6.4.3 Suitable Bridge Types

The following bridge types are considered to be suitable for these spans of 350 m to 400 m mentioned above, based on our experience and knowledge of bridge engineering:

a) Steel arch bridge
b) Steel truss bridge
c) Suspension bridge
d) Cable-stayed bridge

In selecting the most applicable type of bridge for these proposed sites, not only should economics and engineering considerations be taken into account, but the following factors will also influence the selection:

- Construction site requirement e.g. navigation, topographic, geological, etc.
- Construction costs
- Structural stability for natural phenomena e.g. earthquakes, wind forces, etc.
- Material availability
- Safety and ease of construction
- Environmental requirements
- Effect on road users

The result of this review of the bridge types is as follows; and is summarized in Table 6.4.1.

a) Steel Arch Bridge

An arch bridge is the most attractive from an aesthetic aspect with it's well known pleasing structural appearance.

It is considered that a mid-level steel deck steel balanced arch bridge would be suitable for the proposed sites. However, employing this type of arch bridge will increase the construction cost, because the main span of the bridge will extend beyond the economic span length for this type, in order to comply with the navigation requirements of a rectangular clearance of 70 m x 384 m or 342 m respectively for the proposed sites. The bridge span will therefore exceed the economic span range.

b) Steel Truss Bridge

A Cantilever steel truss bridge would be a suitable structure for crossing over the Canal.

An advantage of the steel truss bridge is that it employs the cantilever method for erection of the bridge. The merits of employing this type of bridge are as follows:

- The weight of each section of truss member or element forming the bridge is relatively low, thus permitting the use of smaller construction/ transportation equipment.
- Erecting by the cantilever method can be done using the balanced cantilever system, which eliminates the need for temporary stays and supports.
- The construction period will be relatively short, as a result of the prefabricated segmental construction and the lifting methods used for the suspended span.

Conversely, the construction cost may be equal to, or slightly higher than that of a cable-stayed bridge, as these costs are influenced by the live loads and design codes specified.

However, this type of bridge will also have some disadvantages, in particular from an environmental aspect due to the congested appearance of each bridge element, which is dependent upon the bridge designer's personal preference.

c) Suspension Bridge

Suspension bridges are usually used for a wide range of spans on account of their structural benefits, as well as the ease and safety of the construction works.

However, in recent years, there has been a trend to use suspension bridges where the span is in excess of some 500 m, or for light weight bridges or bridges for special use, such as a pedestrian bridge over a steep-sided valley.

The main feature of suspension bridges is that anchorages are required at both sides of the bridge to withstand the longitudinal forces from the main cables. The dimensions of the foundations of the anchorages are influenced by the seismic code specified, and also by the geotechnical and topographical conditions of the area.

These factors influencing the requirements for the anchorages will cause a considerable increase in the construction costs.

A suspension bridge is not considered to be economic for the medium span lengths of 200 m to 500 m.

d) Cable-Stayed Bridge

A Cable-Stayed Bridge has the advantages of structural efficiency and economy as well as aesthetics.

Many structures of this type have recently been built worldwide. Moreover, the economical span range for this type of bridge has been extended dramatically by the use of the multi-strand cable arrangements, as a result of the development of corrosion protective systems for the cable strands. In addition advanced construction technology, in combination with computer technology, has greatly increased the efficiency of design and construction of this bridge type.

The construction of a cable-stayed bridge employs the incremental launching system, and incorporates the balanced cantilever method, using the permanent structural cable stays in a temporary condition, but nevertheless aligned into their permanent locations. The costs for falsework are therefore considerably reduced.

Taking all the these factors into account, it was concluded that the cable-stayed bridge type is the most suitable type of bridge for this Canal crossing. The results of this review of the bridge types is summarized in Table 6.4.1 as follows:

Table 6.4.1 Comparison of Bridge Types

Factors	a) Steel Arch Bridge	b) Steel Truss Bridge	c) Suspension Bridge	a) Cable-Stayed Bridge
Construction Site Requirements	△	△	○	◎
Construction Costs	△	△	○	◎
Structural Stability	○	◎	○	○
Material Availability	△	△	△	○
Safety and Ease of Construction	△	○	◎	◎
Environmental Requirements	○	△	◎	◎
Effect on Road Users	△	△	○	○
Comparison Summary	△	△	○	◎

Sources: Study Team

Keys: ◎ Excellent
○ Fair
△ Poor

6.5 Bridge Crossing

6.5.1 Alignment and Profile

(1) Number of Lanes

There are three options of number of lanes namely: 4 lanes, 2 lanes, and 2 lanes with an additional lane for slow traffic as shown in Fig. 6.1.1.

(2) Vertical Grade

There are two options of vertical grade namely: 4.0 % and 3.3 % were selected for comparison study.

Vertical grade of 4.0 % is the maximum vertical grade for a design speed of 80 km/hr based on the Japanese standard.

Vertical grade of 3.3 % (1/30) is the maximum vertical grade of the Egyptian private regulation. A lower vertical grade is preferable taking into consideration the Egyptian vehicle mechanical condition at present, and the long approach sections.
(Refer to Chapter 8)

(3) Alternative Road Arrangements

The following four combinations of number of lanes and vertical grades were selected for comparison study.

- Option 1 Divided 4 lanes with vertical grade of 4.0 %
- Option 2 Divided 4 lanes with vertical grade of 3.3 %
- Option 3 2 lanes with vertical grade of 3.3 %
- Option 4 2 lanes and a climbing lane with vertical grade of 4.0 %
  (4 lanes for the main bridge: refer to the plan in Fig. A6.5.12)

The main bridge with 4 lanes in Option 4 is necessary to meet a structural requirement for stability of the main bridge and to provide the space for shift of climbing lanes on the main bridge.

The lengths of the bridge crossing for these four alternative road arrangements are shown in Table 6.5.1.

Table 6.5.1 Length of Bridge Crossing

Unit: m

Location	Vertical Grade (%)	Length of Bridge and Embankment									
		Main Bridge	Approach (East Bank)			Approach (West Bank)			Total		
			Viaduct	Embankment	Total	Viaduct	Embankment	Total	East Bank	West Bank	Grand Total
Qantara	4.0	730.0	1,170.0	427.5	1,597.5	1,380.0	205.0	1,585.0	1,962.5	1,950.0	3,912.5
	3.3	730.0	1,420.0	593.8	2,013.8	1,680.0	318.6	1,998.6	2,378.8	2,363.6	4,742.4
Ferdan	4.0	650.0	1,040.0	422.5	1,462.5	1,370.0	180.0	1,550.0	1,787.5	1,875.0	3,662.5
	3.3	650.0	1,270.0	556.4	1,826.4	1,730.0	202.4	1,932.4	2,151.4	2,257.4	4,408.8
Ismailiya	4.0	650.0	840.0	435.0	1,275.0	1,240.0	197.5	1,437.5	1,600.0	1,762.5	3,362.5
	3.3	650.0	1,160.0	454.4	1,614.4	1,500.0	311.4	1,811.4	1,939.4	2,136.4	4,075.8
Seraboium	4.0	650.0	850.0	450.0	1,300.0	1,270.0	242.5	1,512.5	1,625.0	1,837.5	3,462.5
	3.3	650.0	1,120.0	524.7	1,644.7	1,540.0	262.3	1,802.3	1,969.7	2,127.3	4,097.0

Source: Study Team

(4) Comparison of Alternative Road Arrangements

Outline description of these four options are given below and the results of the comparison of the alternative road arrangements are shown in Table 6.5.2.

