, situated some 400 metres from the proposed bridge and which in some years holds over 50 per cent of the Forth islands SPA breeding common tern population. The requirement to avoid disturbing wintering birds associated with the Firth of Forth SPA, whilst at other times of the year avoiding disturbance to breeding and feeding terns associated with the Forth Islands SPA, may require onerous seasonal constraints that could significantly affect the construction programme for the bridge. In addition, the potential impacts on and interaction with the common tern colony of the Leith Docks SPA may also need to be considered.

Bridge D would also have a direct impact on the eastern end of St Margaret's Marsh SSSI and has implications for the water-levels affecting the remainder of the site. However, this is effectively a man made habitat, and it may be possible to create compensatory habitat to the west.

The scale and duration of the options indicating most potential impact on Natura 2000 sites, i.e. the SPAs and SAC, (Corridor E Tunnel and D Bridge) give limited scope for seasonal timing of construction operations. This difficulty, as discussed above, is further compounded by the opposing seasonal interests of all of the sites. All routes would require an Appropriate Assessment[10] with regard to these Natura sites.

[10] Where a project/plan is likely to have a significant effect on Natura 2000 sites (eg SPA/SAC) in Great Britain, Regulation 48 of the Habitats Regulations requires that an Appropriate Assessment (AA) be undertaken prior to the giving of any consent or permission. The AA assesses the implications of the project/plan for the site, in view of that site's particular designated features and conservation objectives. Note the need for AA's extends to projects/plans outwith the boundary of the site in order to determine their implications for the interest(s) protected within the site.

Other issues are more difficult to evaluate due to the patchiness of data. However, all corridors will impact on protected species such as badger, bat and otter. Non designated sites will also be affected by all options, in most cases this will lead to a loss of ancient woodland.

5.5.7 Landscape

Introduction

The following section considers the potential impacts of the four crossing options and their associated infrastructure on the landscape resource of the study area.

The study area comprises some very diverse landscape types largely resulting from the unique geological processes which underpin the landscape and the resulting agricultural and mineral wealth which first attracted settlement to the area. The current landscape of the area centred around the Firth of Forth reflects this combination of human and geological influences and forms a distinctive character marked by volcanic outcrops, intricate shorelines and wide sweeping views across the Forth. Hills to the north and south of the Firth form a backdrop for views within the area, as well as providing long distance elevated view across the Firth. The rail and road bridges in particular are a strong focus for views within the study area and are an important, iconic landmark for Edinburgh, the Lothians and Fife and well as Scotland as a whole.

Landscape Designations

The landscape designations identified in the Dunfermline and West Fife, Rural West Edinburgh and Edinburgh City local plans are illustrated in on the relevant drawings in Volume 2 and include:

- Gardens and Designed Landscapes (GDL);
- Area of Great Landscape Value (AGLV);
- Area of Outstanding Landscape Quality (AOLQ);
- Greenbelt; and
- Tree Preservation Orders (TPO).

Landscape Character

Scottish Natural Heritage, in conjunction with partner Councils, has undertaken detailed review and classification of the various landscape areas and types of landscape in Scotland. The north section of the study area is covered by Fife Landscape Character Assessment, dated 1999 (Review Number 113) and the southern section by the Lothians Landscape Character Assessment, dated 1998 (Review Number 91).

Appraisal Outcome

The potential impact on landscape character has been considered for each crossing option. The extent to which the four different options would affect the existing landscape character varies substantially depending on the individual components of each scheme option and the capacity of the existing landscape to absorb these components. It should be noted that the character of the Firth of Forth and the coastal fringe landscapes is very dependant on atmospheric and weather conditions with haars and low cloud substantially changing the experience and character of the landscape.

The main sources of landscape impact associated with the crossing options would be as a result of the new road construction connecting the crossings with the existing road network, road upgrades including widening, re-profiling and junction alterations, tunnel and portals, the bridge structure and toll plazas (if required).

Mitigation measures associated with the reduction of potential adverse impacts on landscape character would involve detailed consideration of the vertical and horizontal alignment of the new roads, junction arrangements and tunnel portals during development of the scheme design and would include the following mitigation measures and objectives:

- Achievement of best fit with the contours;
- Retention and best use of existing vegetation;
- Protection for nearby properties through the use of existing features;
- Avoidance where possible of the loss or damage to landscape features such as specimen trees, hedges, water features; and
- Avoidance where possible of the loss or damage to sites of ecological or archaeological interest.

The key principles of the landscape mitigation measures would include:

- Any new planting should use native species to increase the biodiversity and nature conservation value of the area; and
- Landscape planting, earthworks (mounding and earth shaping) and other mitigation measures where appropriate to minimise the visual impact of the scheme and enhance the existing local landscape character and structure.

Summary

Table 5.4 below summarises the potential impacts on landscape.

Table 5.4: Summary of Assessment

Option	Overall Temporary Effects	Overall Permanent Effects
Corridor C - Tunnel	Moderate to Major Adverse	Moderate Adverse
Corridor D - Bridge	Major Adverse	Major to Moderate Adverse
Corridor D - Tunnel	Minor to Moderate Negative	Minor Negative to Neutral
Corridor E - Tunnel	Minor to Moderate Negative	Minor Negative to Neutral

Overall, all of the four options are considered to have significant permanent impacts on the landscape resource of the study area with Tunnel Crossing E and Tunnel and Bridge Crossing D the most significant. Bridge Crossing D has the potential to result in Major to Moderate Adverse impacts due to the introduction of a third bridge crossing and the fragmentation of the landscape as a result of the introduction of the extensive section of new road and the associated demolition of residential properties. Similarly Tunnel Crossing D would result in fragmentation of the landscape and the loss of residential and commercial premises. Impacts associated with Tunnel Crossing E have the potential to be Major Adverse as a result of the direct impacts on Dundas Castle GDL, a landscape resource of national importance.

5.5.8 Visual Amenity

Introduction

The following section considers the potential impacts of the four crossing options and their associated infrastructure on the visual amenity of the study area.

Landscape and visual impacts are closely related issues with considerable overlap between the two assessments. Visual amenity is defined as the pleasantness of the view or outlook of an identified receptor or group of receptors. The visual impact assessment determines the degree of anticipated change to visual amenity, considering buildings, areas of public open space, roads and footpaths that would occur as a result of the proposed scheme. The buildings, open spaces, roads and footpaths that would yield views of the crossing options are collectively referred to as 'receptors'.

Appraisal Outcomes

To the north of the Forth the majority of receptors are located in the urban areas of Inverkeithing, Rosyth and south-eastern parts of Dunfermline as well as a number of scattered receptors across the more open countryside. To the south of the Forth receptors are generally more dispersed with various scattered receptors across the rolling countryside with groups of receptors generally limited to the urban area of South Queensferry.

Visual impacts would result from various elements of the proposed crossing options but most notably from the new infrastructure, the bridge structure and the tunnel portals. The mitigation commitments outlined in the landscape character assessment have been considered during the visual assessment process and are reflected in the appraisal of overall permanent effects.

Volume 2 contains visual impact drawings which identify the key visual receptors associated with each of the four crossing options. Major Adverse impacts would be associated with residential properties which have immediate views of the development or where the focus to their view would substantially change. Visual impacts would be less where receptors are less sensitive to change such as commercial buildings or where the changed view is peripheral and more distant.

Bridge Crossing D would have the greatest visual impact due to the extensive visual influence it would exert. All of the tunnel crossing options to the north of the Forth would have a broadly similar extent of visual influence whilst to the south of the Forth, Tunnel Crossings C and E would have the least visual influence. Tunnel Crossing D would have less of a visual impact on receptors than Bridge Crossing D, although more than the other tunnel options.

Summary

Table 5.5 below summarises the potential temporary and permanent impacts that each of the four options are considered to have on visual amenity.

During the construction period, the majority of receptor groups which directly overlook the development corridor, or with immediate views towards it would experience significant and adverse visual impacts as a result of the visually intrusive construction activity associated with the construction of the development. In the long term, significant and adverse visual impacts would be limited to more sensitive receptor groups (expectation and importance of the changed landscape to the receptor) and those with an immediate orientation towards the development.

The majority of visual impacts would result from the new infrastructure associated with all of the crossing options, to a lesser extent the tunnel portals and most extensively from the new bridge structure of Bridge Option D. Whilst all of the four crossing options would result in various receptors experiencing impacts ranging from Major Adverse through to Minor Adverse or Neutral depending on their proximity to the development and their angle of view it is considered that Bridge Option D would have the greatest visual impact due to the extensive visual influence that the bridge would exert.

Table 5.5: Summary of Assessment

Option	Overall Temporary Effects	Overall Permanent Effects
Corridor C - Tunnel	Minor Adverse – Major Adverse	Minor Adverse – Major Adverse
Corridor D - Bridge	Minor Adverse – Major Adverse	Minor Adverse – Major Adverse
Corridor D - Tunnel	Minor Adverse – Major Adverse	Minor Adverse – Major Adverse
Corridor E - Tunnel	Minor Adverse – Major Adverse	Minor Adverse – Major Adverse

5.5.9 Agriculture and Soils

Introduction

This assessment considers the effect the options have on agricultural land and soils. It also includes potential occurrences of contaminated land, on or close to each crossing option. Baseline information was obtained by means of a desk study review of designated areas, land classification maps and aerial photography. No fieldwork was carried out to confirm the findings of the desk study.

Details regarding the key issues in relation to Agriculture and Soils are provided in Appendix D

Appraisal Outcomes

Do Minimum

The Do Minimum option would not cause a significant impact on agriculture or soils as there would be no significant additional land take or construction of other structures associated with this scenario, in the immediate study area.

Permanent Impact on Agricultural Land Quality (All Options)

All the options affect agricultural land which is mostly classified as prime quality agricultural land. Therefore, the permanent effect for all the options are assessed as moderate negative.

Permanent Impact on Severance or Loss of Agricultural Land (All Options)

All the options have a significant impact on the loss and severance of large areas of agricultural land. In order to assess the impact individually for each corridor it is necessary to know how much of the land will be viable post construction due to severance. However, due to time and access constraints consultation with Scottish

Executive Environment and Rural Affairs Department (SEERAD) and individual farmers was not possible and is therefore, not included in this assessment. With the information available the impact for all the corridors is assessed as moderate to major negative due to the large area of land potentially affected which exceeds the threshold for significant impact as defined in STAG.

Permanent Impact on Designated Areas (All Options)

Corridor D Tunnel and Corridor D Bridge do not affect any fields that are protected under a national or local designation. However, Corridor D Tunnel affects agricultural land that is within the Countryside Policy Area (Rural West Edinburgh Local Plan - RWELP) and Corridor E Tunnel affects agricultural land that is within the Greenbelt (RWELP). Therefore, there is a moderate negative impact for these two options.

Permanent Impact relating to Construction Sites (All Options)

For all the options the shaft construction sites would most likely result in the permanent loss of the entire field due to the size of the permanent structures together with their required access routes. This together with the loss of prime quality agricultural land means a moderate negative impact has been assigned except where the loss of land is within the Countryside Policy Area for Corridor D Tunnel, where a major negative impact has been assigned.

Permanent Impact on Soils (All Options)

Due to the degradation of soil quality during storing and the time it takes for soils to restore its structure after being reinstated, a minor negative impact on soils is considered for Corridor D Bridge.

A significant negative impact is considered for all the tunnel options as they would potentially disturb larger quantities of soil, particularly during cut and cover activities. In addition, there would be considerable quantities of spoil to be disposed of from the tunnel options. Some of this could be disposed of to landfill or disposed of to designated marine areas outwith the Firth. Alternatively, as most of this material will comprise marine sediments and boulder clay some of this material could be used for various other construction or restoration projects, such as land reclamation, within and outwith Scotland. Overall, for all tunnels the impact is assessed as being moderate negative.

Note that in this case the lengths of approach roads have been assumed to be similar for all options.

Permanent Impact relating to Contaminated Land (All Options)

The appraisal of contaminated land issues is solely based on evidence from current and historical Ordinance Survey maps at this stage. The actual presence of contaminated land will be investigated by preliminary ground investigations proposed for the crossing options and ultimately by a detailed investigation on the route of the selected option. The appraisal indicates that there is some potential for occurrence of contaminated land on all routes. However, Corridor D Tunnel and Corridor E Tunnel have the greatest potential for contamination being a significant issue, based on the number of potential occurrences noted and the range of industrial activities involved. Corridor C Tunnel is indicated to have the least potential.

Summary

Table 5.6 below summarises the findings of this sections. The appraisal has shown that there are potentially significant negative impacts (i.e. moderate or major negative impacts) on agriculture and soils for all the options. However, with the information available the bridge option appears to be very slightly advantageous as it appears to affect the least agricultural land area and the alignment doesn't pass through any policy areas. Furthermore it has a lower potential for locally altering the soil structure due to the nature of construction of a bridge over that of a tunnel. Based purely on examination of historical map evidence, it appears that Corridor C Tunnel is the best option with respect to contaminated land, while Corridor D and E Tunnels are the worst. However, the information used to derive this conclusion is only indicative.

Table 5.6: Summary on Agriculture and Soils

Option	Overall Temporary Effects	Overall Permanent Effects
Corridor C - Tunnel	Negligible	Moderate to Major Negative
Corridor D - Bridge	Negligible	Moderate to Major Negative
Corridor D - Tunnel	Negligible	Moderate to Major Negative
Corridor E - Tunnel	Negligible	Moderate to Major Negative

5.5.10 Cultural Heritage

Introduction

This section discuss the archaeological and cultural heritage issues associated with the four crossing proposals of the Firth of Forth, followed by a discussion of potential impacts and broad mitigation measures.

Baseline data was collected for the study area, designed to cover the various options and the surrounding area, from the following sources:

- City of Edinburgh Sites and Monuments Records held on the Canmore[11] database;
- Fife Sites and Monuments Records held on the Canmore database;
- West of Scotland Archaeology Service for West Lothian;

[11] Canmore – The Royal commission for the Ancient and Historic Monuments of Scotland (RCAHMS) database of archaeological sites, monuments, buildings and maritime sites in Scotland.

- The Statutory List of Buildings of Special Architectural or Historic Interest;
- The National Monuments Record of Scotland;
- The Inventory of Gardens and Designed Landscapes in Scotland; and
- Local Plans.

The data from these was plotted onto base mapping. Sites located within approximately 500m of each proposed route alignment are discussed and an initial assessment of archaeological potential has been made.

Generic Impacts

Assessment of impacts on Cultural Heritage receptors has been made based on the data available from Historic Scotland, the Historic Environment Records and the National Monument Record for Scotland. A walkover survey was not undertaken at this stage.

Impacts on the archaeological and heritage sites have been made based upon the information available to date. Once an option has been chosen and more detailed plans developed it is likely that the impact assessment will change. Full details regarding the impacts discussed, in brief, below can be found in the Cultural Heritage STAG tables submitted as part of this report.

Corridor C Tunnel

The Corridor C Tunnel would create both direct physical impacts and indirect visual impacts upon archaeological sites, the built heritage and historic landscapes. Both direct and visual impacts would also be caused by the linkages to the current road network. There would be adverse impacts upon four sites of national importance, four sites of regional importance and five sites of local importance. These impacts are both direct and visual.

The magnitude of the impact from this option is considered to be Moderate Adverse.

Corridor D Bridge

The Corridor D Bridge option would create both direct physical impacts and indirect visual impacts upon archaeological sites, the built heritage and historic landscapes. Both direct and visual impacts would also be caused by the linkages to the current road network. There are nine sites of national importance, 13 sites of regional importance and five sites of local importance that would be adversely affected by the proposed option.

The magnitude of the impact form this option is considered to be Major Adverse.

Corridor D Tunnel

The Corridor D Tunnel option will create both direct physical impacts and indirect visual impacts upon archaeological sites, the built heritage and historic landscapes. Both direct and visual impacts will also be caused by the linkages to the current road network. There are five sites of national importance, eight sites of regional importance and five sites of local importance that would be adversely affected by this option.

The magnitude of the impact form this option is considered to be Moderate Adverse.

Corridor E Tunnel

The Corridor E Tunnel option would create both direct physical impacts and indirect visual impacts upon archaeological sites, the built heritage and historic landscapes. Both direct and visual impacts would also be caused by the linkages to the current road network. There would be adverse impacts upon five sites of national importance, nine sites of regional importance and seven sites of local importance.

The magnitude of the impact of this option is considered to be Moderate Adverse.

Summary

The table below summarises the likely permanent impacts upon the cultural heritage resource by the proposed crossing options. The preferred option in terms of archaeology and cultural heritage is the C Tunnel as this has the least impact upon archaeological and heritage sites. The least preferred option is the D Bridge option as it has the most adverse impact upon archaeology and cultural heritage.

Table 5.7: Summary of Impacts on Cultural Heritage

Option	Permanent Impact	Sites of National Importance	Sites of Regional Importance	Sites of Local Importance
C Tunnel	Moderate Negative	4	4	5
D Bridge	Major Negative	9	13	5
D Tunnel	Moderate Negative	5	8	5
E Tunnel	Moderate Negative	5	9	7

Environmental Summary

The findings from the environmental appraisal are summarised in Table 5.8 below.