- Option 1 will meet the future traffic demand crossing the Suez Canal, however, the vertical grade is considered to be too steep for Egyptian vehicles at present. The construction cost of this option is relatively high.

- Option 2 is the most preferable for traffic operation, however, the construction cost of this option will be highest.

- Option 3 is the cheapest alternative, however, this option has some problems in traffic operation (There is the a possibility that the traffic demand will exceed the traffic capacity of the road, and traffic congestion due to parking of broken down vehicles) and stability of the main bridge.

- Option 4 is relatively cheap alternative, however, this option has a problem with traffic capacity (There is possibility that the traffic demand will exceed the traffic capacity of the road). It is relatively difficult to expand to 4 lane viaducts in the future when traffic volume will increase.

Although, the vertical grade of 4.0 % is too steep for some Egyptian vehicles at present, this problem will be solved by an operation rule of the outer-lane for faster traffic and inner-lane for slow traffic, and the performance of Egyptian vehicles should improve in the near future.

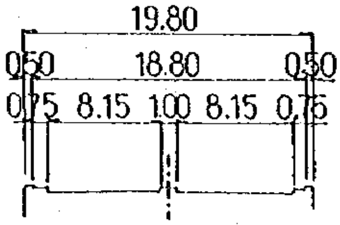
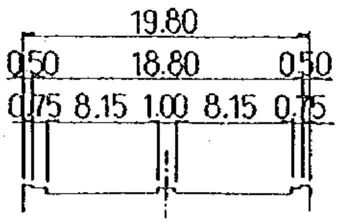
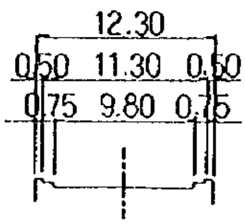
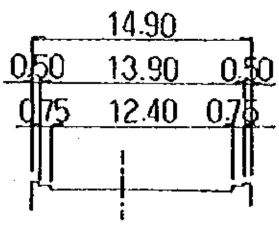
(5) Policy to Decide Alignment

The alignment of the road crossing the Suez Canal will be decided based on the following policy.

- The Bridge crossing the Suez Canal will span the channel at right angles as well as at a point where the alignment of the Suez Canal is straight.

- The road crossing the Suez Canal will connect to Ismailiya - Port Said Road on the West Bank and New Central Highway on the East Bank. The Study Team assumed that the intersection between the road crossing the Canal and the existing arterial roads will be at the same level and the road crossing will meet at right angles with the existing roads.

Table 6.5.2 Comparison of Alternative Plans

Alternatives	Cross Section	Lane No. Width (m)	Vertical Grade (%)	Bridge Area (m²) (Length : m)		
				Main Br.	Approach	Total
Option 1 4 Lanes with vertical grade of 4.0%		4 Lanes 18.8	4.0	12,600 (670)	49,900 (2,655)	62,500 (3,325)
Option 2 4 Lanes with vertical grade of 3.3%		4 Lanes 18.8	3.3	12,600 (670)	62,000 (3,300)	74,600 (3,970)
Option 3 2 Lanes with vertical grade of 3.3%		2 Lanes 11.8	3.3	7,900 (670)	38,900 (3,300)	46,800 (3,970)
Option 4 2 Lanes and a climbing lane with vertical grade of 4.0%		2 Lanes + climbing lane (M) 18.8 (A) 13.9	4.0	12,600 (670)	36,900 (2,655)	49,500 (3,325)

Source : Study Team

- The Bridge crossing over the Channel should be straight.

- A larger radius not requiring a transition curve, a radius of 2,000 m or more for design speed of 80 km/hr, will be used for the road crossing the Canal where possible.

- Agricultural land is very valuable in Egypt, therefore, the road crossing the Canal will avoid areas of agricultural land. In addition, residential areas one where resident relocation is necessary or land acquisition is expected to be difficult, will be avoided.

- Approach spans should be located in areas of higher elevated and/or on areas with firm bearing stratum, to reduce the construction cost of the approach sections of the bridge.

- Swamp areas will be economize construction of approach viaducts and embankments in these area.

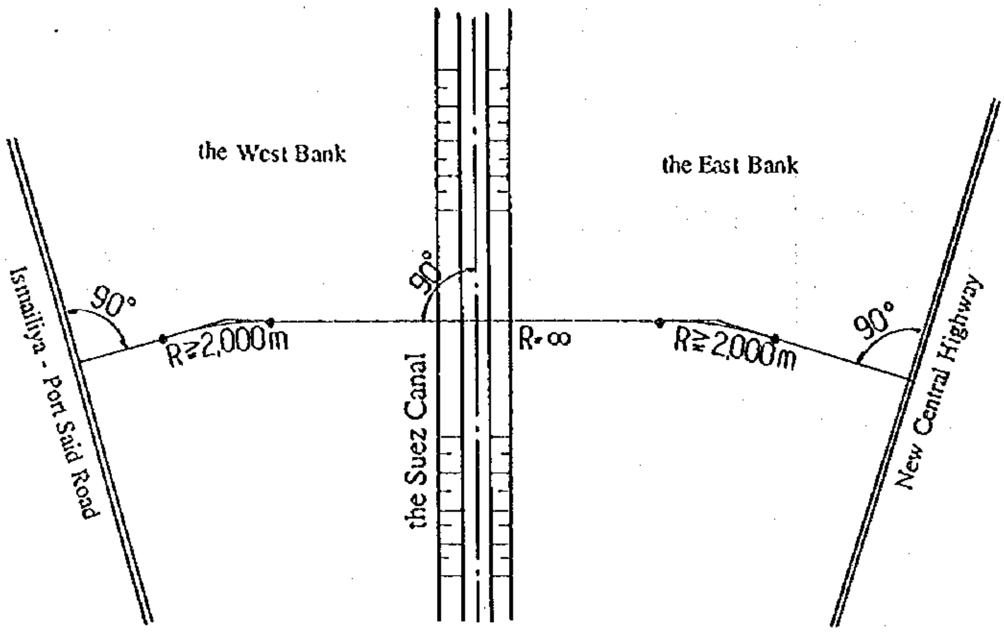


Fig. 6.5.1 Schematic Road Alignment

6.5.2 Main Bridge

(1) Selection of Bridge Types

1) Preliminary Design Results

The following three cable stayed bridge types of 360 m main span length have been examined for the main bridge construction;

i) Prestressed concrete box girder,
ii) Concrete-steel composite girder, and
iii) Steel box girder

The approximate construction cost comparison for the three types of 360 m main span lengths are shown in Table 6.5.3

Table 6.5.3 Approximate Construction Cost Comparison of Three Alternative Types

Alternative	Bridge Length (m)	Construction Cost (million US$)		
		Superstructure	Substructure	Total
PC Box Girder	650	12.1	10.9	23.0
Composite Girder	702	16.9	6.4	23.3
Steel Box Girder	650	15.8	8.2	24.0

Note: Construction costs of PC box girder and Steel box girder include additional approach viaduct construction length of 52 meters. The cost is for main structure construction only.
Source: Study Team Estimate.

The estimated construction costs of these three types is virtually the same taking into account the cost estimation accuracy. Therefore other factors such as ease of construction, durability and maintenance requirements are significant factors in deciding the selection of the main bridge type.

The construction of the prestressed concrete box girder option is the simplest and most efficient method, as it uses the balanced cantilever method incorporating precast units. It is not preferable to employ the cast-in-place balanced cantilever method which would take about one year longer to construct. The precast units, which are cast at the precasting yard will weigh approximately 100 tonnes each. They can be transported either by rail or barge and lifted into position some 70 meters above surface of the Canal. The same procedure can be used for the steel box girder option, but the box girder segment will weigh less than 50 tonnes and is hence much easier to transport and lift into position.

For the steel-concrete composite girder option, precast concrete deck slabs are assembled using high strength cast-in-place concrete prior to launching the balanced cantilever girder. These precast concrete slabs will weigh about 15 tonnes and be lifted up at the pylon sides. This work does not require any special skills.

As a result of the use of auxiliary piers at the side spans, the deflection under vehicle loading is relatively small for the prestressed concrete girder and steel box girder types (center span length-deflection ratios of 1/1,500 and 1/650 respectively). For the steel-concrete composite girder, the ratio is 1/530 which is less than 1/400 specified in this Project.

The durability the precast concrete deck slabs in the composite girder option presents a severe problem, as they are the elements directly subjected to the heavy vehicle loading. There are very few construction records of composite girder type cable stayed bridges in the world and no data relating to the deck slab durability. However, the records of simple composite girder bridges of 20-40 m span length show that severe problems of concrete deck slab damage by heavy vehicle traffic occurs. When it becomes necessary to replace the damaged concrete deck slabs, the problem of transferring the compressive forces taken by the concrete slabs to other temporary members will have to be faced.

The maintenance requirement for steel box girder and composite girder types necessitates the repainting of the steel girder about once every 10 years. As the rainfall and humidity conditions are favorable at these bridge sites, only about 0.7 million US$ will be needed for these maintenance works.

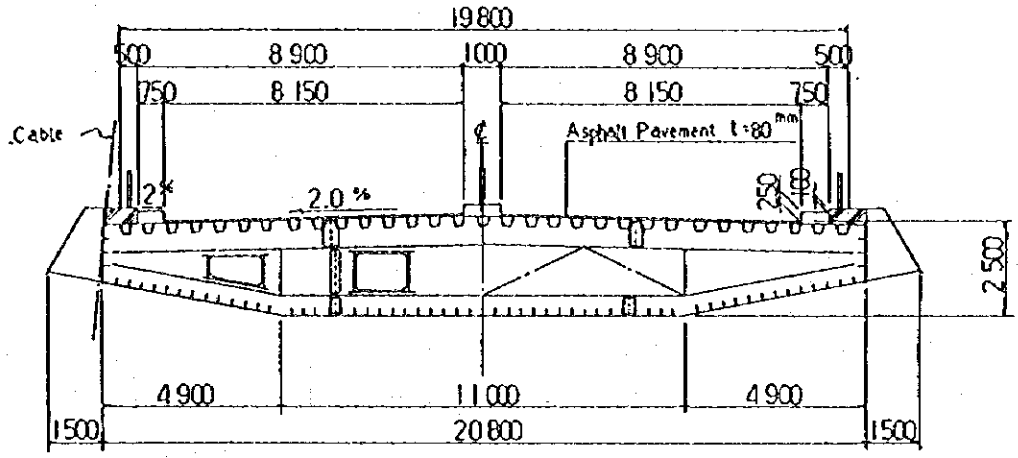
The construction will be as follows:

Steel box girder	:	3 years 9 months
PC box girder	:	4 years 9 months

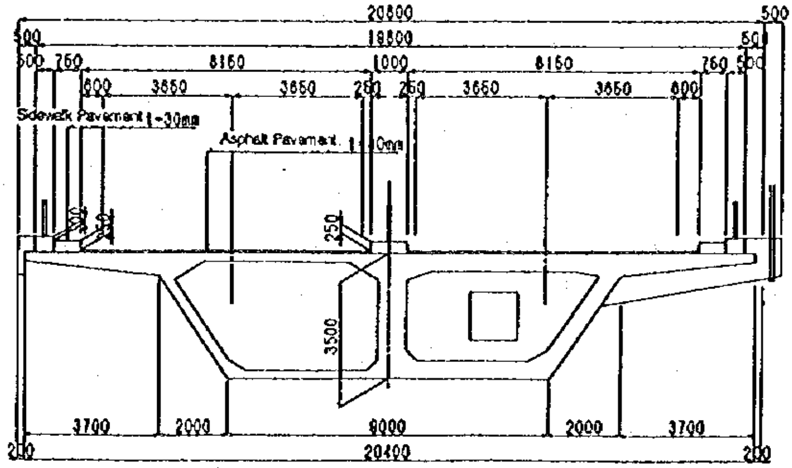
There will be a difference of one year between the steel box girder and the PC box girder.

In the implementation of the bridge construction, the safety of vessels plying the canal must be kept the prime consideration. In implementing the safety measures for the safe passage of vessels, the construction period over the canal must kept to a minimum.

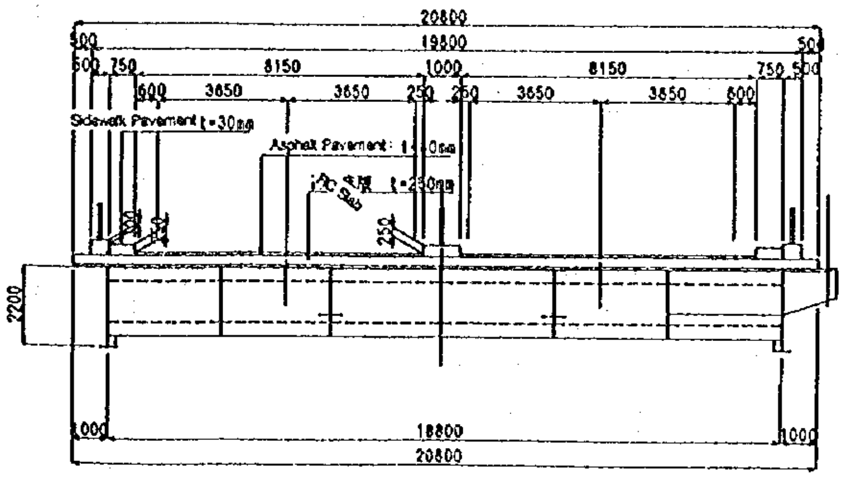
Hence, for this project, from the viewpoint of keeping the construction period short in order to enforce the safety rules for the transitting vessels, the PC box girder cannot be recommended.