Table 5.8: - Permanent Environmental Impacts

Topic	Tunnel C	Tunnel D	Tunnel E	Bridge D
Noise and Vibration	Moderate negative*	Moderate negative*	Moderate negative*	Moderate negative*
Global and Local Air Quality**	Minor positive	Minor positive	Minor negative	Minor positive
Water Quality	Minor negative to Neutral	Minor negative to Neutral	Minor negative to Neutral	Minor negative to Neutral
Geology	Neutral	Neutral	Neutral	Neutral
Biodiversity	Moderate to Minor negative	Moderate to Minor negative	Major to Moderate negative	Major to Moderate negative
Landscape	Moderate to Major negative	Major to Moderate negative	Major negative	Major to Moderate negative
Visual Amenity	Moderate negative*	Moderate negative*	Moderate negative*	Moderate negative*
Agriculture and Soils	Major to Moderate negative	Major to Moderate negative	Major to Moderate negative	Major to Moderate negative
Cultural Heritage	Moderate Negative	Moderate Negative	Moderate Negative	Major negative

** NB: For Visual Amenity and Noise & Vibration some properties for each option will suffer Major Negative impacts whilst other will be subject to Minor Negative or Neutral impact. Depending on the properties proximity, and in the case of visual amenity the views of the proposed development, the median level of impact has been used in this summary.*
*** NB: For Global and Local Air Quality, the assessment is based on global air quality i.e. CO_2 emissions only.*

The findings show that environmental impacts for most options will generally be similar. However, the main exception to this are impacts on biodiversity where Corridor E Tunnel and Corridor D Bridge proposals may have Major to Moderate impacts.

For Corridor E Tunnel this is due to the proposed immersed tube that will disturb sediments and may impact on the Firth of Forth SPA and Forth Islands SPA, which are protected at the European level, as well as other European protected species such as cetaceans. In addition, approach roads at the southern end of Corridor E Tunnel pass through the Dundas Castle GDL, which is a national designation.

For Corridor D Bridge there is a significant risk of indirect disturbance to protected species particularly within the Forth Islands SPA but also relating to the Firth of Forth SPA, which may impose significant seasonal constraints during construction, as the Forth Islands SPA protects breeding birds (i.e. spring and summer) whilst the Firth of Forth SPA protects over-wintering birds. In addition, the northern landfall of Corridor D Bridge passes through the St Margaret's Marsh SSSI, protected at national level, and would involve the loss of some areas of ancient woodland.

5.6 SAFETY AND SECURITY

5.6.1 Safety

Introduction

Each of the proposals would involve a change in the distance travelled, and the numbers travelled, on different sections of the road network. These changes would result in either improvements, or deterioration, in the number and severity of road accidents. Standard methodologies are available to forecast the overall impact on personal injury accidents, the severity of these accidents, and a monetised cost of these injuries.

Key Issues

The principal user groups affected by changes in road accidents would be car occupants. Given that the principal changes would be on the strategic road network, there is anticipated to be no significant impact upon pedestrians, cyclists and equestrians.

There are not considered to be any specific other social groups, or spatial areas disproportionately affected by the proposals in relation to road accidents.

Appraisal Outcomes

The appraisal of accidents has compared the "do-minimum" scenario to the four appraised options, for the years of 2017 and 2022. Outcomes are presented in Table 5.9 and 5.10 below.

Table 5.9: Forecast Personal Injury Accidents in the Modelled Area- 2017

Accident Category	Do Min.	C Tunnel	Diff	D Bridge	Diff	D Tunnel	Diff	E Tunnel	Diff
Damage only	129755	128811	-944	128423	-1332	128709	-1046	128442	-1313
Slight	13084	12943	-141	12917	-167	12934	-150	12912	-171
Serious	1072	1058	-14	1056	-16	1056	-15	1056	-16
Fatal	135	132	-2.1	132	-2.3	132	-2.4	132	-2.4

Note: Diff is the difference between the Do Minimum value (Do Min) and the Option.

Table 5.10: Forecast Personal Injury Accidents in the Modelled Area – 2022

Accident Category	Do Min.	C Tunnel	Diff	D Bridge	Diff	D Tunnel	Diff	E Tunnel	Diff
Damage only	135827	134820	-1007	134418	-1410	134659	-1169	134391	-1436
Slight	13755	13607	-148	13580	-175	13594	-161	13572	-183
Serious	1125	1111	-14	1109	-17	1109	-16	1108	-17
Fatal	142	140	-2.1	139	-2.4	139	-2.5	139	-2.4

Note: Diff is the difference between the Do Minimum value (Do Min) and the Option.

Typically, the proposals result in reductions in fatal and serious accidents across all proposals, in both 2017 and 2022.

In terms of accident numbers, considering all accident types over both the forecast years, the bridge in corridor D and the tunnels in corridors D and E are most advantageous in terms of accident reductions. There are also reductions in accidents in Corridor C but not of the same magnitude of the other two.

Using the forecasts presented above, it is possible to calculate monetised savings over the sixty year assessment period. These are presented in Table 5.11 below.

Table 5.11: Forecast Accident Savings (Present Value of Benefits, 2002 prices and values)

Crossing	Corridor	Accident Savings
Tunnel	C	£184.4 million
Bridge	D	£223.0 million
Tunnel	D	£210.6 million
Tunnel	E	£228.0 million

The total accident savings are of a similar magnitude for all the proposals. However, the results confirm that Corridors D (tunnel and Bridge) and E perform better than Corridor C.

5.6.2 Security

Appraisal of security is concerned with any material impact that the proposals may have upon the security of the users. The appraisal also considers who (which groups of people) are most at risk and how issues can be mitigated.

Key issues

Transport infrastructure carries an inherent risk that vehicles would suffer breakdowns or similar incidents requiring drivers to stop and leave their vehicles. Drivers "stranded" by the side of the road are vulnerable to accidents and potential crime. Mitigation against this could include the provision of CCTV, hard shoulders, communications and help points and vehicle recovery patrols.

The provision of transport infrastructure of national importance may entail a risk of terrorist attack. The severity of this risk is considered to be equal amongst all users. Whilst the provision of a replacement bridge across the Firth of Forth would not increase the security implications beyond the current level, it is recognised that the severity of the consequences of an attack within a tunnel are such that the security implications are greater. Mitigation against these risks could include operational management measures such as event training and other emergency preparations.

It is recognised that there may also be personal security risks arising from the implementation of complementary measures (see Chapter seven). These would include the provision of enhanced public transport. This would result in an increase in public transport users in the area, which is likely to result in an increase in people waiting at bus stops and rail stations. Personal security implications exist for all public transport uses, particularly vulnerable groups. Mitigation against this could include the provision of CCTV, help points and manning of stations and stops. It is recognised that, for existing users, increased public transport patronage can represent increased safety as large numbers of people are likely to deter potential criminals.

Appraisal Outcomes

There is not considered to be any significant difference in security between the options. The majority of issues can be managed through best practice in relation to bridge and tunnel operations.

5.7 ECONOMY

5.7.1 Transport Economic Efficiency

Introduction

This section describes the Transport Economic Efficiency (TEE) part of the Economy objective of STAG. Section 8.2.1 describes the TEE as assessing "…the contribution which a transport proposal may make to economic welfare through consideration of the resultant transport costs and benefits."

This section describes the key issues in the calculation of the TEE outcomes and then provides the outcomes themselves.

Key Issues

The methodology adopted follows the guidance given in STAG sections 8.2 to 8.6. It makes use of the standard HM Government guidance contained in WebTAG[12] section 3.5.6, and of the Department for Transport (DfT) software TUBA (Transport User Benefits Appraisal), which was developed by the DfT for undertaking economic appraisals for transport schemes.

The Transport Model for Scotland[13] (TMfS) was used to derive the forecasts required to undertake the TEE assessment. TMfS is the official model of Transport Scotland, which is maintained and updated periodically by consultants on their behalf. It models all responses to possible transport interventions, such as changing mode, destination, time of travel etc and has recently been updated to a 2005 base, including the latest land use forecasts, as provided by each local authority.

The model includes representations of three time periods: AM peak (08:00-09:00), Inter peak (average hour of 10:00-16:00) and PM peak (17:00-18:00).

Two future year scenarios (2017 and 2022), were used to provide inputs to the assessment.

The outputs are calculated by comparing the forecast outcome with each scheme in place with the forecast outcome without the scheme. The transport benefits and disbenefits identified are then, therefore, only due to the effects of the scheme implementation.

[12] www.webtag.org.uk
[13] www.tmfs.org.uk

Not all benefits to transport users have been quantified in this assessment. For example, it was not possible to monetise the quality or reliability benefits within this assessment. The quantified benefits are presented in 2002 prices, with values discounted to 2002 values as required by STAG. They are assessed over a period of 60 years from the opening of the crossing.

Appraisal Outcomes

Table 5.12 presents a summary of the TEE results for each crossing scenario.

Table 5.12: Summary of Transport Economic Efficiency (£million, 2002 values and prices)

Sub-Objective		Tunnel C	Tunnel D	Bridge D	Tunnel E
Transport Users	Travel time	3,558.4	4,087.1	4,660.4	4,954.0
	User Charges	-242.1	-255.5	-276.0	-272.1
	Vehicle Operating Costs	1,217.8	1,318.8	1,495.4	1,507.2
Private Sector Operator Impacts	Investment Costs	0	0	0	0
	Operating & Maintenance Costs	0	0	0	0
	Revenues	-62.9	-70.2	-81.9	-82.6
	Grant/Subsidy payments	0	0	0	0

Corridor E tunnel shows the highest level of user travel time benefit, followed by Corridor D bridge, Corridor D tunnel and then Corridor C tunnel.

The disbenefits in user charges are very similar for all scenarios. These reflect the increase in the amount of tolls paid due to the reintroduction of a tolled crossing across the Forth, as assumed in the modelling. Vehicle operating costs increase as the distance travelled by cars increases. As with the travel time benefit, Corridor E shows the most benefit, followed by Corridor D bridge, Corridor D tunnel and then Corridor C tunnel.

The drop in revenues accruing to private sector operators is due to a drop in the numbers using public transport. However, it should again be emphasised that these scenarios do not have any complementary public transport measures.

5.7.2 Economic Activity and Location Impact

Introduction

This section provides a summary of the Economic Activity and Location Impact (EALI) analysis which has been undertaken for the Forth Replacement Crossing. EALI analysis aims to describe the impacts of transport investment on the economy using the measures of income or employment. EALI analysis is intended to identify how and under what circumstances transport projects might impact on the economic performance of different areas.

The analysis has been undertaken for the following areas:

National: Scotland

Regional: The South East Regional Transport Partnership area

Local: A local study area defined as south Fife (Dunfermline, Inverkeithing, Rosyth, Dalgety Bay and Cowdenbeath) and west and central Edinburgh and West Lothian.

Transport Investment and Economic Performance

The Forth Crossing Replacement is anticipated to have the following impacts:

- Impacts on Existing Businesses: the proposals for the Forth Replacement Crossing could impact on existing businesses in three ways. Firstly, it could impact on costs as consistent more reliable journeys would enable businesses to obtain goods/deliver goods more cost effectively. Secondly, the proposals may enable businesses to expand their markets through quicker, more reliable access to new customers and potential suppliers. Finally, there may also be labour market impacts if the catchment area for staff is increased.

- Impacts on New Businesses: the proposals for the Forth Replacement Crossing may increase the attractiveness of an area to new businesses which would lead to increased employment opportunities. These businesses may be new to UK as a whole (e.g. foreign direct investment (FDI)) or new to the local / regional economy (e.g. they have relocated from elsewhere in the UK/Scotland). The origin of the relocating business is important in economic development terms as its presence in one area may be at the expense of another area.

- Impacts on Land Use: the proposals for the Forth Replacement Crossing might enable some sites to be brought forward for development which would not otherwise have been possible. This could influence the location of future development sites and create employment opportunities. However, these impacts would be local rather than national or regional in character.

The appraisal of the corridors would consider the impact of each of these mechanisms on the geographies defined in Section 5.5.2.

Key Issues

At the local level, the details of corridors and their junctions are important as each one may give rise to different land use development patterns and their contribution to the local economy. However, at the national and regional level, it is anticipated that there would no difference between the corridors in terms of their impact on economic performance.

The analysis assumes that with the Replacement Crossing operating only as a replacement, the Do-Minimum situation against which the Forth Replacement Crossing is assessed is a situation in which the existing Bridge is closed to traffic.

Option Appraisal –

Impacts on Existing Businesses

Scotland Impacts

The current FRB plays an important role in the strategic transport network of the Scottish economy. It provides a link between Edinburgh and Fife, but also from Edinburgh to Dundee, Aberdeen and the North East and to Perth and Inverness in the Highlands and Islands. As such, reliable journeys on the route would impact on businesses well beyond the immediate hinterland of the bridge in Edinburgh and Fife.

Businesses in sectors which are heavily dependent on moving goods to markets in the Central Belt and further south rely on the Forth Crossing for reliable, consistent journeys. Sectors which would benefit include food and drink manufacture, haulage and distribution and non-food manufacturing. Other sectors rely on the movement of people and include tourism and business services. The Tables in Appendix E provide a summary of the sectoral impacts.

If the Forth Replacement Crossing operates as a replacement to the current Forth Road crossing, there would be a positive impact on the Scottish economy relative to the do-minimum scenario. The Replacement crossing would provide direct access between Edinburgh and Fife and would assist with delivering the forecast economic growth. It is expected that, without the Replacement Crossing, the traffic conditions across and around the Forth would restrict the ability of the economy to achieve its growth forecasts. It is not possible to quantify the exact contribution of the Replacement Crossing in terms of jobs and income as transport is only one of a number of factors which would influence the performance of Scottish businesses in future years, but the role of the Replacement Crossing as a “link” between the central belt and northern/north eastern areas of Scotland would have a positive impact on national economy.

At the national level, there is no difference in the performance of the corridors.

Regional Impacts

At the regional level, the current FRB is crucial to the Edinburgh labour market. The development of the Edinburgh economy has relied, in part, on its neighbouring authorities as a source of labour. In 2001, over 60,000 people lived in the neighbouring authorities and worked in Edinburgh. Some of 11,000 of these people lived in Fife. Indeed, there are some parts of Fife where 20-40 per cent of residents are working in Edinburgh.

The increasing role of Fife in the growth of the Edinburgh economy is evident in the housing market. In 1995, 5 per cent of house sales in central/southern Fife were to households relocating from Edinburgh. By 2003, 14 per cent of “second-hand” house sales and 28 per cent of new build sales were to households relocating from Edinburgh. The Census is the main source of data on were people live and work, but 2001 is the latest available and is now quite dated. However, data from National Statistics (Annual Survey of Hours and Earnings) shows that the number of residents in employment in Fife has increased by 6% over 2002 to 2006 while the number of jobs in Fife has only grown by 1%. Over the same period, jobs in Edinburgh have grown by over 7% while the number of residents in employment has only grown by 2%. Hence, Fife has an important role to play in the Edinburgh city region in the future.

If the South East is to achieve its future economic potential it is essential that labour can move easily throughout the region. With the Forth Replacement Crossing, it is considered that there would be a positive impact on the regional economy relative to the do-minimum scenario. This would primarily be felt through the labour market, but also existing businesses which need to move goods and people between Fife and the rest of the South East area would be able to do so more easily. There would be continuing opportunity for the Edinburgh labour market to recruit from Fife where the housing market is strongly influenced by the Edinburgh economy.

At the regional level, there is no difference in the performance of the corridors.

Impacts on New Businesses

Transport infrastructure can play a role in business location decisions where the transport infrastructure is one of a number of factors which influence the location decision. It is not the only factor affecting decisions, but it can be considered a *necessary* but not a *sufficient* condition for a business choosing a new location.

Scotland Impacts

The do-minimum scenario is likely to increase congestion and reduce reliability for movements across the Forth. This could affect business location decisions and result in a minor adverse impact on the Scottish economy. Under the do-minimum scenario the traffic conditions across the Forth may result in other areas of Scotland becoming more attractive to new business investment, which overall would result in a neutral impact on the Scottish economy. However, given the importance of the South East area of Scotland to the country and the dominance of the financial services sector it is possible that some companies may only be interested in locating in the South East/Edinburgh area such that they may choose another location outside Scotland in the do-minimum situation.

The Replacement Crossing may stimulate new investment in the regional economy which could be displaced investment from elsewhere in Scotland or it could be new investment to Scotland. As a result, the overall impact at the Scotland level would be neutral or possibly positive depending on the source of the investment.

Regional Impacts

In this situation, it is considered that the Forth Replacement Crossing would have a positive impact on the South East in terms of attracting new investment. The Replacement Crossing would add to the “place competitiveness” of the region and contribute to the economic development aims of the Fife Structure Plan in terms of highlighting Fife’s attractiveness within East Central Scotland and also adding to the attractiveness of the West Edinburgh area which is one of the most important development zones in Scotland.

At the regional level, there is no difference in the performance of the corridors.

Impacts on Land Use

While the Replacement Crossing could affect land use in the general area of the crossings, the impacts on land use would be primarily felt around the landfall areas of the replacement bridge/tunnel. In this situation, the key issue relates to the performance of the individual corridors.

Corridor C

In terms of the potential impact in the immediate vicinity of the landfall areas, the Corridor C tunnel proposal would connect well with development areas in Rosyth and Dunfermline. It would also have the potential to integrate with community regeneration activity areas in Dunfermline.

On the southern side of the Forth, the Corridor C tunnel proposal would connect well with employment and development areas along the M9 including Livingston and the Almond Valley, Winchburgh/East Broxburn/Uphall and Armadale. These areas are identified as core development areas for approximately 12,000 houses.

This Corridor would have a positive contribution to local economic development, particularly benefiting those areas to the west of the study area e.g. West Lothian.

Corridor D

In terms of the potential impact in the immediate vicinity of the landfall areas, the close proximity of both the bridge and tunnel proposals landfall sites to the existing bridge in the north of the Forth, limits its impact on potential local economic development. However, relative to the do-minimum situation this corridor could have the potential to integrate with community regeneration areas in Dunfermline.

South of the Forth, the corridor connects well with the West Lothian towns discussed under Corridor C, but it also connects well with Edinburgh Park/South Gyle/Sighthill and Newbridge/Kirkliston/Ratho. Community regeneration activity in West Edinburgh (Parkhead, Murrayburn and Sighhill) may also benefit.

This Corridor would also have a positive contribution to local economic development, particularly benefiting those areas to the west of the study area e.g. West Lothian and west Edinburgh.

Corridor E

In terms of the potential impact in the immediate vicinity of the landfall areas the close proximity of the Corridor E tunnel proposals to the existing Bridge North of the Forth limits its impact on potential local economic development. However, relative to the do-minimum situation this corridor has the potential to integrate with community regeneration areas in Dunfermline and Inverkeithing.

South of the Forth, the corridor connects with one of the key development areas in Edinburgh – Waterfront Edinburgh where there is significant brownfield development potential for business and housing development in Granton and Leith. Community regeneration activity in north and west Edinburgh may benefit.

This Corridor would also have a positive contribution to local economic development, particularly west and central Edinburgh.

Summary

Table 5.13 provides a summary of the main economic and locational impacts of the Forth Replacement Crossing using a seven point scale. At the national level, the main positive impacts are to be felt on existing businesses. At the regional level, existing businesses and new businesses are forecast to experience positive impacts. At the local level, all the corridors are anticipated to have positive economic development effects with Corridors C and D tending to favour West Lothian while Corridor E tends to favour north and central Edinburgh.

Table 5.13: Summary of Potential Impacts

Economy	Corridor C	Corridor D		Corridor E
	Tunnel	Bridge	Tunnel	Tunnel
Impact on Existing Business				
National Impacts	√√	√√	√√	√√
Regional Impacts	√√√	√√√	√√√	√√√
Impact on New Business				
National Impacts	-/√	-	-	-
Regional Impacts	√√	√√	√√	√√
Impact on Land Use				
Local Impacts	√√	√√	√√	√√

5.8 INTEGRATION

5.8.1 Integration

Appraisal of Integration covers three main elements:

- Transport Integration;
- Land use Transport Integration; and
- Policy Integration.

Each sub-objective is considered below in turn.

5.8.2 Transport Integration

Introduction

The transport integration sub-objective relates to improvements in public transport services and ticketing that contribute to the realisation of a "truly seamless network". It includes consideration of improvements to public transport infrastructure and information.

Key Issues

The schemes being promoted do not directly include public transport services, ticketing initiatives, nor improved passenger infrastructure and information.

A range of complementary measures are being considered to support the project. These would be designed to improve public transport services and ticketing. Whilst comprehensive, the complementary measures would not deliver improvements which would result in a "truly seamless public transport network." All benefits would be captured by the economic assessment.

The possible exception is for Corridor D Bridge, where there is an option for the bridge deck cross-section to be designed to accommodate a light rail alignment (see Chapter 7 for discussion). If this option was taken forward, and if a light rail scheme was subsequently provided, then it is considered that this would contribute to a step change in transport integration.

Appraisal Outcomes

In the context of a replacement crossing, it is considered that there would be no impact for transport integration for corridor C (Tunnel), D (Tunnel) and E (Tunnel). Corridor D (Bridge) also has no impact, although it is noted that this would change if the option to provide a light rail alignment was taken forward.

5.8.3 Land Use - Transport Integration

Introduction

The Land Use Transport Integration sub-objective requires consideration of the fit between the proposals and established land use /transport planning guidance. Firstly, it is necessary to ensure that the alignments of the routes do not conflict with existing, or future land use designations identified in the relevant local plans. There is also wider consideration of whether the proposals fit with the policy contained in the relevant structure plans, and national planning policy.

Beyond this, there is a requirement to consider the impact of the proposal upon significant existing or proposed developments. A particular focus of this assessment is whether the proposal would be likely to increase or reduce the number of car trips, or their average length, or have significant implications with respect to sustainable transport modes.

Key Issues

An assessment of the fit of the various alignments with land use policy designations has been previously undertaken and reported in the appendices to Report 3 – Option Generation and Sifting. Overall, this assessment revealed that the various road connection alignments have the potential to conflict with future allocations for housing. At this stage it is difficult to be precise on the scale of scope of these potential conflicts. However, any conflicts are not deemed to be ones that cannot be resolved through the next stage of the design process together with the planning consents process.

Wider land use / transport policies have previously been reviewed in Report 2 – Gaps and Shortfalls. The principle of providing a replacement crossing, which enhances sustainable transport options but does not increase capacity for SOV, is supported by the approved Fife structure plan, SEStrans Regional Transport Strategy and the Edinburgh and Lothians structure plan.

The Scottish Executive's Planning Policy Guidance 17 –Transport and Planning promotes the integration of transport and land use, promoting sustainable development. With a principle of providing no additional capacity for general traffic on the replacement crossing, each of the corridor alignments are in accordance with this general principle.

Significant existing and future land use developments that may be affected by the provision of the replacement crossing are the implementation of the West Edinburgh Development Framework, the expansion of Edinburgh Airport and future housing allocations in Fife and West Lothian. If acting as a replacement crossing, there would be difficulties in ensuring that access to and from these major developments is achieved in a sustainable manner unless complementary measures can be introduced.

Measures will be taken, where possible, to accommodate local aspirations assuming that they are in keeping with relevant policies.

Appraisal Outcomes

All alignments perform similarly with respect to land use transport integration. When operating as a replacement to the FRB, there is minimal positive integration with land use.

5.8.4 Policy Integration

Introduction

The Policy integration sub-objective requires that the proposals are tested in relation to the following policy areas.

- Disability
- Health
- Rural Affairs
- Social Exclusion
- Detailed consideration against national transport targets.

Key Issues

There are not considered to be specific disability issues associated with any of the schemes being considered within the appraisal. The design of all new facilities (bridges, tunnels and connecting roads), and associated operational procedures, would be in accordance with appropriate legislation.

In terms of a replacement crossing there is not expected to be any impacts as the facilities available for disabled users would be similar to those currently enjoyed on the existing FRB.

Health impacts of transport relate primarily to the impacts of air quality and road safety, and also the wider suppression/encouragement of physical activity. There is also the issue of how the proposals assist in providing access to health care. Air quality and road safety impacts are reported separately (Environment and Safety). If the replacement crossing includes facilities for cyclists and pedestrians, there would be no adverse impact on physical activity. Clearly this would be easy to provide for the bridge crossing but not the tunnel options. All the tunnel corridor options would directly impact on physical activity where it would not be possible to provide access for cyclists and pedestrians.

None of the proposals directly impact upon Rural Affairs policies. Any rural impacts are the environmental and land use impacts associated with changes in the use of existing agricultural land.

A key consideration for areas of social inclusion is the ability to improve affordable transport to key destinations. There is little difference between each of the proposals contained within the appraisal.

Scotland's National Transport Strategy (Scottish Executive, 2006) confirmed the continuation of the aspirational target to stabilise road traffic volumes at 2001 levels by 2021. Achievement of this target requires a significant absolute reduction in current traffic volumes. None of the proposals are likely to achieve this. Overall, the impact of each proposal is likely to be either neutral (if no new capacity is provided), or an increase in traffic volumes (if additional capacity for HOV is provided). Other national targets and performance indicators are either considered elsewhere (carbon dioxide emissions in environment, road safety in safety) or are considered to be neutral (for example increases in walking and cycling for local trips)

Summary

The integration appraisal has considered the impact of the proposals upon Transport Integration, Land Use Integration, and Policy Integration. If the new crossing is used as a replacement crossing there is limited opportunity for successfully promoting sustainable complementary transport measures. As a consequence, there is limited opportunity for effective transport, land-use or policy integration unless additional capacity is made available for dedicated public transport (bus, coach) and HOV lanes. However, this cannot be done with the tunnel options without the need for another bore. The bridge option could utilise the hard shoulder as a running lane for sustainable modes outlined above.

Furthermore, the Corridor D Bridge option provides the opportunity to consider an option to provide a cross-section that would enable a light rail alignment. This is discussed further in Chapter 7. If this option were exercised, it would provide a positive integration impact.

5.9 ACCESSIBILTY AND SOCIAL INCLUSION

5.9.1 Public Transport Coverage

Public transport enables people to access employment, training, health and other services. This can be of particular importance to disadvantaged groups such as those on low incomes, the elderly and disabled people, who do not have access to private cars. For this reason, it is important to explore the impacts of a transport project upon public transport network coverage.

In relation to the replacement crossing the opportunities that exist for enhancing the public transport network coverage would be limited beyond simply replicating the services which used to use the FRB. However, when compared against the Do – Minimum situation of no crossing at Queensferry then this is a significant enhancement.

While all proposals would have beneficial impacts for public transport network coverage, Corridor D and E proposals would be more beneficial than Corridor C. The proximity of Corridor D and E proposals to the existing public transport network, associated infrastructure and developed areas would enable an enhanced public transport network to better serve the needs of its users. In contrast, it is recognised that the Corridor C proposal could expand the public transport network into areas which are not well served at present.

5.9.2 Community Accessibility

There are few significant levels of community severance associated with these proposals. Corridor E tunnel and Corridor D Bridge proposals are not associated with any community severance. Corridor D tunnel may result in severance in the Inverkeithing area and a limited degree of severance in the Carmelhill area on the southern shore. Corridor C Tunnel proposal may result in community severance between Dunfermline and Rosyth, however, this is unlikely to be significant as the presence of a railway line is already likely to have severed links between the areas.

In terms of improving access to services by walking and cycling, the bridge option in Corridor D would accommodate the facilities that would be lost from the FRB. However, this would not be possible within any of the tunnel options.

In terms of improving access to services by public transport, improved linkages with Edinburgh would be likely to improve access to all relevant services. All options would maintain the cross- Forth linkages that would be lost in the Do – Minimum situation.

In terms of access to local services, the strategic nature of all of the options mean that the impacts would be limited. When operating as a replacement crossing, the direct connections to the strategic transport network may reduce congestion in urban areas such as Queensferry and Inverkeithing which could also improve access to local services.

5.9.3 Comparative Accessibility

For the purpose of this appraisal it is considered that transport infrastructure users can be divided into the following categories based on their primary mode(s) of transport:

- Pedestrians and cyclists;
- Car users (this category includes car users who have adequate access to suitable public transport but choose to use private vehicles); and
- Non-car owners (this category encompasses all “captive” public transport users and therefore, includes venerable groups such as the young, the elderly and low-income groups).

The proposal-specific comparative accessibility impacts are detailed below.

Corridor C Tunnel

This proposal would result in increased accessibility in areas such as Rosyth, Dunfermline, Limekilns and Charlestown. The main beneficiaries of this element of the proposal are likely to be car users. The provision of a new cross-Forth link in this area has the potential to improve cross-Forth public transport services within the area. However, the distance of this proposal from the primary public transport network and areas of "attractors" such as employment, housing and services make this proposal less attractive for public transport than the other two corridors.

This proposal would result in a considerable loss of cross-Forth accessibility in the South Queensferry and Dalmeny area. This disbenefit may adversely affect car users proportionally more than non-car owners, as the cross-Forth rail service from Dalmeny would act as a buffer to retain accessibility for this group. This proposal would result in a shift in the primary cross-Forth public transport network away from the A90 towards the M9. This may entail some degree of benefit for non-car owners in areas such as Kirkliston as a result of increased public transport services. However, longer-distance cross-Forth services are unlikely to significantly increase accessibility for these groups above the levels already provided by public transport services with a more local orientation. Operating as a replacement, a tunnel would mean that current cross-Forth pedestrian and cycle links would be severed as a tunnel is not able to accommodate these modes.

Corridor D Bridge

Operating as a replacement for the existing FRB, the similarity of this proposal to the existing crossing, on the north shore of the Firth of Forth, would result in minimal impacts upon accessibility depending upon the detail of the network connections. On the southern shore of the Firth of Forth, this proposal would link with South Queensferry and retain existing levels of accessibility in this area, albeit Dalmeny residents may have to travel further to access the new crossing which is likely to entail disproportionate disbenefits for non-car owners. Cycle and pedestrian links would be re-directed across the new bridge replacing the former links on the existing bridge.

Corridor D Tunnel

As with the Bridge proposal in this corridor, operating as a replacement for the existing crossing, this proposal would result in minimum accessibility impacts on the north shores of the Firth of Forth. However, on the southern shore this proposal connects to the M9 as opposed to serving South Queensferry. This is likely to result in a proportionally greater disbenefit for non-car users than for car owners. Operating as a replacement, a tunnel would mean that current cross-Forth pedestrian and cycle links would be severed as a tunnel is not able to accommodate these modes.

Corridor E Tunnel

This proposal working as a replacement for the existing FRB would result in increased accessibility in the Kirkliston area which is likely to be of most benefit to car uses.

Operating as a replacement for the existing FRB, this proposal reduces accessibility in the North Queensferry, Inverkeithing and Rosyth areas which is likely to result in a proportionally greater disbenefit for non-car users than for car owners.

5.10 COSTS TO GOVERNMENT

5.10.1 Introduction

This section presents an assessment of the Cost to Government of the crossing scenarios. It discusses how the cost estimates were calculated for each scenario. These costs are presented in current prices.

It then calculates the net cost of the proposals in 2002 prices and values so that they can be compared with the TEE benefits presented in section 5.7.

Finally, a summary is presented, which compares the benefits that can be expressed in money-terms with the costs.

5.10.2 Cost Calculation Methodology

Tunnelling costs were developed by carrying out a detailed cost estimate for Corridor C Tunnel. Cost rates for each component of the tunnel construction were taken from industry standards such as Spons, and from project experience elsewhere, to enable an overall cost estimate to be established. With the exception of the immersed tube section in Corridor E, the three tunnel options share many similarities. A unit cost per metre length of tunnel for the SCL, TBM, and Cut and Cover tunnelling techniques was derived from the detailed costing estimate for Corridor C. These were then adjusted if appropriate and applied to the alternative route alignments to build an overall cost estimate for each option. Other costs such as site mobilisation and the tunnel control room were assumed to be the same for all three options.

Costs for the immersed tube section of Corridor E Tunnel have been derived by using overall project costs for other major comparable projects in the UK and abroad. These costs have been collated and a unit cost per length of immersed tube tunnel has been calculated.

Estimates for the costs of constructing the bridge were originally derived at the Setting Forth stage using, as a basis, rates obtained from the Second Severn Crossing. Detailed costing of the bridge superstructure for the suspension and cable stayed bridges for corridor D was carried out between February and June 2007. The bridge superstructure accounts for approximately two-thirds of the overall cost. It was considered that this was a significant portion of the bridge on which to develop more detailed costing information.

The bridge was designed to accommodate pedestrians and cyclists. Wind shielding was also included.

Cost estimates of the annual operation and maintenance costs of the tunnel options were carried out by reviewing reported costs for the existing Forth crossing, as well as a review of power supply requirements for tunnel services such as lighting and ventilation from other similar tunnelling projects in the UK and abroad. Estimates of typical annual operation and maintenance costs for the bridge options were derived using comparisons with other major long span bridges. To these figures were added the cost of major periodic maintenance items, including resurfacing, painting, replacement of bearings and movement joints, and replacement of hangers

In calculating the cost of constructing the network linkages, each alignment option was considered individually and broken down into its respective sections to the north and south of the Firth of Forth. Within each section the length of individual road types was completed based on the proposed carriageway cross-section. All cross-sections have been based on official guidance.

The remaining costs are those for preparation and supervision, which were calculated by applying a standard percentage to the costs of construction, and the cost of purchasing the land.

Table 5.14 presents a summary of the construction costs for each option, in Q4 2006 prices. Note that the 'other' costs are the preparation, supervision and land. Optimism Bias has been applied to the costs, as described in Section 5.11.

Table 5.14: Costs of Constructing the Replacement Crossing (£millions, 2006 prices)

Corridor	C	D	D	D	E
Crossing Type	**Tunnel**	**Tunnel**	**Cable-Stayed Bridge**	**Suspension Bridge**	**Tunnel**
Crossing Construction	1,527	1,418	789	974	1,738
Network Connections Construction	425	447	464	464	355
Other Costs	374	349	219	250	365
Total	2,326	2,214	1,472	1,689	2,458

A per metre cost for each cross-section was initially based on Spons Q4 2006 unit estimate rates for roadworks. These rates were checked and amended in accordance with recent construction projects and guidance. The per metre costs included all road construction elements including drainage, earthworks, pavements, fencing and barriers, accommodation works and signage and road markings. For each route all structures including underbridges, overbridges and viaducts, were identified and costs produced on a per item and metre basis. It should be noted that toll plazas were included in the costings of each option. However, it is unclear at this stage as to whether these would be required.

Additional road maintenance costs have also been calculated. This was done by calculating the additional road length, and applying standard rates per kilometre built. These rates vary by type of road.

Table 5.15: Ongoing Costs of Replacement Crossing (per annum, £millions, 2006 prices)

Corridor	C	D	D	D	E
Crossing Type	Tunnel	Tunnel	Cable-Stayed Bridge	Suspension Bridge	Tunnel
Crossing Maintenance and Operation*	9.8	9.1	10.8	10.8	9.1
Network Connections Maintenance*	0.3	0.5	0.4	0.4	0.4
Total	10.1	9.6	11.2	11.2	9.5

5.10.3 Present Value of Cost to Government

This section presents calculations of costs so that they can be compared with the transport benefits presented in the TEE section (Section 5.7). The costs that STAG requires to be assessed are:

- public sector investment costs;
- public sector operating and maintenance costs;
- grant/subsidy payments;
- changes in revenue; and
- changes in indirect taxation.