Steel Box Girder



Prestressed Concrete Girder



Steel - Concrete Composite Girder

Fig. 6.5.2 Bridge Types of Main Bridge

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

2) Conclusion

The steel box girder alternative has been selected for the main bridge type, mainly because of the ease of construction and good durability.

(2) Span Arrangement

The length of the main span is dictated by the conditions set by SCA, that canal side surface of the pylon shall be 1.5 meters beyond the canal crest. Assuming an 8 meters pylon size, the minimum main span lengths for Qantara and the other locations will be as follows;

Qantara	:	384 + 8 + 3 = 395 meters
Others	:	342 + 8 + 3 = 353 meters

In addition to this requirement, the consideration of ship collision with the pylon foundation as well as the pylon column must be taken into account. There is a very low possibility of the pylon structure being affected by ship collision, based on the analysis of ship collision in the Appendix A6.2.7 and A9.1. Therefore the following main span lengths have been determined for preliminary design purposes;

Qantara	:	404 meters
Others	:	360 meters

For the two alternative types of steel box and prestressed concrete box girders, the auxiliary piers for the side spans have been positioned to improve the main girder stiffness and the reduce the construction costs. A side span length ratio of 0.4 (span length of 163 and 145 meters for Qantara and others, respectively) has been selected for the purpose reducing the construction cost.

For the steel-concrete composite girder alternative, a side span length (171 meters for Ferdan), somewhat longer than the other alternatives, has been selected in order to produce positive bending moment at the side spans under dead load and stay cable prestressing conditions. This will prevent the transfer of undesirable tensile stresses into the concrete deck slab. General elevations of the three alternatives are to be found in the Appendix (Fig. A6.6.1 to A 6.6.5).

(3) Foundations

Generally, cast-in-place concrete piles and concrete caissons are normally used for bridge foundations in Egypt. Based on the geological investigation, the soil conditions alongside the canal at the four locations are very similar from a foundation point of view. The strata for several meters below the surface indicates loose fine sands but beneath this layer there are dense sand layers with thin bands of stiff to hard clays.

Therefore, the elevation of the base of the foundations in dependent upon the future dredging elevation of the Canal (-27 meters), and minimum length of 10 times the pile diameter requirement, and not soil conditions.

For the cast-in-place type pile, a diameter of 2.5 meters has been selected based on the availability of piling machines in Egypt. The bearing capacity of each pile has been estimated based on the pile end soil bearing capacity (280 t/m2). One pile cap has been designed for every two pylon columns.

For the concrete caisson type, one caisson has been designed for each pylon column. The two caissons for the one pylon structure are connected by a concrete slab.

The preliminary designs for the foundations using concrete piles and caissons for the steel box girder type are shown in Table 6.5.4.

Table 6.5.4 Comparison of Pile and Caisson Foundations

Foundation Type	Dimension per Pylon	Bearing Capacity, Ground Reaction	Construction Cost (million US$) per Pylon
Concrete Pile	Pile: dia 2.5m, length 25 m Number: 30 Nos Pile Cap: 30 x 36.25 m t = 6 m	Pile head bearing capacity under vehicle loading: 1,770 tones	1.9, including pile cap cost.
Concrete Caisson	Caisson size: length: 18.5 m width: 12 m depth: 25 m Number: 2 Nos	Earthquake loading: Maximum vertical reaction at base: 187 t/m² Horizontal reaction at side wall: 14 t/m2 5 m below caisson top	1.6, including the cost for caisson sinking equipment

Source: Study Team Estimate

As shown in Table 6.5.4, caisson type foundation is more economical. However, the use of caisson sinking equipment such as hydraulic jacks with ground anchors will be required as the weight of the caisson concrete will be insufficient to overcome the soil bearing the frictional resistances. This is an uncertain factor in the selection of caisson foundations. But in this feasibility study stage, the caisson foundation type has been selected by reason of cost.

(4) Pylons

The pylon has been designed as a reinforced concrete structure. The pylon (column) height above the girder is governed by the effectiveness of the stay cables. Current data on large scale cable stayed bridges indicate that this dimension is normally between 0.17 and 0.20 of main span length. For this study, the value of 0.20 has been used. Total heights of pylons will be as follows;

Main span length 360 meters: height = 150 meters

Main span length 404 meters: height = 160 meters A twin pylon column has been selected for the following reasons;

i) better torsional rigidity against wind action,
ii) reduction in total bridge width due to narrower median width.

A distance of about 22 meters is required between the pylon columns at the girder elevation. The two inclined tapered pylon columns are rigidly connected together by transverse beams at three elevations to react as a rigid frame pylon against transverse force actions (refer to Fig. A6.6.1 to A6.6.5 in Appendix).

(5) Superstructures

1) Stay Cable

The multi-stay fanned cable system is used for this long span cable stay bridge, because of the lower tension in each cable, which simplifies the anchorage structure, shortens the length of the cantilevered girder and simplifies the replacing of stay cables during the maintenance work. These cables are located at about 12 meter intervals and thus the tensile forces in them are less than 390 tons.

2) Girder

Single-box girders (girder depth 2.5 m) have been designed for the steel box types. The stay cables are anchored at the outerside of the girders. A steel deck plate of 12 mm thickness with ribs has been used and minimum thickness of a bottom plate of box girder should be 10 mm.

6.5.3 Approach Viaducts

(1) Selection of Bridge Types

The profile of the approach viaducts is largely dictated by the change in elevation of the road from about +10 m to +70 m. This requires that the span length and structure type be carefully studied. The type of structure to be studied has been selected from the following types;

i) continuous bridge type, and
ii) adoption of the span lengths of 20 to 60 meters.

Based on the above criteria, the following bridge types and span lengths have been chosen;

i) steel box girder (span length of 50 to 60 m), and
ii) steel plate girder (span length of 20 to 50 m).
iii) prestressed concrete box girder (span length of 40 to 60 m),
iv) prestressed concrete I girder (span length of 20 to 40 m),

The construction costs of these bridge types using various pier heights are summarized in Table 6.5.5 (1) to (3).

These three Table give the following results;

i) The bridge span length is dependent upon the pier height. The most economical span lengths are as follows;

H = 60 m: L = 40 m or 50 m using steel plate girder,
H = 40 m: L = 30 m or 40 m using steel plate girder,
H = 20 m: L = 20 m or 30 m using steel plate girder.

ii) The next most economical options are as follows;

H = 60 m: L = 50 m or 60 m using PC box girder,
H = 40 m: L = 30 m or 40 m using PC I girder, and
H = 20 m: L = 20 m or 30 m using PC I girder.