The costs are therefore, presented in 2002 prices, with values discounted to 2002 values. They are assessed over a period of 60 years from the opening of the crossing. Optimism bias has been applied, as described in Section 5.11. Table 5.16 presents the results for each scenario. Costs are indicated by negative values. Positive values are gains to government.

Table 5.16: Cost to Public Sector (£millions, 2002 values and prices)

Corridor Crossing Type	C Tunnel	D Tunnel	D Cable-Stayed Bridge	D Suspension Bridge	E Tunnel
Public sector investment costs	-1,881.3	-1,788.5	-1,190.5	-1,368.1	-1,993.3
Public sector operating and maintenance costs	-161.4	-153.8	-162.9	-162.9	-152.6
Grant/subsidy payments	0	0	0	0	0
Revenues	282.8	300.8	331.8	331.8	335.6
Taxation impacts	-327.5	-326.2	-375.7	-375.7	-361.8

The public sector investment costs are the capital costs that are spent to construct the crossings and associated network connections. Corridor D bridge is the least expensive option, with the cable-stayed variant being less expensive than the suspension bridge.

The public sector operating and maintenance costs are the ongoing burden imposed on the public purse by the crossings and associated network linkages. All options impose a very similar level of ongoing expenditure.

Grant/subsidy payments are sometimes required in transport schemes in order to fund a service provided by a private company (e.g. First ScotRail, bus operators etc) that does not cover its own costs. That is not the case in this scheme, so all values are zero.

Public sector revenues are affected by the change in the amount of toll revenue collected. All scenarios increase the amount of toll revenue collected by the government, due to the reintroduction of a tolled crossing across the Forth.

Indirect taxation revenues would change when a scheme shifts expenditure to or from fuel, which is heavily taxed, and to or from public transport fares, which are not taxed. This must be reflected in the assessment. All scenarios increase the indirect tax revenues collected by the government, though Corridor C tunnel and Corridor D tunnel show the lowest increase.

5.10.4 Monetised Summary

This section presents the benefits from the TEE section of the analysis and compares them with the Cost to Government shown above. This allows a judgement to be made as to the value for money of the schemes. However, it should be emphasised that not all transport benefits are able to be monetised, and that there may be other benefits to society, not transport related, that could result from the implementation of the scheme.

Table 5.17: Monetised Summary of Costs and Benefits (£millions, 2002 values and prices)

Corridor	C	D	D	D	E
Crossing Type	Tunnel	Tunnel	Cable-Stayed Bridge	Suspension Bridge	Tunnel
Present Value of Benefits (PVB)	4,655.6	5,303.1	6,026.1	6,026.1	6,317.1
Present Value of Costs (PVC)	-2087.4	-1967.7	-1,397.3	-1,574.9	-2,172.2
Net Present Value (NPV)	2568.2	3,335.3	4,628.8	4,451.1	4,144.9
Benefit to Cost Ratio (BCR)*	2.23	2.70	4.31	3.83	2.91

* ratio, not monetary value

The Net Present Value (NPV) is calculated as the Present Value of Benefits (PVB) minus the Present Value of Costs (PVC). It, therefore, calculates the net benefit to society. The Benefit to Cost Ratio (BCR) is the Present Value of Benefits divided by the Present Value of Costs multiplied by minus one. This, therefore, presents the amount of benefit society gets from each pound spent on the project.

In all scenarios analysed above the monetised benefits are greater than the costs. Corridor D Bridge produces the most favourable results, with the lower cost of the cable-stayed variant giving the highest NPV and BCR. The most favourable tunnel option is that of Corridor E. This option produces the highest level of monetised benefits, but at a significantly higher level of cost than Corridor D Bridge. This results in an inferior NPV and BCR.

Table 5.18 presents the ranking of the schemes (1 = best, 5 being worst) for each item of the monetised summary.

Table 5.18: Monetised Summary Scheme Ranking

Corridor Crossing Type	C Tunnel	D Tunnel	D Cable-Stayed Bridge	D Suspension Bridge	E Tunnel
Present Value of Benefits (PVB)	4	3	2=	2=	1
Present Value of Costs (PVC)	4	3	1	2	5
Net Present Value (NPV)	5	4	1	2	3
Benefit to Cost Ratio (BCR)	5	4	1	2	3

5.11 RISKS AND UNCERTAINTY

Overview of Bridge Key Risks

One of the key risks associated with the bridge option relates to the environment and the possible impacts on the Firth of Forth SPA, the Forth Islands SPA and the River Teith SAC and/or their qualifying species. Although it is not expected that there would be any direct impacts due to the introduction of appropriate mitigation measures, there remains the possibility of indirect impacts on these Natura 2000 sites from the construction and operation of the bridge. To date, there is limited environmental information available to base more detailed assessments on but survey work is underway, and further surveys planned, to cover the seasonal issues associated with wildlife. A full Environmental Impact Assessment for the chosen scheme, carried out in accordance with the Environmental Impact Assessment (Scotland) Regulations 1999, is due to be completed by late 2008. It is considered unlikely that Scottish Natural Heritage (SNH) would be able to formally comment on the proposals until this has been completed.

However, it is known that there are currently seasonal building restrictions imposed by SNH on the construction of the New Upper Forth Crossing at Kincardine. This prevents construction on more than two consecutive bird breeding seasons. The impact of this constraint, if applied to the construction of a bridge, has been estimated to extend the 6 year programme for a suspension bridge by around 8 months. The cable stayed bridge programme would be extended from 5.5 years by ten months.

The greater availability of information regarding ground conditions, relevant to the construction of Corridor D Bridge, in comparison to the tunnel proposals significantly reduces the comparative risk of the bridge proposal. However, there are a number of risks that have been identified and must be given due consideration.

There are two main risks apparent during the construction phase for Corridor D Bridge relating to the bridge anchorages and the erection of the main cables.

During construction of the south anchorages for the FRB, an explosion occurred at the bottom of the tunnels. This was believed to be due to a sudden and unexpected release of methane gas into the workings. This is an extremely important design consideration which must be incorporated into the design and construction of any new suspension bridge. Therefore, it is proposed to use gravity anchorages to reduce excavation and hence minimise construction risks. At the north landfall there is also a potential risk of methane within the rock. Two possible methods have been considered. In one method, the main steel suspension cables would be anchored into the rock and a second option could include for gravity anchorages on the north side.

Risks of delay, relating to climatic conditions are inherent with the erection of the main cables. The Preformed Parallel Wire Strands method, as outlined in Chapter 4 and Appendix C is slightly less prone to weather and poor visibility risks than aerially spun cables. However, the risks of delay due to adverse weather conditions remain, whatever method is employed.

Further risks exist following and during construction, namely those of ship impact. These risks exist for all bridge types, but are more apparent for the Cable stayed Bridge. For this option, the Grangemouth navigation channel runs close to the southern pylon, increasing the risk of ship impact. Again, this risk can be mitigated against at the design stage, where the main bridge piers and foundations would be designed to resist impact. Reinforced concrete would be used for the towers to avoid potential damage in the event of a fire following ship impact.

Overview of Tunnel Key Risks

The environmental risks associated with the tunnel options are likely to be less than those associated with the bridge. However, the use of an immersed tube in the middle section of Corridor E has been identified as a risk due to the impact that dredging the bed of the Forth and disturbing sediments would have on the two SPAs within the Firth.

The presence of dolerite may result in underwater blasting being required. This, and potential increases in sediment loading, would have a direct impact on the Atlantic salmon and lamprey runs that are present in the Forth relating to the River Teith SAC. In addition, blasting may affect other European Protected Species using the Firth such as cetaceans (whales and dolphins) and basking sharks, which are specifically protected from "reckless" harm by the Nature Conservation (Scotland) Act 2004. Such potential impacts may require seasonal constraints to be imposed on blasting and, therefore, would pose a major risk to the programme.

A further risk is that there is little or no geotechnical information available in Corridors C and E and only limited data for Corridor D. Whilst this affects the bridge option in Corridor D, it is more severe for the tunnel options where conditions may vary along the entire length of the routes.

Therefore, interpolation of the limited existing geotechnical data has been necessary. The risks associated with each tunnelling technique have been speculated based on both previous experience and suggested trends and observations in the geotechnical data.

It is proposed that the approach tunnels on either shore are constructed using the SCL method. As described in Appendix B, this is an open face method that relies on the mined strata being sufficiently stable in the short term to allow temporary support to be installed with only a limited amount of advance ground stabilisation. Typically, spiles (long steel or fibre glass dowels) are drilled into the face or crown to stabilise the ground and rock bolts installed radially to mobilise the strength of the ground in the short term. These ground support measures would be used in combination with sprayed concrete applied to exposed cut surfaces and in greater thickness radially to provide a temporary structural shell. The structure would then be completed by installing a waterproof membrane and an in situ structural concrete lining.

The use of the SCL method depends on the strata being sufficiently stable to allow a largely unsupported excavation. Threats to the stability of the excavation include significant and rapid changes in ground conditions and the presence of flowing water or water under pressure. It is suggested that faults may be present on the southern shore and doleritic intrusions are observed throughout the area. The SCL method provides a flexible and cost effective way of managing the creation of the underground space and a better means of mining through dolerite than by the use of a TBM where drill and blast excavation may be required. The presence of water would affect the depth to which the SCL tunnels can be taken and, hence, the position of the ventilation shafts on either shore.

Earth Pressure Balance TBM's are proposed to drive through the glacial materials in the region below the Forth. This closed face technique at high hydrostatic pressure is the only way by which these materials can be mined at the proposed horizon. The glacial deposits would be at high hydrostatic pressure and may include organic material and boulders. Often these glacial deposits include tree trunks which present a challenge to TBMs that cannot easily excavate through them. Obstructions such as this and large boulders need careful consideration as they cannot be easily removed. It is likely to be very difficult to enter the face of the TBM without significant stabilisation of the ground to reduce man entry hydrostatic pressures. In this instance stabilisation would need to be undertaken from within the machine as access from the river bed would be impractical when undertaken in an unplanned manner. This process would present tunnellers with engineering challenges.

Creating cross passages between the tunnels would necessitate ground stabilisation by ground treatment or ground freezing. This might be possible from within the tunnel but would be challenging. Planned pre-installation of ground treatment blocks from the surface in a marine environment would be the most likely and successful way of addressing this construction issue.

Hitting or mining through dolerite with a TBM would be extremely difficult and would necessitate a change in method to open face drill and blast. Intervention from the river bed would be needed to manage this situation, should it arise. Site investigations would need to accurately identify dolerite intrusions and the alignment changed to avoid them. It is suggested that Corridor D would hit dolerite near to Beamer Rock. It is assumed that intervention from the surface would be required to manage this interface.

Corridor E incorporates an immersed tube tunnel beneath the deep water channel. Should dolerite be found in the dredged excavation it is likely that marine drill and blast or intervention from the surface would need to be employed. The submerged connections between the immersed tunnel ends and the bored tunnel are likely to be completed using interventions from the surface by cofferdam or caisson.

Mine workings are likely to be in close proximity to the southern approach tunnels in both corridors C and E. The workings would need to be stabilised in a zone around the twin bored tunnels before construction in these areas.

The means and methods described in Appendix B and the risks raised in this section have been promoted based on our current high level understanding of the geotechnical conditions. These views may change based on a better understanding of the strata and hence the risks involved in construction. The primary source of risk contingency at this stage is the lack of geotechnical information. Secondary to this is the significant engineering challenges introduced with driving TBM tunnels at high hydrostatic pressures and creating cross passages in such extreme conditions. Avoiding cross passages would force evacuation and emergency access/egress to be beneath the road deck. This approach would increases the diameter of the tunnel by approximately 2 metres making it one of the largest TBM driven tunnels in the world.

Clearly from the above there are, therefore, significant risks associated with the buildability and deliverability of the tunnel options. Initial market sounding has supported the view that there are significant difficulties to be encountered with the construction of a tunnel. Ground Investigation surveys are being commissioned and would be undertaken later in 2007 and 2008. The information gained from such survey work would allow the risks to be quantified.

Optimism Bias

STAG highlights a systematic tendency for project appraisers to be overly optimistic. As a result, STAG requires appraisers to make explicit adjustments for this bias. The standard optimism bias for fixed links i.e. bridges and tunnels is 66 per cent. This has been used for all elements of the corridor options with the exception of the network connections. The standard 44 per cent has been applied to these elements.

5.12 MONITORING AND EVALUATION

Introduction

Monitoring is an on-going process which involves the gathering and interpretation of information regarding the performance of a project against the established objectives. In this case, monitoring is required to ensure that, should any of the proposals be taken forward, they meet the planning objectives as set out in section 3.4. The monitoring would be carried out by the promoter of the scheme; Transport Scotland.

The monitoring strategy for each of the planning objectives is set out below.

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

Selected vehicle journey times provide a measure of change between the current and forecast situations. An analysis of the level of crowding on the cross-Forth services in the AM peak would also be undertaken, as this is a key factor in people's perception of the 'level of service' they are receiving from a rail trip.

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

How well the transport network is operating can be measured by the average speed of vehicles on the network.

Improve the reliability of journey times for all modes.

A measure of congestion will be used as a proxy measurement for this objective. An appropriate congestion indicator is the number of hours lost due to travel being slower than speed achieved on each road when traffic is flowing freely. In the absence of the introduction of any bus priority measures, the reliability of bus journeys is a function of the journey time of private road vehicles. Where specific priority measures are provided (bus lanes or HOV lanes) then further monitoring would be required to distinguish the effects. In addition, a subjective assessment of the ability of the network to deal with emergency incidents can be undertaken.

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

The measurable outcome for this objective is the mode split between car and public transport trips across the Firth of Forth.

Improve accessibility and social inclusion.

Social inclusion is measured through an assessment of how the socially deprived can access centres of major employment. The time taken for cross-Forth movements to access employment by both private and public transport would be assessed, to show the change in accessibility brought about by implementation of the relevant project.

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

The total vehicle flow over the existing FRB, and particularly the total flow of HGVs is closely linked to the requirement for maintenance and resurfacing work on the bridge carriageways. Annual 'total vehicle' and 'HGVs' flows would be prepared for each time period.

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

This information would be extracted from detailed information relating to environmental designations within the study area. An assessment of regional emissions (in tonnes), noise and visual impact would be undertaken, using standard environmental monitoring.

Support sustainable development and economic growth.

The 2002 report "Scotland's Transport Delivering Improvements: Transport Indicators for Scotland", published by the Scottish Executive outlines performance targets for the objectives to support sustainable development. These are transport emissions, "freight lifted" and modal shifts. The performance target for economic growth is identified as road traffic congestion. The targets of Transport emissions, freight lifted, modal shift, and road traffic volumes (congestion for economic development) are already reported upon as part of the other planning objectives.

Monitoring conclusion

Before the monitoring programme is agreed upon by Transport Scotland, consideration must be given to the actual availability of the data, practicalities of collecting new data, its format, whether it would properly reflect the indicators proposed and the cost of obtaining it. Indicators and targets should be subject to regular reviews to ensure that they continue to properly reflect the performance of the project against its objectives, throughout the monitoring period.

Evaluation

Evaluation is required to demonstrate how effectively a project has met the established planning objectives following its implementation. An evaluation would utilise information gathered for monitoring purposes but may also involve the analysis of additional data gathered specifically for the evaluation.

STAG defines two types of evaluation – Process Evaluation and Outcome Evaluation.

Process Evaluation

Process evaluation is primarily concerned with how well the project has been implemented. Process evaluation of this project would be carried out within the first two to three years following project implementation and would focus on the following two themes:

- Operational Characteristics;

Evaluation would examine the usage of sustainable transport provisions such as HOV lanes and their operational configuration to ensure that the benefits derived from such provision are both realised and maximised.

- Timescales and Costs.

Evaluation would examine the timescales and costs of the project to ensure that lessons can be learnt and applied to future projects to ensure delivery *on time and on budget.*

Outcome Evaluation

Outcome evaluation examines a project's performance against the established targets or, in this case, planning objectives. Outcome evaluation is usually undertaken five or more years after project implementation to ensure that the longer term impacts of the project can be examined.

Outcome evaluation analyses the performance of the project against each of the planning objectives, utilising a combination of data gathered throughout the monitoring process and other relevant data necessary to support the process.

Conclusion

The paragraphs above demonstrate that Transport Scotland will take steps to validate and evaluate the scheme and to monitor its performance in the operational phase.

The planning objectives are set out together with actions to be taken to ensure that the project meets these objectives and to identify future gaps and shortfalls within the project area.

5.13 SUMMARY OF STAG PART 2 APPRAISAL

5.13.1 Introduction

The STAG Part 2 Appraisal considers performance against planning objectives, implementability, and the government's five transport appraisal criteria: Environment, Safety, Economy, Integration, and Accessibility and Social Inclusion.

Four options have been considered within the appraisal: tunnel options on corridors C, D and E, and a bridge option on corridor D.

5.13.2 Performance Against Planning Objectives

Findings are currently as per the outcome of the STAG Part 1 Appraisal. Bridge options tended to be better than tunnel options, as these had the potential future possibility of additional capacity for sustainable transport. Corridor C was considered to be less favourable than Corridors D and E, as it was furthest from the existing crossing.