The cost differences of both options are marginal, within a few per cent. The steel plate girder type is the preferred option on account of ease of construction and cost. However, it will be necessary to add the maintenance cost (about 4 million US$) for repainting and maintaining the girders every 10 years for the steel plate girder option. Taking these factors into account, the following bridge type and span lengths are recommended;

Table 6.5.5 (1) Construction Cost Summary (Pier Height 60 m)

Unit: thousand US$

Type of Bridge	Span Length (m)	Cost of Superstructure	Cost of Substructure	Total	Unit cost per Span Length
Steel Box	60	700.5	303.3	1,003.8	16.7
Girder	50	574.5	283.0	857.5	17.1
Steel	60	580.5	303.3	883.8	14.7
Plate	50	425.5	283.0	708.5	14.2
Girder	40	292.0	247.1	539.1	13.5
Prestressed	60	490.8	360.1	850.9	14.2
Concrete Box	50	395.2	335.3	730.5	14.6
Girder	40	301.6	303.3	604.9	15.1

Source: JICA Study Team

Table 6.5.5 (2) Construction Cost Summary (Pier Height 40 m)

Unit: thousand US$

Type of Bridge	Span Length (m)	Cost of Superstructure	Cost of Substructure	Total	Unit Cost per Span Length
Steel	50	425.5	177.2	602.7	12.0
Plate	40	292.0	160.9	452.9	11.3
Girder	30	190.8	145.5	336.3	11.2
Prestressed	50	395.2	207.3	602.0	12.0
Concrete Box	40	301.6	184.0	485.5	12.1
Girder	30	217.5	163.0	380.5	12.7
Prestressed	40	283.6	177.2	460.8	11.5
Concrete I	30	187.4	157.9	345.3	11.5
Girder					

Source: JICA Study Team

Table 6.5.5 (3) Construction Cost Summary (Pier Height 20 m)

Unit: thousand US$

Type of Bridge	Span Length (m)	Cost of Superstructure	Cost of Substructure	Total	Unit Cost per Span Length
Steel Plate	30	190.8	67.3	258.1	8.6
Girder	20	108.4	54.9	163.3	8.2
Prestressed Concrete Box Girder	30	217.5	78.0	295.5	9.9
Prestressed	30	187.4	83.9	271.3	9.0
Concrete I	20	111.4	64.2	175.6	8.8
Girder					

Source: JICA Study Team

H = 60 m: L = 60 m using PC box girder,
H = 40 m: L = 40 m using PC I girder, and
H = 20 m: L = 30 m using PC I girder.

(2) Span Arrangement

Using the method of selecting the bridge type and span length to the pier height decided above, the method of bridging for each route has been carried out taking into account the number of continuous spans, 200 to 250 meters of total length. The abutment height has been assumed to be about 10 m high for the West Bank and about 20 m high for East Bank, respectively.

(3) Foundations

Cast-in-place concrete pile foundation has been used for the foundation of the approach viaduct. According to the geological investigation, a cemented stiff to hard fine sand layer (SPT more than 50) is located 5 to 7 meters below the ground surface. A spread footing foundation could also be used in this area if the ground water is well below the bedding elevation.

On the West Bank, the bridge route runs through farm land criss-crossed by irrigation canals. On the East Bank, the route runs almost entirely through desert area, and the ground water level is well below the surface. Therefore the spread footing type foundation could be used on the East Bank. However as the development plans for the East Bank are not known at the present time, the spread footing type will not be used at this stage.

(4) Substructures

Twin columns of concrete pier have been selected, taking into account the possibility of staged construction (refer to Fig. 6.5.3). To simplify the construction, the width of the pier remains constant but the thickness varies with the height to resist the forces acting upon it.

(5) Superstructure

The width of the concrete girder has been selected to accommodate two traffic lanes in one direction. For a pier height in excess of 50 meters, a prestressed concrete box girder of 60 meters span length has been selected. Prestressed concrete I girder of 40 and 30 meters span lengths have been used for pier height of 50 to 30 meters and less than 30 meters, respectively. A continuous 4 to 8 span girder has been chosen for the superstructure as this will improve the vehicle ride and help resist earthquake action. At the high pier sections, a rigid connection between the girder and the pier, omitting a bearing pad, would be a way to reduce the construction cost.

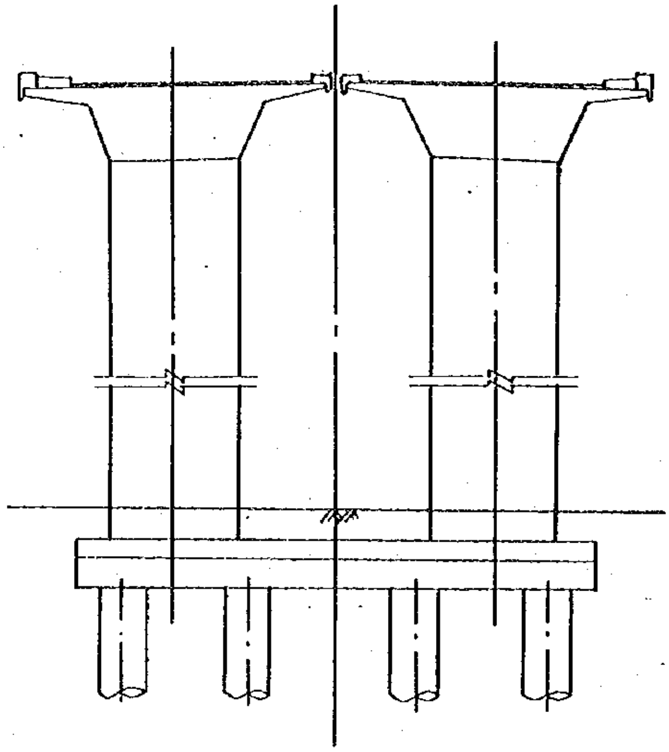


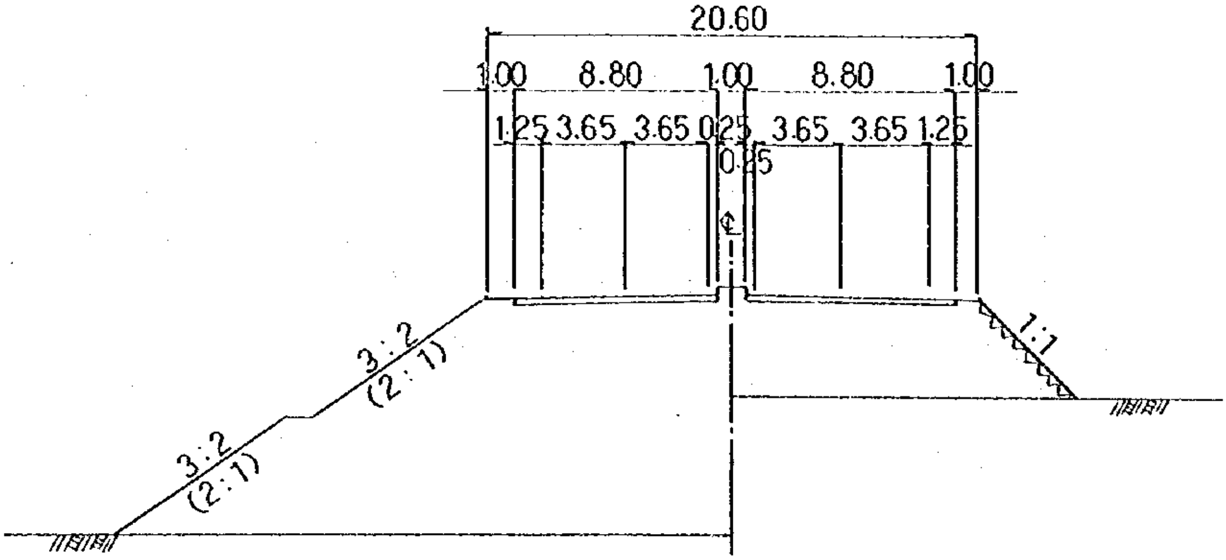
Fig. 6.5.3 Section of Viaduct

6.5.4 Approach Embankments

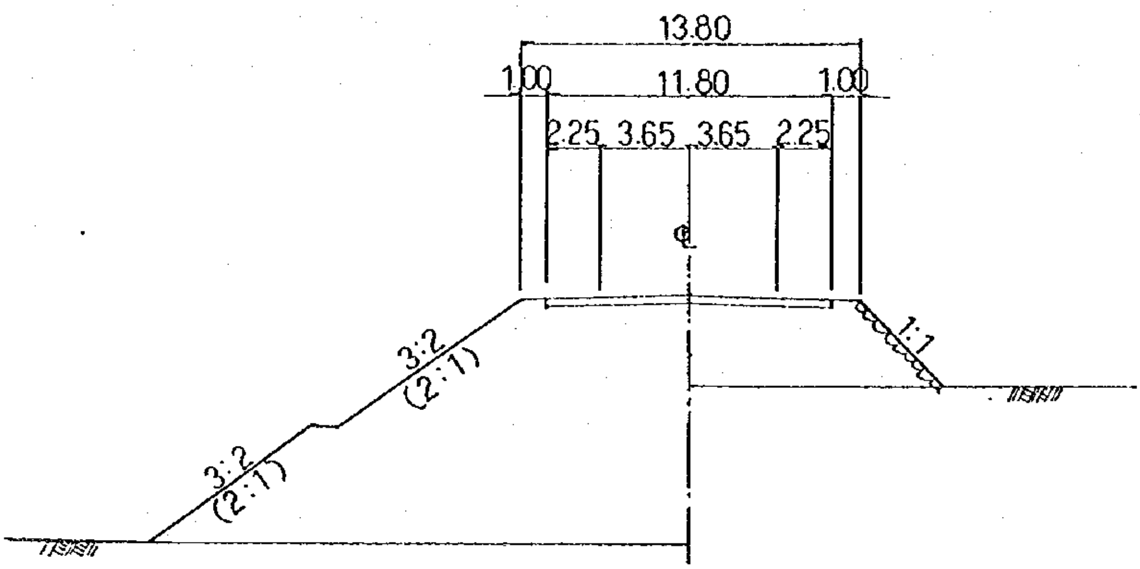
(1) General

The approach embankments are the structures connecting the approach viaducts to the access roads.

The height of the embankments depends upon the soil condition of the site and the economics of construction, taking into consideration the cost of the acquisition of the farm land. The farm land in the Project sites has been developed for many years and it is not economical to acquire such established farm land for the huge area required. (For example for a 10 to 15 m high embankment, between 60 m and 75 m width of farm land will be acquired). On the East Bank side (Sinai Side), a high embankment will be examined based solely on the geological conditions, whilst on the West Bank Side, a low embankment of about 5 m or less height will be examined, to minimize land use at the site (refer to Fig. 6.5.4).



4 Lane Road



2 Lane Road

The East Bank Side **The West Bank Side**

Note: Numbers in parentheses indicate the slope inclination required by the stability calculation of the embankments.

Fig. 6.5.4 **Standard Cross Section of Approach Embankment (Provisional Profile)**

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

(2) Material

As a principle, the approach embankments will be built using local sand from around the Canal road crossing site. However, using high quality materials from a quarry is considered to be required to maintain the stability of the approach embankments because the approach embankment will be high. (Refer to Paragraph 10.4.2)

The sand to be used for the approach embankments will be selected at an early stage of construction.

(3) Maximum Height

The height of the approach embankments considerably affects the construction cost of the Canal crossing bridge. The higher the embankment is constructed, the lower the cost of the bridge structure will be. However, the height of embankments is limited as they can become unstable. In addition, high embankments will detract from the aesthetics of the Canal crossing bridge.

The maximum height of the embankments will be selected during the detailed design taking account of stability of the embankments and land acquisition area. The Study Team will assume a maximum height shown below for the time being.

- For the East Bank side and the West Bank side at Ferdan
  The maximum height will be 15 m to 20 m based on the stability of the embankments.
- For the West Bank side at Qantara, Ismailiya and Srabuiom
  The maximum height will be 5 m to 10 m to minimize land use.

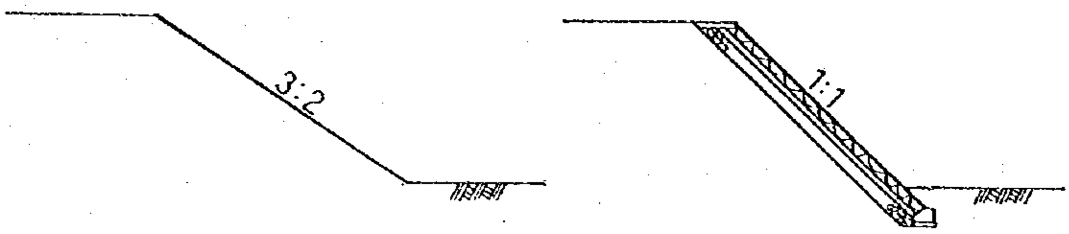
(4) Side Slope

In accordance with the Egyptian standards, the maximum slope of an embankment whose height is more than 3.0 m is 3:2 (horizontal: vertical).

The slope of the approach embankment will be further studied and selected in the detailed design taking consideration of strength of soil used for the embankments. The Study Team is assuming a slope shown in order to maintain stability of the embankment for the time being (refer to Fig. 6.5.5).