5.13.3 Implementability

There are currently a greater number of technical risks for the three tunnel options. This is due to uncertainties in relation to ground conditions. Corridor E Tunnel also has issues associated with the construction of an immersed tube tunnel.

5.13.4 Environment

The Environmental Appraisal findings show that environmental impacts for most options would generally be similar, typically minor to moderate adverse. However, the main exception to this are impacts on biodiversity where Tunnel E and Bridge D options may have Major to Moderate adverse impacts.

For Corridor E Tunnel this is due to the proposed immersed tube that would disturb sediments and may impact on the Firth of Forth SPA and Forth Islands SPA, which are protected at the European level, as well as other European protected species such as cetaceans. In addition, approach roads at the southern end of Corridor E Tunnel pass through the Dundas Castle GDL, which is a national designation.

For Corridor D Bridge there is a significant risk of indirect disturbance to protected species, particularly within the Forth Islands SPA, but also relating to the Firth of Forth SPA. This may impose significant seasonal constraints during construction, as the Forth Islands SPA protects breeding birds (i.e. spring and summer) whilst the Firth of Forth SPA protects over-wintering birds. In addition, the northern landfall of Corridor D Bridge passes through the St Margaret's Marsh SSSI, protected at national level, and would involve the loss of some areas of ancient woodland.

5.13.5 Safety

Typically, the proposals result in marginal reductions in all accident types in all options. Corridor D Tunnel, Corridor E Tunnel and Corridor D Bridge perform similarly, with accident savings valued around £220 million. Corridor C Tunnel produces benefits at a slightly lower level of approximately £180 million.

No specific security issues have been identified which would differentiate between the options. The majority of issues can be managed through best practice in relation to bridge and tunnel operations.

5.13.6 Economy – TEE

In all scenarios analysed above the monetised benefits are greater than the costs. Corridor D Bridge produces the most favourable results, with the lower cost of the cable-stayed variant giving the highest NPV and BCR. Corridor E is the most favourable tunnel option. This option produces the highest level of monetised benefits, but at a significantly higher level of cost than Corridor D Bridge. This results in an inferior NPV and BCR. The higher level of benefits is thought to arise as a consequence of the proximity of the southern connections with routes into the city of Edinburgh. This could be considered to be undesirable given current regional and local policies.

5.13.7 Economy – EALI

At the national level, the main positive impacts are to be felt on existing businesses. At the regional level, existing businesses and new businesses are forecast to experience positive impacts. At the local level, all the corridors are anticipated to have positive economic development effects with Corridors C and D tending to favour West Lothian while Corridor E tends to favour north and central Edinburgh.

5.13.8 Integration, Accessibility and Social Inclusion

All options perform similarly in relation to Integration. This also applies to the Accessibility and Social Inclusion criteria. This is particularly the case given that a replacement crossing is being compared with a scenario where the FRB does not operate as it does at present.

6 Operation of a Twin Crossing Strategy

6.1 INTRODUCTION

Chapter One explained how a decision can be taken on the refurbishment of the existing FRB once a replacement crossing has been constructed and opened to traffic. This decision can be made on the level of investment that is needed to bring the structure back to the appropriate "load carrying" capability. This capability would be determined by the use to which it is intended to put the refurbished structure to.

Once this is known then it would be possible to determine how the replacement crossing and the refurbished FRB might operate together to meet the needs of the long term cross Forth transport demands in a sustainable manner.

This chapter, therefore, provides an overview of the possible operational arrangements for the proposed crossings of the Firth of Forth.

The key objective is to develop an operational arrangement, which complies with the requirements of the study brief, current national policies, complements the proposed alignments and allows flexibility during abnormal conditions.

The existing FRB is constructed to dual two lane standard, with no hard shoulders. There are no restrictions to any vehicle during normal operational conditions when the posted speed limit is 50 mph.

The bridge is currently tolled only in one direction, with the toll plaza located on the northbound carriageway, on the south side of the bridge. The current bridge operates at capacity during peak times with reoccurring congestion in both the morning and evening peaks. During abnormal conditions the Bridge Master employs a number of operational procedures, to manage various restrictions:

- total closure to all vehicles, (high winds / accidents) – vehicles are diverted over the Kincardine Bridge. Information is relayed to drivers via Variable Message Signs / Radio / Web site from the Traffic Scotland Control Centre / FETA Control Centre and the diversion route is sign posted to the Kincardine Bridge;

- total closures to Wind Susceptible Vehicles, (WSV's), (high winds) – WSV's are diverted over the Kincardine Bridge. Information is relayed to drivers via Variable Message Signs / Radio / Web site from the Traffic Scotland Control Centre / FETA Control Centre. The diversion route is sign posted to the Kincardine Bridge; and

- lane closure, (accident, incidents, maintenance) – traffic management measures are introduced over the bridge and on approaches to the bridge. Information on the lane restrictions are relayed to drivers via Variable Message Signs / Radio / Web site from the Traffic Scotland Control Centre / FETA Control Centre.

Any new crossing would need to provide safe and efficient operations both during normal and abnormal conditions, but at the same time adhere to Transport Scotland current polices and the overarching principals of the commission.

6.2 UNRESTRICTED OPERATIONAL PROCEDURES

Possible operational scenarios were developed without any restrictions. Scenarios were developed for the following crossing arrangements:

- twin crossings (one way operation on each crossing): The existing bridge is renovated and retained for four lanes of traffic. The bridge is combined with a new road bridge or tunnel of D2M standard. The crossings operate in either a southbound or northbound direction only;
- twin crossings (two way operation on both crossings): The existing bridge is renovated and retained for four lanes of traffic. The bridge is combined with a new road bridge or tunnel of D2M standard. The crossings operates both in the southbound and northbound directions;
- replacement crossing (D2M): The existing bridge is taken out of commission and a replacement road bridge or tunnel is constructed to D2M standard;
- replacement crossing (D3M): The existing bridge is taken out of commission and a replacement road bridge is constructed to D3M standard; and
- replacement crossing (D4M): The existing bridge is taken out of commission and a replacement road bridge is constructed to D4M standard.

All options have been defined for a bridge or tunnel alignment, with the exception of the replacement strategies utilising a D3M or a D4M cross section, which only considers a bridge option, (as a tunnel option would require twin bores in each direction to achieve these options and as such would make a tunnel option for D3M and D4M un-economical).

The following traffic operational measures were considered for all of the above crossing arrangements:

- any - provision of a lane for all vehicles, unrestricted access;
- rail based Light Rapid Transit (LRT) - The provision of a LRT system is only considered for new bridge crossings as the existing bridge cannot accommodate a LRT system of this type and tunnels are restricted from combining LRT and normal traffic due to safety considerations;
- bus lane - provision of a lane for bus only access;
- HOV lane - provision of a lane for vehicles with more than one occupant, (2+ or 3+ HOV lane);

- hard shoulder running - provision of additional running lane utilising the hard shoulder for vehicles during peak periods;
- tidal traffic flow systems - provision of traffic management system to increase the provision of running lanes in one direction during peak periods;
- low emission ("green") - provision of lanes for low emission vehicles; and
- non-HGV lanes - provision of lanes for non-HGV traffic. The removal of HGV's from the existing crossing may prolong the life of the existing deck or may reduce the level of maintenance required on the existing structures.

The above operational can be combined, i.e. HOV lane provided during peak periods on the hard shoulder.

Assessment of the operational consideration for the following groups would be given after the conformation of the preferred operational option:

- blue badge holders;
- taxis;
- cyclists; and
- pedestrians.

The outcomes from the above unrestricted operational arrangements are illustrated in Tables F.1 to F.8 in Appendix F, which have yielded over 160 operational options.

The operational considerations are for normal running conditions only. The impact of planned and emergency lane / carriageway closures would be covered in detail in a subsequent section.

6.3 OPERATIONAL CONSTRAINTS

The assessment process for assessing the suitability of the various operational arrangements is illustrated by the flow chart in Figure F.1 in Appendix F.

Any operational arrangement must conform to three main criteria:

- current Transport Scotland policies;
- commission requirements; and
- operational considerations.

The above criteria are detailed in the following sections.

The National Transport Strategy, and associated action plans (Scotland's Railways, Freight Action Plans and the Bus Action Plan), were published on 5 December 2006. In terms of delivering the future transport system for Scotland, the NTS maps out three key strategic outcomes, comprising:

- improved journey times and connections;
- reduced emissions; and
- improved quality, accessibility and affordability.

> The NTS states that "*our strategic networks are particularly important for connecting our cities, connecting our towns with cities, and bringing people and goods to those cities. They are also critical for providing key routes into our wider regions, including the Highlands and Islands, to our regeneration areas, to England, and to global markets to contribute to the accessibility of Scotland as a whole*."

Any operational arrangement for the new crossing must comply with these key requirements.

The requirements of the commission reflect the overarching transport policies of the government and are detailed below:

- facilitation of economic growth;
- promotion of accessibility;
- promotion of choice and rising awareness of the need for change;
- promotion of modal shift;
- enhancement of the environment and promotion of cleaner fuels and vehicles;
- management of demand; and
- promotion of road safety.

A key operational consideration for a twin crossing of the Forth is whether or not to operate the crossings in a one-way or two-way system. The following considerations are compared between one-way and two-way operations:

- traffic flow: at present the majority of vehicles crossing the Forth are heading for destinations in the greater Edinburgh area. Under two-way operations the potential for congestion at peak periods would be less, as there is more flexibility to divert traffic from one crossing to another during busy periods or if an incident occurs.

- lane / carriageway closure: under one-way operations an incident could close either part or the whole crossing. A two-way arrangement allows greater flexibility during abnormal conditions or maintenance conditions;

- public transport / LRT: most southbound public transport routes will be heading towards the greater Edinburgh area, one-way operation of a twin crossing strategy may better serve public transport. However, this is very much dependent on whether northbound routes would be diverted excessively from their existing routes; and

- high winds: severe wind impact on Wind Susceptible Vehicles (WSV's) on average 150 hours per year; assuming that the new crossing would be wind-shielded, only two-way operation would improve the level of service during high winds.

In most cases, a two-way strategy better serves the requirement of the network and as such one-way operations have not been considered further.

Based on the constraints detailed in the previous section, a number of operational arrangements have been eliminated from the assessment.

Appraisal has only been undertaken for corridors that progressed from the Stage 1 STAG appraisal for further development.

The option of low emission "green" vehicles has not been considered further at this stage until an assessment can be made on the enforceability of controlling such vehicles. The experience of the London congestion charging scheme will be monitored and the potential to include low emission vehicles within HOV or Bus lanes will be considered at a future date.

The provision of four lanes of traffic in each direction (two for general traffic; two for bus/HOV's) is considered sufficient to accommodate all future requirements for cross Forth vehicle traffic. Therefore, operational arrangements containing hard shoulder running or tidal flow systems have not been considered further at this stage of the commission.

However, it should be noted that the hardshoulder width assumed within the cross section presented in Figure 4.3, whilst appropriate for Urban 50 mile per hour design standards, would not allow for the operation of hard shoulder running. A further 0.55 metres would be required.

All eliminated options have been greyed out within Table F.1 to Table F.8 in Appendix F.

The remaining options have been advanced for further consideration against the proposed alignments from the Part 1 STAG appraisal; these options are detailed in Table F.9 and Table F.10 (Appendix F).

6.4 ALIGNMENT OPTIONS

Four crossing options were carried forward from the Part 1STAG appraisal. These were:

- Tunnel – Corridor C
- Bridge – Corridor D
- Tunnel – Corridor D
- Tunnel – Corridor E

The key considerations associated with each are discussed below.

Corridor C Tunnel

The location of the alignment of this corridor does not provide an attractive option for public transport heading to / from Edinburgh City Centre to Fife when acting as a replacement crossing. Provision of a public transport lane on a replacement crossing is likely to increase the journey time of public transport heading to / from Edinburgh City Centre As a consequence public transport provision would need to be focussed on the FRB in the twin crossing strategy.

Vehicle restrictions on the existing crossing could result in additional distance and time travelled by traffic from the local communities north and south of the existing bridgehead.

The new crossing would benefit strategic traffic as it provides good connections through its links to the existing motorway network. Pedestrians and cyclists would not be able to use the tunnel, for safety reasons. Therefore, provision would need to be maintained for both pedestrians and cyclists on the existing crossing under a twin crossing strategy. Management of traffic during abnormal conditions would be achieved with strategically located VMS.

Maintenance of the existing bridge will have a significant impact on network operations under a twin crossing strategy. During any periods of maintenance of the existing bridge, usage of public transport services could suffer, unless temporary operation measures are introduced to maintain public transport priority.

Corridor D Bridge

The Corridor D Bridge option is able to serve better existing public transport when compared to the other three options. Having taken the decision to provide pedestrian and cycle facilities on the replacement bridge, there is the flexibility of both crossings having this facility. However, with the wind barriers provided on the new crossing, safety considerations may dictate that the cyclists and pedestrians use the new crossing.

High wind protection on the new crossing would suggest that all HGVs should be segregated onto the new crossing – this would also have potential benefit for prolonging the life span of the existing bridge.

Vehicle restrictions on the existing crossing would have little impact on the distance and time travelled by traffic from the local communities north / south of the bridgehead.

The management of traffic during abnormal conditions would be achieved with strategically located VMS. The proximity of the two crossings to each other would mean that any delays associated with switching crossings would be minimised.

The bridge option is the only feasible way of combining LRT and road traffic in a single structure (in the tunnel options a completely separate bore would be required). This corridor offers the best potential arrangement for operational flexibility (depending on possible introduction of LRT on the new crossing or a bus lane on the existing bridge). LRT would be located within the central lanes of the new bridge. This would, however, result in a difficult alignment at the start / end separation between road / LRT (assuming a rail based system – e.g. tram).

Corridor D Tunnel

Provision of a public transport lane on a replacement crossing is likely to increase the journey time of public transport heading to and from Edinburgh City Centre from Fife. This is a consequence of the location of the tunnel portal in relation to existing public transport routes). However, the alignment of Tunnel D is better equipped to service public transport in comparison with Tunnel C.

New crossing would benefit strategic traffic as it has good connections with existing motorway network. However, any vehicle restrictions on the existing crossing could result in additional distance / time travelled by traffic from the local communities north / south of the bridgehead.

The management of traffic during abnormal conditions would be achieved with strategically located VMS. The maintenance of the existing bridge would have a significant impact on network operations under a twin crossing strategy. During any such period of maintenance, public transport usage could suffer, unless temporary operation measures are introduce to maintain public transport priority.

Corridor E Tunnel

The alignment of the tunnel in Corridor E is the best of the four for public transport services between Central Fife and Edinburgh. However, it may lengthen journey times for services currently operating in the northern bridgehead due the portal location (which is some distance from existing crossing).

Any vehicle restrictions on the existing crossing could result in additional distance / time travelled by traffic from the local communities north / south of the bridgehead.

The location of the existing park and ride facility at Ferry Toll would have to be reviewed.

The new crossing would benefit strategic traffic as it would provide good connections to the existing motorway network. The management of traffic during abnormal conditions would be achieved with strategically located VMS.

As with the other tunnel options the maintenance of the existing bridge would have a significant impact on network operations under a twin crossing strategy. During any such period, public transport usage could suffer, unless temporary operation measures are introduce to maintain public transport priority.

The above route alignments are assessed with the preferred operational arrangements in Tables F.9 and F.10 of Appendix F.

6.5 RECOMMENDED OPERATIONAL ARRANGEMENT

It is apparent that certain crossing options would deliver greater improvements to public transport and encouraging more sustainable travel modes such as HOV.

Similarly other alignment options would cause a greater benefit or detriment to non sustainable travel modes. Table F.11 in Appendix F provides an assessment of the operational arrangement with each of the proposed crossing options. A summary of the most promising remaining operational arrangements is contained below in Table 6.1. For clarity the second column in Table 6.1 contains the original designation of the operational strategy tested and reported in Table F.11 in Appendix F. The reference to “2.3 and 2.4” in Table 6.1 denotes that this arrangement was evaluated with and without rail based LRT included.

Table 6.1: Summary of the Operational Options for each Corridor

Summary Evaluation Designation	Operational Option Designation used Table F.11	Description of Operation		
		Crossing	Lane 1	Lane 2
OP 1	2.3 (C)	New	Any Vehicle	Any Vehicle
	2.4 (C)	Existing	Bus/HOV	Bus/HOV
OP 2	2.3 (E)	New	Bus	Any Vehicle
	2.4 (E)	Existing	HOV	Non- HGV
OP 3	2.3 (S)	New	Bus/HOV	Any Vehicle
	2.4 (S)	Existing	Bus/HOV	Any Vehicle
OP 4	2.3 (Z)	New	Any Vehicle	HOV
	2.4 (Z)	Existing	Bus	Non- HGV
OP 5	2.3 (AA)	New	Bus/HOV	Any Vehicle
	2.4 (AA)	Existing	Bus/HOV	Non HGV

From the five arrangements carried forward to the final assessment, Option OP1 is considered as the most attractive operational arrangement for a twin crossing strategy. This has two lanes for any traffic and the existing bridge carrying separate HOV and Bus Lanes in each direction. The major disadvantage to this arrangement is that SOV and HGVs from local communities or vehicles wishing to access or return from the area within the A720 boundary would have an increased travel distance and likely journey time. Further, abnormal conditions may cause HGV traffic to cross on the existing crossing. The disadvantage to these vehicles would have to be compared against the benefits for both HOV and Bus usage.