- For the East Bank side and the West side at Ferdan : 3:2
- For the West side at Qantara, Ismailiya and Srabuiom :
  1:1 with the surface of the slope protected by stone masonry to minimize land use

The inclination of the approach embankment slopes will be studied in Chapter 10. The inclination of the approach embankment slopes will be determined based on the result of the stability calculation of the embankment. A slope protection of the approach embankments will be also studied in Chapter 10.



Slope 3:2 **Slope 1:1**

Fig. 6.5.5 Slope of Embankment

6.5.5 Access Roads

(1) General

The access roads are the roads which connect the Canal crossing bridge or tunnel to the existing road network. The access roads are expected to be on low embankments.

Access roads providing the connection between the crossing and the existing arterial road network are:

- West Bank (main land) : Ismailiya - Port Said Road
- East Bank (Sinai Side) : New Central Road

However, at the Srabuiom site, the West Bank access road will have to be linked to the Suez - Ismailiya Road, because of the remote location of the Cairo - Port Said Road.

At the Qantara site, the East Bank access road is also considered to be linked to the local road between the Qantara Ferry Station and the new industrial area, due to the remote location of the New Central Road. This also creates a shorter connection to the northern part of Sinai.

(2) Material

The embankment of the access roads will be built using local sand from around the Canal road crossing site. The sand to be used for the embankments will be selected at an early stage of construction.

(3) Height

The access road structure will be formed on low embankments about 1.5 m above the ground, except in low swampy areas where a more substantial embankment will be required. Concrete pipe or culvert structures will be required for crossing the irrigation canals in the cultivated areas and the height of the access road will be decided taking account of these crossing structures.

The height of the access roads above the surrounding land will be approximately 2.0 m to 3.0 m to match the height of the Flat Desert Road and to provide the space for the crossing structures.

(4) Side Slope

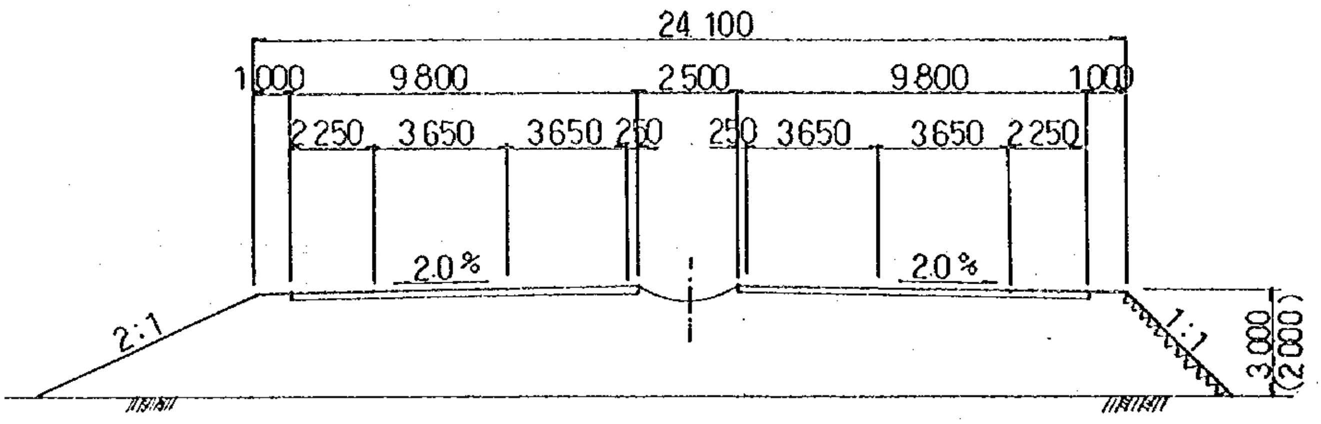
The Egyptian standards recommend and embankment slope of 2:1 (horizontal: vertical) where the height is 2.0 m to 3.0 m and 3:2 for the height more than 3.0 m.

The slope of the embankment of the access road will be determined after further study. The Study Team is assuming a slope shown in order to maintain stability of the embankment at present (refer to Fig. 6.5.6).

- For the East Bank side and the West side at Ferdan : 2:1 or 3:2
- For the West side at Qantara, Ismailiya and Srabuiom :
  1:1 with the surface of the slope protected by stone masonry to minimize land use

The inclination of the access road embankment slopes will be studied in Chapter 10. The inclination will be examined in detail and decided in the detailed design.

A slope protection of the access road embankments will be also studied in Chapter 10.



Note: The number in parentheses indicates the embankment height on the East Bank.

Slope 2:1 **Slope 1:1**

Fig. 6.5.6 Standard Cross Section of Access Road for 4 Lane Road (Provisional Profile)

6.5.6 Construction Methods and Schedule

(1) Main Bridge

1) Foundation

Caisson cutting edge will be set at elevation of +2.0 m on the ground. It will be then sunk to a level of -25.0 m employing the method of caisson wall casting, dredging and sinking in a continuous sequence. When the base of the caisson attains foundation level, invert concrete base slab will be placed using tremie pipes. In order to overcome the resistance to sinking a system of hydraulic jacks attached to ground anchors will be employed.

2) Pylon

The pylon column will be constructed using climbing formwork. Each lift of 2 to 4 meters will be completed about every 3 days. A tower crane will be required for handling and lifting of all materials.

3) Main Girder

The steel box girder will be assembled in almost 6 m sections at the assembly yards, near the bridge site and transported to the Canal site by rail. It will then be transported to the designated locations of center span or side span, using a barge in the Canal for the former and road transport for the latter respectively. The section will then be raised to the required level by jib cranes. It will be set in position using the balanced cantilever method of erection in conjunction with the staying cables.

4) Stay Cable

The stay cables will be transported to the bridge deck level in reels. Fitting of the cable onto pylon side position will be carried out using the tower crane. Prestressing will be done using a center hole jack.

(2) Approach Viaducts

1) Foundation

A boring rig equipped with a 1.0 to 1.5 meter diameter auger will be used for drilling the bores for the concrete piles. For some areas on the West Bank, steel sheet pile cofferdam may be required for the pile cap construction, due to the high water table or presence of surface water.

2) Piers

The concrete pier will be constructed using climbing formwork. A crane is incorporated into the climbing formwork for lifting up the materials. More than 30 piers will need to be constructed on each bank. 5 to 6 teams on each bank will enable the construction of the piers to be completed within one year.

3) Superstructure

Balanced cantilever launching out method from the pier head will be used for PC box girder bridge in conjunction with traveler cranes. The pier head section will be constructed upon the scaffolding fitted to the pier top.

The PC I girder bridge will be produced in the girder precast yards, transported the site and lifted up into position by mobile crane where the pier height is less than 30 meters. For the section where the pier height is more than 30 meters, an erection gantry will be used to launch the concrete girder. Then the cast-in-place concrete deck slab will be constructed.

(3) Approach Embankments and Access Roads

1) Approach Embankments

These will be constructed using local selected sand fill, spread and compacted in suitable layers at optimum moisture content using conventional earthworks equipment. The slope will be trimmed to the desired batter and protected with stone pitching laid in mortar.