A secondary operational arrangement would be the Option OP3 operational arrangement for all of the proposed alignments. This arrangement has the same operational arrangement on both crossings, with one lane for any vehicle and one for bus plus HOV. The main disadvantage with this arrangement is that it is unlikely that the bus plus HOV lane on the new crossing would yield significant benefits for three of the options. However, for Tunnel alignment E, there is potential that this option may be the optimum arrangement as this offers potentially the best tie-in arrangements with a proposed HOV lane on the southbound M90 (details of which are contained in Chapter 7). The performance of this lane would greatly depend on the uptake of the HOV lane and the number of bus services out of Edinburgh City Centre.

Consideration was given to the inclusion of rail based LRT within the tunnel options. However, this was rejected as it is not possible to combine rail based modes with road traffic within the same tunnel bore. As a result if a separate tunnel bore is required, then it is possible that the currently proposed road tunnel alignments may not in fact be best suited to the operational requirements of a rail based LRT system.

There are difficulties in capacity terms, of combining a rail based LRT system with road base traffic, on a D2M cross section on Corridor D Bridge. This has precluded this arrangement for any serious consideration. Therefore, the preferred operational arrangement has been combined with a LRT system on a D3M cross section (where the third lane is exclusively for the LRT operations).

An additional operational arrangement was considered for Option OP3, with the introduction of a Light Rail Transit system across the Corridor D Bridge. Under Option OP3, three lanes of public transport would be provided (two bus lanes plus one LRT). Such arrangements could not be justified based on the volume of trips using public transport, and as such, have not been considered further.

Therefore, the most attractive arrangement for Corridor D Bridge including rail-based LRT would be Option OP1, with two lanes for any traffic and a centrally located LRT system on the new crossing with separate Bus and HOV lanes on the existing bridge. Again, the major disadvantage of this arrangement is that SOV and HGVs from local communities wishing to access Edinburgh City Centre would have an increased travel distance and likely journey time. Further, abnormal conditions may cause HGV traffic to require to cross on the existing crossing. The disadvantage to these vehicles would have to be compared against the benefits for HOV, Bus and LRT usage.

6.6 OPERATIONAL CONSIDERATION UNDER ABNORMAL CONDITIONS

The main incidents impacting on the operation of the current crossing are:

- high winds;
- vehicle breakdowns;
- accidents; and
- maintenance.

The provision of a new crossing would not eliminate these operational constraints. However, certain forms of construction and operational arrangements would lessen their impact.

It is clear that any new operational arrangement must allow flexibility during abnormal conditions to ensure efficient and safe operation of the network.

The following operational arrangements are considered under the same abnormal conditions in Table 6.2 below:

Table 6.2: Summary of the Lane Arrangements for each proposed Operational Option

Option Designation	Description of Operation		
	Crossing	Lane 1	Lane 2
OP 1	New	Any Vehicle	Any Vehicle
	Existing	Bus/HOV	Bus/HOV
OP 3	New	Bus/HOV	Any Vehicle
	Existing	Bus/HOV	Any Vehicle
OP 1 with LRT	New	Any Vehicle	Any Vehicle and LRT
	Existing	Bus/HOV	Bus/HOV

For the consideration of network operations under abnormal conditions the provision or non-provision of a rail-based LRT system has no bearing on the operational consideration of the crossing, (however, the presence of LRT may assist in diverting a number of trips onto the LRT during abnormal conditions). It is, therefore, not necessary to consider Option OP1 with LRT under abnormal conditions separately.

Option OP1: This operational arrangement has the new crossing open to any traffic, with separate lanes on the existing crossing for Bus and HOV. Due to the fact that buses/HOV's are restricted to the existing bridge, additional traffic management would be required during abnormal conditions.

The following traffic management arrangement would be in place during abnormal conditions:

- carriageway closure (incident / maintenance): All traffic would divert across the alternative crossing;
- If the closure occurred on the new crossing, the restriction on the existing bridge may be removed during the closure (and possibly only for light vehicles) this could be done using active traffic management (see Chapter 7 for details);
- if the closure was on the existing bridge bus and HOV traffic would divert onto the new crossing. During planned maintenance it may be possible to convert one of the lanes on the new crossing to Bus and HOV;
- lane closure (breakdown / accident);
- If the lane closure was on the existing crossing the Bus and HOV lane would combine operations onto one lane, which should minimise the impact of the incident;
- if the lane closure was on the new crossing the operation would reduce to one lane for any traffic, based on current traffic level there would be a potential for significant congestion if the incident occurs during peak periods; and
- Full Bridge Closure (High Wind): It has been assumed that the new crossing would be provided with wind shielding or be a tunnel and as such would not be affected by high wind events. Therefore, Wind Susceptible Vehicles (WSV's) on the existing crossing would be diverted over the new crossing.

Option OP3: This operational arranagement has the same management of traffic on both crossings, with one lane for any vehicle and one lane for bus plus HOV in both directions. Due to this replication of the traffic operations, it would require less traffic management to divert the traffic between the crossings during abnormal conditions. This could be done using active traffic management (see Chapter 7 for details).

The following traffic management arrangements would apply during abnormal conditions:

- carriageway closure (incident / maintenance): All traffic would divert across the other crossing. The lane allocation would remain the same during the diversion, ensuring that public transport and HOV traffic maintain a level of priority during the abnormal conditions;

- lane closure (breakdown / accident): Depending on the location of the lane closure, any restrictions would need to be immediately removed from the crossing with the lane closure. If required, lane restrictions on the other crossing which is not closed may need to be lifted for the duration of the incident; and

- bridge closure (high wind): It has been assumed that the new crossing would have a form of wind shielding or be a tunnel and as such would be not be affected by high wind events. Therefore, WSV's on the existing crossing would be diverted over the new crossing. The existing bridge would remain open for cars

Both of these operational arrangements offer sufficient flexibility to deal with any operational difficulties during abnormal conditions.

The current management and control system run by Traffic Scotland and FETA would be able to divert traffic using existing Variable Message Signs and Lane Control Signals (LCS) on the approaches to the bridge. However, it is anticipated that additional Traffic Scotland infrastructure would be required to ensure safe and effective traffic control.

6.7 CONCLUSIONS

Based on the assessment of 160 different operational arrangements the following two options have been recommended:

- **Option OP1:**
  New crossing: Two lanes for any vehicles.
  Existing Crossing: One bus lane and one HOV lane.

- **Option OP3:**
  New Crossing: One lane for any vehicle and one lane for Bus + HOV.
  Existing: One lane for any vehicles and one lane for Bus + HOV.

If LRT was to be considered as part of a new crossing (bridge option only), them the recommended operational arrangement would be:

- **Option OP1 with LRT:**
  New crossing: Two lanes for any vehicles with LRT down the centre lanes.
  Existing Crossing: One bus lane and one HOV lane.

The final recommended operational arrangement can be confirmed after more detailed assessment of all of the above options.

7 Assessment of Complementary Measures

7.1 INTRODUCTION

Complementary measures are those schemes which, whilst considered alone would be unlikely to 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 supporting element of the overall strategy they could be introduced as early, quick win, stand alone packages in advance of a replacement crossing.

These measures can, therefore, be considered as having a role to play at three different times in the future:

- In advance of the construction of a replacement crossing;
- As part of the replacement crossing strategy; and
- As part of a twin crossing strategy if the existing FRB was to be refurbished and brought back into use.

It is envisaged that the future operational control of both a replacement crossing and possible refurbished existing crossing would use the latest electronic traffic detection and management technology. This would provide the flexibility necessary to optimise the use of the roadspace available for all road users, while offering the opportunities to respond to incidents rapidly and hence reducing any resulting congestion from the build-up of traffic. Examples of these incidents include:

- a broken down vehicle or road accident;
- emergency or planned maintenance; and
- abnormal or slow moving vehicles.

A number of the possible proposals listed below are currently being considered as part of other separate on-going studies (i.e. M90 HOV lane proposals; Cross-Forth Ferry proposals). Where possible use has been made of existing information to further develop these into a comprehensive package supporting the FRCS objectives.

After summarising each of the possible complementary measures, this chapter assesses their performance against the study objectives, considers their operation and ease of implementation. The final assessment would also consider the proposed cost of introducing the scheme.

7.2 COMPLEMENTARY TRANSPORT MEASURES

7.2.1 High Occupancy Vehicle (HOV) Lane - (Southbound M90)

At present there are only three examples of HOV lanes in use in the UK, none of which operate on motorways. However, plans for two motorway pilot schemes are currently underway for HOV lanes on the M1 in Bedfordshire and at the junction of the M606/M62 south of Bradford, West Yorkshire. The introduction of HOV lanes is currently being investigated by Fife Council on behalf of SEStran who have been studying two options to implement HOV lanes on the southbound approach to the FRB. One option involved creating a HOV lane in the offside lane of the M90/A90 and the second uses the nearside lane on the same route. The second option is currently favoured by Fife Council and involves the use of signal controls on the main carriageway and slip roads to allow HOV traffic priority over other vehicles. The scheme primarily involves the use of the hardshoulder for HOV running with some localised additional carriageway widening. The current estimated cost of introducing the nearside lane option is £12.8 million.

The purpose of these lanes would be to encourage drivers to share cars for journeys across the Forth, thereby reducing the number of single occupant vehicles on cross Forth routes. 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 access to the HOV lanes leading to the existing bridge or replacement crossing and, potentially, across the crossings. This would allow them to avoid the queues on the approaches to these crossings in the same manner that bus lanes permit easier access through congested areas.

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.

In a situation where the existing road bridge is refurbished and brought back into use, it may be possible that one of the two lanes in each direction would become a HOV lane. Even if the existing bridge closed completely (or temporarily for refurbishment), once the new crossing was complete, the use of HOV lanes would more than likely be continued across any new crossing to encourage a reduction in SOV trips as part of the overall management of that crossing.

There is significant existing research available from around the world on the use of HOV lanes and in particular from the USA where there are over 2,500 miles[14] of operational HOV lanes currently in use. Some of the most important points noted from this research about the successful operation of HOV lanes are as follows:

[14] National Audit Office, Tackling Congestion by Making Better Use of England's Motorway's and Trunk Roads, November 2004.

- HOV lanes are superior to all vehicle General Purpose (GP) lanes only if there is a substantial travel time differential between the HOV lane and GP lane and only if the HOV lane is well utilised, which requires both a high proportion of HOV's and a high volume of (general) traffic[15];

- To avoid confusion, drivers need to be fully informed of how the scheme operates and during what periods of the day regulations are in place. Without the proper pre-scheme information campaign and post-opening enforcement any new HOV scheme is likely to be unsuccessful in its early stages[16]; and

- Where HOV lanes have been most successful the local/regional authorities have employed associated complementary transport measures such as tolling, ramp metering and other demand management measures[17].

As an example of the effectiveness of HOV lanes, a report by Washington State Department of Transportation states that during peak periods nearly a third of people on Puget Sound Freeways (US equivalent of a motorway) are carried in 17% of vehicles, which are using HOV lanes[18]. More details regarding HOV experience in the US is contained in Appendix G.

Therefore, to maximise the effect of this scheme, it would seem logical to introduce this measure 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 understood that SEStran are now seeking to develop the scheme further in conjunction with Transport Scotland. In the short term, the introduction of a possible HOV lane would be to use the existing D2M standard cross-section with the hard shoulder acting as the HOV lane. However, there are safety concerns regarding the existing proposals for this scheme, which could see the introduction of traffic signal control on the M90 southbound main carriageway to allow HOV's priority during the peak periods. In the longer term possible motorway widening of the M90 could result in a D3M with two general traffic lanes and the outside lane operating as an HOV lane with a conventional hardshoulder for breakdowns/accidents.

[15] The University of California – Transportation Center, High Occupancy Vehicle Lanes – Not Always More Effective Than General Purpose Lanes., May 1997
[16] The University of Virginia – Virginia Transportation Research Council, Traffic Control for High Occupancy Vehicle Facilities in Virginia, January 1998.
[17] Ohio Department of Transportation, High Occupancy Vehicle Alternatives in Ohio – A Summary and Assessment of HOV as a Transportation System Alternative, October 2000.
[18] Washington State, Dept. of Transportation, Freeway HOV System, March 2005.

The proposals for a HOV lane could be introduced in advance of any replacement crossing. However, it would require to be curtailed before the northern bridgehead due to insufficient available space on the existing bridge. The benefits of a HOV lane would be similar if a replacement crossing was introduced as it could possibly use hard shoulder running during peak periods if the new crossing was a bridge. It is noted however, that the cross section illustrated in Figure 4.3 indicates a hardshoulder on the new bridge of 2.75 metres, consistent with 50 miles per hour Urban Standards. Consideration would need to be given to increasing this to at least the standard width of 3.3 metres if the hardshoulder was to be used as a HOV lane.

However, if the replacement crossing was a tunnel the HOV lane would need to be curtailed at the northern bridgehead as there would be insufficient space in the tunnel bore to accommodate a dedicated lane. Finally, as part of a twin crossing strategy, a southbound HOV could be incorporated, allowing a continuous dedicated lane to operate over either one or both crossings.

7.2.2 Bus Priority Extension

Currently, bus priority measures on the eastbound A90 approaching Barnton roundabout from the FRB enable 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 of reducing delays to buses.

In the short term, bus priority measures could be introduced both within the southern bridgehead area and also in Fife. On the south side outbound (or bridge bound) measures could be introduced which would complement the A90 eastbound measures described above. These would help reduce delays to buses heading towards the bridge (and perhaps across it) and would be particularly helpful during the evening peak periods.

Within the Fife (northern) Bridgehead the introduction of a comprehensive bus priority network could be introduced linking the centres of Dunfermline and Rosyth with the M90/A90 corridor. These measures could be based on the existing “Greenways” scheme currently in operation in Edinburgh, supported by a “real-time” public transport information system at major stops along the corridors. These would be aimed at improving reliability and journey times for existing services and would encourage, consolidate and, hopefully, lead to increased bus patronage. The Edinburgh bound services could be integrated with the proposed M90/A90 HOV scheme and would benefit significantly from a dedicated bus lane as part of any new crossing strategy.

In a similar way to the HOV lane described above, bus priority can be introduced prior to any replacement crossing being completed but, like the HOV proposals, is limited by the lack of available capacity on the existing bridge. However, benefits would arise from the implementation of localised schemes on the approaches to the existing bridge. Where the existing bridge is replaced by a new crossing, bus priority could be integrated with the HOV proposals and as part of twin crossing strategy could be continuous across the Firth using either one or both crossings.

In the longer term these measures could be upgraded to accommodate the introduction of a bus based light rapid transit system which could utilise dedicated roadspace available on a refurbished existing bridge.

7.2.3 Park and Choose Sites

Park and Choose Sites are a natural extension of the already well established Park and Ride sites currently operating in the Fife northern bridgehead. Instead of being particularly focussed on providing interchange with a single 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 area, and express services linking population centres.

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 proposed as part of the operating strategy for the new crossing. SEStran's recently launched the website "TripshareSEStran.com" which allows people looking to car share opportunities to find similar people from their local area going to the same destination. This could easily be adapted to offer the trip-sharing opportunities from a Park and Choose location. The big advantage of this approach is that should a car sharer not be able to return with the designated driver they have an alternative mode of travel back to the site via either bus or rail to complete their journey, in their own car.

Park and Choose sites are currently being considered at Halbeath, Rosyth, Inverkeithing, Ferrytoll and Dalgety Bay. The expected modes to be provided at these sites and the necessary improvements required are listed below:

- Halbeath (Bus and possibly Rail Park and Choose) - would need work to develop a completely new site;
- Rosyth (Rail, Bus, Park and Choose) - would need additional parking spaces and improved road access and passenger waiting facilities;
- Inverkeithing (Rail, Bus, Park and Choose) - would need increased car parking and improved access and passenger waiting facilities;
- Ferrytoll (Bus, Park and Choose) - would need more parking spaces; and
- Dalgety Bay (Rail, Bus, Park and Choose) - would need more parking spaces and improved access and passenger waiting facilities.

Finally the introduction of the SEStran "One-ticket" for use on buses and trains in the region is a positive step towards public transport integration and reduces the "friction" by users when interchanging between modes.

Introduction of Park and Choose facilities is likely to be phased over a period of time and would complement the introduction of bus priority measures described above. Park and Choose could be developed prior to any replacement crossing being completed and would integrate easily with a new crossing. As part of a twin crossing strategy the prospect of dedicated HOV/Bus lanes being continuously provided across the Forth would act as an incentive to SOV drivers to switch to another mode for their cross-Forth journey.

7.2.4 Cross Forth Ferry Service (Kirkcaldy to Edinburgh)

A major study of possible cross Forth passenger ferry services is currently being lead by Fife Council. The study is considering the commercial viability of introducing a new cross-Forth ferry service between Kirkcaldy and Edinburgh. It is very likely that any potential ferry service would attract both existing car drivers and passengers using the FRB but also existing bus/rail passengers. An operational constraint on any new service would be the fact that there would be occasions when ferry services would not be able to operate due to prevailing bad weather. Therefore, suitable alternative capacity must exist within the network to accommodate for these situations.

It is anticipated that the introduction of a new cross-Forth ferry service could potentially reduce the number of car trips across the Forth by 1% in 2011 and by about 0.5% in 2026[19]. However, a new ferry service would also certainly attract passengers from both existing bus and rail services. This study is due to report on the viability of a ferry service at the beginning of July 2007[20].

Independent of the current ferry options study, a recent announcement by the Stagecoach Group confirmed that they are to move ahead with a trial of using a passenger hovercraft in summer of 2007. This service is due to operate between Kirkcaldy and Portobello (Edinburgh) with an anticipated cross timing of 20 minutes and an operating speed of 35 knots[21]. The craft proposed for the trial, is a Hoverwork Limited BH130 and is reported to be able to operate in sea conditions of waves up to 2 metres. The craft is similar to one currently operating between Ryde on the Isle of Wight and Southsea. The outcome of the trial is awaited.

A cross-Forth ferry service could be introduced during any stage of a replacement crossing strategy.

[19] Options for a Cross Forth Passenger Service, Halcrow, May 2004
[20] Agenda Item No.9 – Cross Forth Passenger Ferry Service, Fife Council, Central Area Services Committee, 2nd February 2007

[21] On Stage (The Newspaper of the Stagecoach Group), Issue 63, Summer 2006

7.2.5 Active Traffic Management

Active Traffic Management (ATM)[22] as the name suggests this is the "active" or real-time management of traffic on parts of the road network with the aim of reducing congestion and delay to drivers. The Highways Agency began a pilot of this approach in September 2006 on the M42 south of Birmingham.

The scheme uses a mix of variable speed limits and hardshoulder running to reduce the effects of congestion on the motorway. Features of the scheme include; variable message signs (VMS) at 500 metre intervals; improved lighting and traffic speed/incident detection and vehicle refuges (for use when the motorway is operating with the hardshoulder open to traffic).

If there is congestion or an incident, ATM would manage the traffic to ease congestion. Under normal conditions traffic is restricted to the use of the three normal running lanes with the national speed limit in place.

Should traffic start to build-up, ATM without hard shoulder running can be activated to help manage traffic. Controlling traffic across all lanes, with the right speed for the traffic conditions, enables the traffic to flow more smoothly. This reduces the need to accelerate and decelerate during periods of heavy traffic, which, therefore, helps to prevent the break down of flow. This helps to reduce congestion.

The system sets the same speed across the carriageway, which reduces the need for drivers to change lanes.

When necessary, the system also sets messages on the driver information signs to inform road users of the road conditions ahead of them. This helps to protect queuing traffic because drivers are aware of slow moving or stationary traffic ahead.

In the case of severe congestion or an incident on one of the normal running lanes, the hard shoulder may be opened to traffic under controlled conditions. Control of this would be via the use of the overhead gantry signs showing drivers that they are now allowed to use the hard shoulder.

The use of ATM on both a new crossing and the existing bridge and approach roads could help to tackle potential congestion at peak or busy times. The use of the latest VMS signing, coupled with the use of automatic number plate recognition cameras, could also provide drivers with estimated journey times between junctions. This, in turn, would help reduce driver frustration that frequently occurs during busy periods. The system should be flexible enough to respond to incidents and help reduce any resulting congestion. The Highways Agency have quoted the cost of the M42 project at £100 million for the 17 kilometre scheme, this equates to approximately £5.8 million per kilometre (this is for a Dual 3 lane motorway). More details on the operation of the ATM are contained in Appendix G.

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[22] http://www.highways.gov.uk/knowledge/1334.aspx

The introduction of ATM is probably the most technically complex of the road network based proposed complementary measures. However, the introduction of these proposals prior to completion of a new crossing would have to be curtailed before the bridge due the lack of available space on the bridge itself. The control of traffic as part of a replacement crossing could be enhanced with the introduction of ATM on both approaches and the crossing itself. As part of a twin crossing strategy ATM offers potentially significant operational flexibility to the management and operation of twin crossings.

7.2.6 Variable Tolls

The use of variable tolls could have significant benefits for reduction in the number of SOV crossing the bridge, particular during peak periods. The use of a variable tolling strategy for HGV's combined with a management strategy to control HGV numbers could help with some of the short term concerns around the stresses that HGV's are placing on the existing road bridge.

However, it is noted that the recent announcements regarding the future of tolls on the Forth and Tay Road Bridges may mean that this option is no longer available for consideration.

Analysis of the most recent origin-destination survey data of drivers (March 2007) indicates that 83 per cent of cars crossing the Forth in the morning peak period (06:30 – 09:30) were SOV, this equates to approximately 6300 vehicles. The remaining 17 per cent are carrying 2 or more people which equates to nearly 1400 vehicles. The introduction of a tolling strategy aimed at encouraging higher car occupancy could have significant benefits for all road users. Introducing variable tolls, based on car occupancy and time of day, may have additional benefits.

Extensive previous work on variable tolls was done as part of FETA's Local Transport Strategy and as part of the SITCoS study. Both of these outlined the benefits that could be achieved through specific variable tolling of SOV. The FETA proposals included a £4 charge for northbound cars during the peak period between 16:00 and 18:00. The SITCoS report looked at a combined tolling strategy on both the existing bridge and on a proposed new bridge crossing.

Collectively, the outcome of this work was that on its own this form of demand management would be unlikely to succeed in delivering a long term reduction in traffic. However, as part of a managed strategy, using the "carrot and stick" (the carrot being improved public transport links/HOV lanes etc.), this approach was considered to have positive merit.

Although light vehicles make up more than 90 per cent of all bridge traffic, the heaviest HGV's represent about 6 per cent but account for 50 per cent of the total load[23] on the bridge. This, as detailed in Report 1, is having an effect on the rate of deterioration of the main support cables. Therefore, the introduction of a tolling strategy that encourages most of these damaging vehicles not to use the bridge

[23] Page 30, FETA Local Transport Strategy, June 2005

would possibly extend the date at which a total ban maybe needed. The result of this would likely be heavier use of the Kincardine crossing and the M9/A9 corridor to Perth by HGV's. However, this may be a necessary sacrifice to extend the operation of the existing bridge.

By way of a comparison, the FRB has amongst the lowest tolls for HGV's of any major tolled bridge or tunnel in the U.K. The current charge is £2 one-way while an HGV crossing the Severn bridge pays £15.30 and the same HGV crossing the Humber bridge £18.30.

Together, with the introduction of other complementary transport measures, variable tolling could play an important part in discouraging the number of SOV trips across the Forth. While the introduction of higher HGV tolls in the short term could help put off any decision to completely close the existing crossing to HGV's.

Variable tolling would be straightforward to introduce in operational terms prior to a new crossing being opened and could easily be continued on a replacement crossing. As part of twin crossing strategy variable tolling combined with the potential for HOV/bus only lanes would offer significant incentives to SOV drivers.

7.2.7 Personalised Travel Planning

Personalised travel planning is a technique in which information is provided to individuals or households aimed at enabling them to choose a different pattern of travel behaviour. The objective is to bring benefits to the individual, as well as reducing car use and/or increasing the use of more sustainable transport modes. These approaches have developed from commercial marketing techniques aimed at increasing public transport use, and raising community understanding or awareness of environmental aspects of transport. This technique is very applicable to this study as most car drivers of SOV using the existing FRB in peak periods are commuters and are, therefore, a fairly stable market to target.

The largest personalised travel planning programme was implemented in South Perth, Australia[24]. Covering over 15,000 households, the impact of the programme was to reduce car driver trips by 14 per cent, a level that has continued after the initial launch. A shift of greater than 10 per cent has also been achieved in many other programmes, including in Germany and Sweden. In the UK, a number of smaller projects of have resulted in a reduction in car driver trips ranging from 5 to 16 per cent. There a number of large scale programmes currently being developed in Worcester, Darlington and Peterborough, as part of the Department for Transport (DfT) - Sustainable Cities initiative.

The "Smarter Travel" research[25] for the DfT concluded that personalised travel planning projects can reduce car use by between 7 and 15 per cent in urban areas and between 2 and 6 per cent in rural and smaller urban areas, with the cost for

[24] http://www.dpi.wa.gov.au/travelsmart/15002.asp

25 http://www.dft.gov.uk/pgr/sustainable/smarterchoices/

large-scale implementation likely to be less than £20 per head. Around 80 per cent of FRB drivers[26] in the morning peak southbound are regular travellers (i.e. they travel more than 4 or more days a week across the Forth) this produces a relatively captive market with several potential options (car-sharing, bus & rail). Using the DfT guidelines, the introduction of targeted personalised travel planning for car based commuters, could have the potential to reduce car trips by between 7 and 15 per cent.

Research suggests that most of the benefits arising from the initial capital investment are retained over the years after implementation, but some continuing (revenue) expenditure would probably be required to maintain the impetus. For bus services, Personalised Travel Planning on a successful route may be commercially sustainable.

7.2.8 Maximise Use of Cross Forth Rail Capacity

It was previously identified in Report 1 that within the peak morning period there were certain rail services which were currently over-capacity (i.e. passengers were unable to find a seat) for the duration of their journey. This was noticeable in services arriving at Edinburgh Waverley between 8:00 and 8:30 am. The existing pattern of cross Forth services tends to create a "honey pot" effect at Inverkeithing where rail passengers drive to this station as service patterns are better, rather than actually going to their nearest railway station. However, evidence from the recently opened new car park at Dunfermline would suggest that it is possible to attract passengers to other stations.

The opening of the Stirling – Alloa – Kincardine railway line would see the diversion of coal trains currently using the Forth Bridge to deliver coal to Longannet power station. As a result, an additional peak hour passenger service would be able to operate. Of all the complementary measures proposed in this chapter, rail use is currently well established and is suitably placed to respond to changes in future demand. Some of these changes are currently programmed with other proposals still being developed.

The SEStran Integrated Transport Corridor Study (SITCoS) examined the potential for providing additional rail capacity on cross Forth rail routes:

- additional capacity could be provided through the provision of longer trains (all trains are assumed to be formed by six-car sets) together with associated platform lengthening. It should be noted that all Fife stations requiring six car platforms now have them;
- an additional two trains to Edinburgh 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;

[26] Data from Forth Road Bridge – Origin Destination Survey on the 20th March 2007.

- The work currently underway at Edinburgh Waverley will permit the operation of more six car trains from the revised platform arrangements;

- a further 1100 seats are to be introduced into the Fife morning peak services by December 2008. Additional parking spaces have recently been added at Kirkcaldy and work is underway to add additional capacity at Markinch and Rosyth; and

- Longer term, 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 £10 million for platform extensions and around £100,000 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. These proposed costs would be somewhat off-set by increases in fare revenue as a result of increased rail patronage on Fife services. Selective door opening may be a more practical option for some of the lesser used stations where platform lengthening may not be cost effective. It should be noted that those stations served by GNER services already have nine car platforms.

In the longer term, electrification of the route would improve train performance through enhanced train characteristics i.e. the better acceleration performance associated with electric train units. Although, technically challenging it would be possible for the Forth Bridge to be electrified at some stage in the future. However, there are a number of constraints with regard to clearances on the existing bridge structure that would have to be overcome to accommodate the necessary overhead wires and supporting steelwork.

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 (current line speed is 55mph) could be achieved over much of the route for less than £10 million. 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 would aid the competitive position of rail as a mode, particularly from north Fife.

Network Rail currently have 2 signal upgrades proposed. Phase 1 in 2008 will improve performance and Phase 2 in 2010 will increase capacity.

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 would be able to be designed that would increase the capacity of the railway network as a whole and the Forth Bridge route would be no exception.

Currently, new signalling systems 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.

Heavy rail has a clear role to play in any future cross Forth Transport Strategy, particularly for those travelling to central Edinburgh destinations. If the Edinburgh Airport Rail Link is built this in turn offers opportunities for passenger from Fife and the northeast to interchange with services to Glasgow without having to travel Haymarket station. It is noted that this project is currently under review.

It is clear that heavy rail has a key role to play in all stages of the emerging Forth Crossing strategy.

7.2.9 Introduce Light Rapid Transit onto the Replacement Crossing

The introduction of enhanced public transport provision, in the form of Light Rapid Transit, on the replacement crossing has been considered as part of this study. Light Rapid Transit encompasses the full range of options from buses, bus rapid transit or light rail. All can be included within the cross section of the proposed bridge or tunnel with the exception of Light Rail.

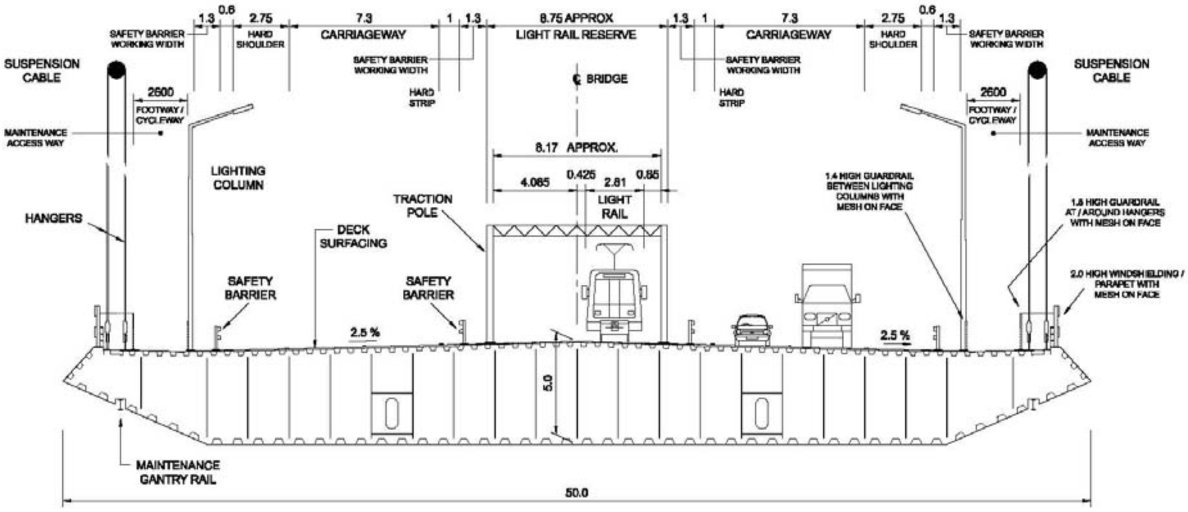
Within a tunnel it is not permitted to combine road and any form of rail based transport in a single bore. Accommodation of modes such as Light Rail would require a third tunnel bore. The additional cost of a third bore to provide a Light Rail capability is unlikely to be justified now or in the near future.

However, it would be possible to accommodate Light Rail on the bridge crossing and a cross section has been developed. It is considered that the most effective method of accommodating light rail on the bridge would be a single deck with light rail at the centre. The resulting overall deck width would be approximately 50 metres and the resultant cross section is shown in Figure 7.1. When compared with the cross section shown in Figure 4.3 it is clear that the inclusion of Light Rail has increased the overall width by 10 metres.

The additional cost for widening (and strengthening) a replacement bridge to accommodate Light Rail has been estimated as between £200 and £260 million in 2006 Quarter 4 prices. This figure includes Optimism Bias and other allowances as summarised in Section 5.10. This is just the additional structural costs and does not include for any of the infrastructure required to operate Light Rail. The sum simply enables the replacement crossing to be "future proofed" for the possible future introduction of Light Rail.

It should be noted that this cross section illustrates only one possible option for the provision of light rapid transit on the new crossing and does not imply any commitment by Transport Scotland to such a proposal.

Figure 7.1: Deck Cross Section for Dual 2 Motorway Standard plus Light Rail



7.3 ASSESSMENT OF COMPLEMENTARY MEASURES

Assessment of the complementary measures has been undertaken to assess the effectiveness of the proposed measures against the study objectives and these have been included in Table 7.1 below. Each measure has been assessed based on it is likely performance and for ease of implementation.

The results produced have been based on careful assessment of the each proposed scheme, using the available information. 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.

Table 7.1: Complementary Measures - Summary of Assessment

Objective / Complementary Measure	HOV Lane	Bus Priority	Park & Choose	Maximise use of Cross Forth Rail	Kirkcaldy – Leith Ferry	Active Traffic Management	Variable Tolls	Personalised Travel Planning	Light Rapid Transit
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	✓✓	✓✓	✓✓✓	✓✓	o	✓✓	o	✓✓	✓✓
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	o	✓✓	✓✓	✓✓	✓	✓	✓✓✓	✓✓✓	✓✓✓
Improve accessibility and social inclusion	✓	✓✓	✓✓	✓✓	✓	o	✓	✓✓✓	✓✓✓
Minimise the impacts of maintenance on the effective operation of the transport network	✓✓	o	✓	o	×	✓✓	o	o	o
Minimise the impact on people, the natural and cultural heritage of the Forth area	o	✓	✓	✓✓	o	✓	o	✓✓	✓✓
Support sustainable development and economic growth	o	✓✓	✓✓	✓✓	o	✓	✓	✓✓✓	✓✓
Overall Performance	✓	✓✓	✓✓	✓✓	o	✓	✓	✓✓	✓✓
Ease of Implementation	✓✓	✓✓	✓✓	✓✓	✓	✓	×××	✓✓✓	××

Key	
✓✓✓	Very Positive Support
✓✓	Moderate Positive Support
✓	Positive Support
o	Neutral
×	Negative Support
××	Moderate Negative Support
×××	Very Negative Support

The easiest and potentially most beneficial measure to introduce at an early stage in any overall Forth Crossing strategy is the use of a specific and targeted personnel travel planning scheme. The cost/impact of such a campaign could provide significant dividends to peak period traffic flows. This scheme also accords well with the recently published SEStran, Regional Transport Strategy which places a (High/Medium) priority on the implementation of a region-wide scheme[27].

All of the other possible complementary measures would require the construction of new infrastructure in some shape or form and would require longer lead in times for implementation. However, their successful implementation would significantly improve public transport service reliability and hopefully reduce single occupancy car journeys across the Forth.

Finally, Table 7.2 below outlines the current best estimate of the cost of each proposed measure.

Table 7.2: Complementary Measures - Summary of Costs

Complementary Measure	Proposed Total Costs (Millions)
High Occupancy Vehicle Lane – A90/M90[28]	£13
Bus Priority	
- A90 northbound bus priority[29]	£4
- “Bus Right of Way” Network Fife[29]	£6
Park & Choose	
- New sites at Halbeath & Rosyth[29]	£7
- Expanded Inverkeithing & Dalgety Bay[29]	£5
- Ferry Toll[29]	£9
Maximise use of Cross Forth Rail	
- Further Capacity Enhancements[29]	approx. £10
- Upgrade of track between Thornton to Inverkeithing[29]	approx. £10
Kirkcaldy to Edinburgh Ferry Service[30]	£16
Active Traffic Management (Halbeath Jnc.3 to Jnc. 1)[31]	approx. £40
Personalised Travel Planning	< £1

[27] SEStran - Regional Transport Strategy 2008 -2023, March 2007
[28] Fife Council – Presentation on HOV Proposals – December 2006
[29] SITCoS Report, June 2005
[30] Options for a Cross Forth Passenger Service, Halcrow, May 2004
[31] http://www.highways.gov.uk/knowledge/1334.aspx

7.4 CONCLUSIONS

Based on the assessment and implementability of the proposed complementary measures it recommended that the following measures are implemented:

- Personalised Travel Planning Scheme
- Maximise use of Cross Forth Rail
- Bus Priority Extension
- Park and Choose Sites
- HOV lanes
- Active Traffic Management

These initiatives would provide quick win benefits and would help to reduce traffic demand on the existing FRB. In addition, they would have a clear role to play in any future replacement crossing strategy.

8 Summary and Conclusions

8.1 SUMMARY AND CONCLUSIONS

8.1.1 Introduction

The objective of this report has been to present the appraisal of the proposals against the established project-specific objectives, implementability criteria, and the Government's transport criteria covering environment, safety, the economy, integration, and social inclusion and accessibility, in line with Scottish Transport Appraisal Guidance (STAG).

The report has assessed proposals for a replacement crossing for the existing FRB if one is required. The possible need for a replacement is due to the lack of certainty that the existing bridge is going to be available in the future. Also recent reports from the FETA would suggest that the refurbishment of the existing crossing would have severe impacts on traffic flows across the bridge for a period of between 3 to 4 years.

The level of repair/refurbishment carried out on the FRB would be determined by the role that is ultimately intended for that crossing and the level of investment required to support that role. For example, if the FRB is intended only for use by light vehicles in future then there may be no requirement to replace the main suspension cables. A decision can also be taken on whether the deck should be replaced thereby removing the need for expensive painting and strengthening of the existing deck structure.

The key point is that once the replacement crossing is open there is flexibility and time to decide how best to refurbish and operate the FRB.

The FRCS is, therefore, primarily concerned with determining the form, function and location for the replacement crossing. Further development of the emerging options for a replacement crossing would be required to determine the role that the existing FRB should play once refurbished. However, this is dependent upon the level of investment that is required to achieve a number of different possible outcomes. A final decision may therefore, have to be left until further information is forthcoming from, amongst others, the FETA Cable Replacement Study.

However, if the FRB was to be refurbished and re-opened then consideration would have to be given to how it could be used in combination with the replacement crossing. This report considers how an operational strategy could be developed. The guiding principle of the operation of this combination would be that there should be no more than two lanes available for general traffic in each direction. Additional capacity should be reserved for sustainable modes such as public transport or HOV.

The report also considers how an operational strategy could be developed in relation to using any new crossing alongside the FRB. An assessment of the complementary measures has been made. These could be implemented prior to a replacement crossing being constructed and as part of a new crossing. These measures are also considered in the context of a twin crossing strategy in the event that the refurbished existing FRB is brought back into commission.

8.1.2 Pre – Appraisal

Pre-appraisal studies provided a review of previous work undertaken within the commission covering the analysis of problems and opportunities (Report 1), the setting of objectives (Report 2), and provides the key outcomes from the option generation and sifting process (Report 3).

The review of existing and future network conditions found that there would be a requirement for increased maintenance on the FRB in the future regardless of the problems associated with the cables. This maintenance cannot be undertaken without temporary traffic management measures being implemented which would restrict the capacity of the crossing. It is also envisaged that due to the type of maintenance works expected to be undertaken on the FRB in the future it would not be possible to limit these traffic management restrictions to weekends or overnight as is currently the case. The forecast increases in daily traffic crossing the Firth of Forth would lead to a spreading of the peak periods and exacerbate the high levels of congestion experienced during restrictions or closures on the Bridge.

A number of environmental constraints were also identified. Study work has found a wide variety of designations, some of which pose more of a constraint on any proposed crossing than others. In the Firth of Forth the Natura 2000 sites comprising the Firth of Forth SPA (which is also a Ramsar site), the Forth Islands SPA and the River Teith SAC represent the highest level of designation, being international designations, and these would strongly influence any replacement crossing. Other designations such as Scheduled Ancient Monuments and Ancient Woodland that are of a national or local significance would also strongly influence any crossing options.

High level expectations for transport network performance on, and in the vicinity of, the Forth Road and Rail Bridges were subsequently defined. These expectations have been used to derive strategic transport planning objectives 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.

Option Generation, Sifting and Development of Options.

A long list of 65 potential options was generated and this 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. Following this process, the approach adopted was to consider the crossing location and whether bridges and/or tunnels would be feasible solutions in following the 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 was been assessed for its suitability for a tunnel or bridge crossing. The work undertaken confirmed that Corridors A and B did not meet the objectives of the study and were therefore, rejected. It was concluded that these corridors would not be considered further within the study.

Corridors C, D and E did, however, perform well to varying degrees against the objectives and these were taken forward to the STAG Part 1 Appraisal, with bridge and tunnel options considered for all three corridors.

8.1.3 STAG Part 1 Appraisal

The STAG Part 1 appraisal was undertaken on the basis of the initial alignments developed for Report 3 – Option Generation and Sifting.

The majority of the planning objectives were met by each of the proposals, although it is evident that the degree to which they are met varies across corridors and crossing types.

At this stage the critical issue which emerged relates to the Environment objective and the planning objective to minimise the impact on people, the natural and cultural heritage of the Forth area. The bridge proposals in Corridors C and E performed particularly badly in this regard as both the northern and southern landfalls cross, or come very close to, the Forth SPA which may lead to loss of SPA habitat. Both were considered to have major adverse impacts on a European designated site and are unlikely to be permitted when viable alternatives exist that have less or no adverse impact. The bridge in Corridor D was considered to avoid this impact.

STAG indicates that any proposal which fails to meet the Part 1 appraisal test should be rejected. In this case, given the importance of the SPA and the likely impact which these bridge proposals would have on it, it was considered that the bridge proposals in Corridors C and E should be set aside and not carried forward to the STAG Part 2 appraisal.

The outcome of the STAG Part 1 Appraisal was that the following proposals were taken forward for further development:

- Corridor C – tunnel;
- Corridor D – bridge;
- Corridor D – tunnel; and
- Corridor E – tunnel.

Corridor Proposals

This covers the design detail and construction methodology of each of the four remaining proposed crossings. Also, included for each option is a summary of the network connections required to connect the new crossing to the existing road network. Attention has been placed on developing technically and operationally robust and efficient solutions for each option.

The tunnel in Corridor C is 8.5 kilometres in length and would be constructed through a combination of TBM and SCL tunnelling techniques. It is expected to take 7.5 years to construct with the capital cost of construction estimated to be £2.3 billion, including network connections and Optimism Bias at Quarter 4 2006 prices.

There are two types of bridge options suggested for Corridor D. The first is a suspension bridge with 1375 metre main span and a 40 metre wide deck. It is estimated that this would take 6 years to construct and cost £1.7 billion, including network connections and Optimism Bias at Quarter 4 2006 prices.

The second type of bridge considered in Corridor D is a cable stayed bridge with two main spans of 650 metres and a 40 metre wide deck. This would take around 6 months less to construct than the suspension bridge and is estimated to cost £1.5 billion, including network connections and Optimism Bias at Quarter 4 2006 prices.

The tunnel is Corridor D is 7.3 kilometres in length and would also be constructed using a combination of TBM and SCL techniques. It would take 7.5 years to construct and cost £2.2 billion, including network connections and Optimism Bias at Quarter 4 2006 prices.

Finally, the tunnel in Corridor E is also 7.3 kilometres in length and would be constructed using a combination of TBM, SCL and immersed tube techniques. It would take 7.5 years to construct and would cost an estimated £2.4 billion, including network connections and Optimism Bias at Quarter 4 2006 prices.

8.1.4 STAG Part 2 Appraisal

Implementability

There are currently a greater number of technical risks for the three tunnel options. This is due to uncertainties in relation to ground conditions. Corridor E Tunnel also has issues associated with the construction of an immersed tube tunnel. There are fewer technical risks with the Bridge in Corridor D.

Environment

The Environmental Appraisal findings show that environmental impacts for most options would generally be similar, typically minor to moderate adverse. However, the main exception to this are impacts on biodiversity where Tunnel E and Bridge D options may have Major to Moderate adverse impacts.

For Corridor E Tunnel this is due to the proposed immersed tube that would disturb sediments and may impact on the Firth of Forth SPA and Forth Islands SPA, which are protected at the European level, as well as other European protected species such as cetaceans. In addition, approach roads at the southern end of Corridor E Tunnel pass through the Dundas Castle GDL, which is a national designation.

For Corridor D Bridge there is a significant risk of indirect disturbance to protected species particularly within the Forth Islands SPA but also relating to the Firth of Forth SPA, which may impose significant seasonal constraints during construction, as the Forth Islands SPA protects breeding birds (i.e. spring and summer) whilst the Firth of Forth SPA protects over-wintering birds. In addition, the northern landfall of Corridor D Bridge passes through the St Margaret's Marsh SSSI, protected at national level, and would involve the loss of some areas of ancient woodland.

Safety

Typically the proposals result in marginal reductions for all accident types in all options. Corridor D Tunnel, Corridor E Tunnel and Corridor D Bridge perform similarly, with accident savings valued of around £220 million. Corridor C Tunnel produces benefits at a slightly lower level of approximately £180 million.

No specific security issues have been identified which would differentiate between the options. The majority of issues can be managed through best practice in relation to bridge and tunnel operations.

Transport Economic Efficiency

In all scenarios analysed above the monetised benefits are greater than the costs. Corridor D Bridge produces the most favourable results, with the lower cost of the cable-stayed variant giving the highest NPV and BCR. The most favourable tunnel option is that of Corridor E. This option produces the highest level of monetised benefits, but at a significantly higher level of cost than Corridor D Bridge. This results in an inferior NPV and BCR. The higher level of benefits is thought to arise as a consequence of the proximity of the southern connections with routes into the city of Edinburgh. This could be considered to be undesirable given current regional and local policies.

A summary of the results is given in Table 8.1 below.

Table 8.1: Monetised Summary of Costs and Benefits (£millions, 2002 values and prices)

Corridor Crossing Type	C Tunnel	D Tunnel	D Cable-Stayed Bridge	D Suspension Bridge	E Tunnel
Present Value of Benefits (PVB)	4,655.6	5,303.1	6,026.1	6,026.1	6,317.1
Present Value of Costs (PVC)	-2087.4	-1967.7	-1,397.3	-1,574.9	-2,172.2
Net Present Value (NPV)	2568.2	3,335.3	4,628.8	4,451.1	4,144.9
Benefit to Cost Ratio (BCR)*	2.23	2.70	4.31	3.83	2.91

* ratio, not monetary value

Economic Activity and Location Impact

At the national level, the main positive impacts are to be felt on existing businesses. At the regional level, existing businesses and new businesses are forecast to experience positive impacts. At the local level, all the corridors are anticipated to have positive economic development effects with Corridors C and D tending to favour West Lothian while Corridor E tends to favour north and central Edinburgh.

8.1.5 Integration, Accessibility and Social Inclusion

All options perform similarly in relation to Integration. This also applies to the Accessibility and Social Inclusion criteria. This is particularly the case given that a replacement crossing is being compared against a scenario where the FRB does not operate as it does at present.

8.1.6 Twin Crossing Strategy

This assessment provides an overview of the possible operational arrangements for the proposed new crossing(s) of the Firth of Forth if a twin crossing strategy were to be introduced after the existing FRB was refurbished and brought back into use.

The key objective is to develop an operational arrangement, which complies with the requirements of the study brief, current Transport Scotland policies, complements the proposed alignments and allows flexibility during abnormal conditions.

Based on the assessment of 160 different operational arrangements the following two options are recommended:

- **Option OP1:**
  New crossing: Two lanes for any vehicles;
  Existing Crossing: One bus lane and one HOV lane.

- **Option OP3:**
  New Crossing: One lane for any vehicle and one lane for Bus and HOV;
  Existing Crossing: One lane for any vehicles and one lane for Bus and HOV

If LRT was to be considered as part of a new crossing (bridge option only), them the recommended operational arrangement would be:

- **Option OP1 with LRT:**
  New crossing: Two lanes for any vehicles with a third lane for rail based LRT ;
  Existing Crossing: One bus lane and one HOV lane

The final recommendation for the operational arrangement can be confirmed after more detailed assessment of all of the above options.

8.1.7 Complementary Measures

Possible Complementary Measures have been identified that would be used to improve the performance of the network on, and in the vicinity of, the Forth bridges and on any replacement 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 HOV lanes, bus priority measures, park and choose sites, further bus services, additional rail capacity, ferry services, active traffic management and variable tolls. It is clear however, that the recent debate in the Scottish Parliament may mean that the use of variable tolls is no longer an option available for consideration.

8.1.8 Recommendations

The principal factors for differentiating between the options are Implementabilty, Environmental Impact, and Economic Efficiency. Other factors are principally altered by the method of operation, or the suite of Complementary Measures.

Corridor E Tunnel has significant adverse environmental impacts associated with the method of construction which may be difficult to mitigate against. The use of an immersed tube in the middle section has been identified as a risk due to the impact that dredging would have on the SPA. Furthermore, there is the possibility that dolerite could be found in the dredged excavation and drill and blasting techniques may be required. Again, this would have an impact on the SPA and sensitive operations in the area such as at Hound Point. The sub-marine interface between the immersed tube and TBM sections is also likely to be technically challenging and presents further risks to budget and programme.

There are also substantial mine workings to the south of Corridor E which have been the subject of grouting to a depth of 60 metres during the construction of the M9 Spur. Further mine workings are likely to be encountered.

All of these factors have resulted in this option being the most expensive of those examined at £2.4 billion. Although Corridor E Tunnel has the greatest monetised transport benefits of all the options this is mainly due to the proximity of its southern connections to the city of Edinburgh which may not necessarily be an outcome which reflects current policy.

This combination of factors suggests that this option should not be considered further.

Of the remaining tunnel options (C and D) there is little to choose between them. Both are estimated to take 7.5 years to construct and have similar costs (£2.2 - £2.3 billion). The monetised benefits of D are marginally better than C due to its proximity to the existing cross Forth corridor. The environmental benefits of both are similar and do not impact on the SPA.

The implementability risks are similar with Corridors C and D and are borne out of the lack of geotechnical survey information that would allow the ground conditions for tunnelling to be predicted with greater accuracy at this stage. It is envisaged that the alignments of each corridor can be altered to avoid any outcrops of doleritic or other hard rock intrusions once these have been identified. It is noted that geotechnical surveys will be carried out later this summer and into 2008 after which further examination of these constraints can be carried out.

When considered as a replacement crossing the tunnel options would not be able to provide the same facilities as a bridge crossing particularly as pedestrians and cyclists would not be permitted into the tunnel.

Corridor D Bridge has fewer risks associated with unknown ground conditions than any of the tunnel options. This is due to the fact that survey information was collected when earlier bridge studies were carried out in the 1990's. The bridge options also have the advantage of being able to be delivered earlier than the tunnels. Estimates of construction programme vary from 5.5 years for the cable stayed option to 6 years with the suspension bridge option. This compares with 7.5 years for all the tunnel options.

The cost of the bridge options, at £1.5 billion for the cable stayed and £1.7 billion for the suspension bridge, is also substantially less than the tunnel options (which range from £2.2 billion to £2.4 billion). This results in the bridge options having the best Benefit Cost Ratio (BCR) of the corridor options. The cable stayed bridge has a BCR of 4.3 and the suspension bridge has a BCR of 3.8

Environmentally, however, the bridge options do not perform as well as the tunnel options in Corridors C and D. There are likely to be direct impacts on the St Margaret's Marsh SSSI in the north side of the corridor. There may also be indirect disturbance to protected species within both the Forth Islands and the Firth of Forth SPAs. These may impose seasonal constraints during construction. The full scale of these impacts would not be known until such time that an Environmental Impact Assessment has been carried out.

It is clear from the above that the bridge option in Corridor D provides the best overall solution for a replacement crossing. It is cheaper than the tunnel alternatives, it is easier to implement and can therefore, be constructed quicker than the tunnels. There are fewer risks associated with the bridge option.

Of the two types of bridge structure the cable stayed bridge has advantages over the suspension bridge in that it is the cheaper option and can be delivered around 6 months earlier. The use of cable stayed techniques would avoid the need for complex foundations on the landfalls therefore, avoiding the methane risk on the southern side. Cable stayed bridges are modern forms of long span crossings and there is therefore, the opportunity to create a vista across the Forth of three different types of bridge construction comprised of the old (Forth Bridge), recent (FRB) and the new (the replacement). The visual impact of this vista is clearly something to be discussed with Architecture and Design Scotland.