2) Access Roads

The nominal 1 m high embankment will be formed as above, and then the road pavement constructed in the conventional manner.

(4) Construction Schedule

Fig. 6.5.5 shows the preliminary construction schedule of the main bridge and approach structures. The total construction period, which will be dependent upon the condition of the bridge site, is anticipated to be between 40 and 45 months.

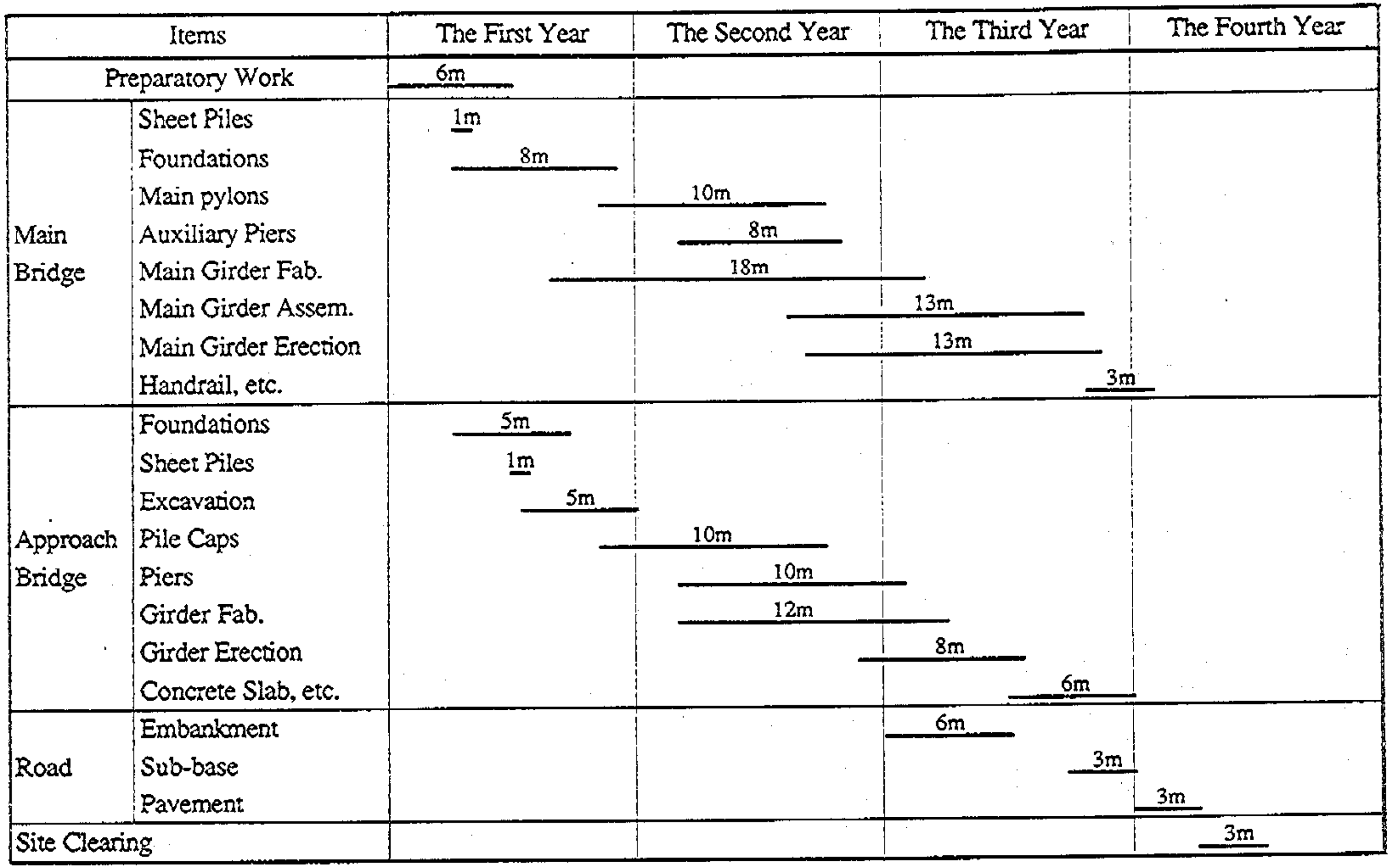


Fig. 6.5.6 Construction Schedule (Ferdan 4 %)

6.5.7 Cost Estimation

(1) Basic Assumptions

1) General

The cost estimation has been compiled using information on the material, labor and equipment costs collected in Egypt and Europe.

2) Labor Costs

For the specialist works, ie., steel box girder assembly, girder lifting, cable fitting and prestressing, etc., the supervisory and key personnel have been allocated to expatriate staff. The general overheads have included key expatriate personnel supported by a full Egyptian team.

3) Materials

Where possible the local products have been used for costing, based on the local rates (reinforcing bar, cement, plywood, aggregates, asphalt, gasoline, diesel oil, etc.). For the steel girder products, stay cables and prestressing tendons which are not available in Egypt, imported prices in US currency have been used.

4) Equipment

All standard equipment used in road construction is generally available in Egypt. The specialist items used for bridge erection such as the traveler crane, jib crane, erection girder, are considered to be imported.

(2) Other Costs

1) Contingencies

A physical risk contingency of 10 % of the basic estimated construction cost has been assumed. A price escalation of 3 % inflation of US currency base per annum has been assumed.

2) Indirect Cost/overhead Cost

The indirect cost/overhead cost includes all costs necessary for preparatory works including a work camp, construction of contractor/consultant's office, laboratory and welfare facilities, transportation cost of materials and equipment, site office management and maintenance cost, and contractor's general overhead costs. A figure of 20 % of the sum of the basic construction and contingency cost has been assumed for indirect/overhead cost.

3) Engineering Cost

A sum equal to 10 % of the basic construction and contingency cost has been estimated as the engineering costs for detailed design and construction supervision by the consultant.

4) Land Acquisition and Compensation Cost

A unit price for land acquisition of 15,000 LE per 0.4 ha has been used for the cultivated areas in West Bank. No land acquisition cost has been estimated for the area on East Bank as this land is empty desert at present.

In addition a resettlement cost has been included based on the assumption of the need to resettle 3 houses per kilometer along the access road.

(3) Project Cost Summary for the Alternative

Table 6.5.6 shows the summary of the project cost for the 4 lane bridge crossing for each alternative route. The cheapest option is the Ismailiya route and the Qantara route is the most expensive.

Table 6.5.7 also shows the summary of the project cost for the 2 lane bridge crossing option. The 4 % alternative includes the construction of additional climbing lanes for the approach viaducts.

6.5.8 Effect of the Bridge Construction on Navigation Safety

(1) Influence on Radar and countermeasure

1) Bridge Structure

A cable-stayed type bridge has been selected as the bridge crossing for the Suez Canal at the four (4) potential site locations. The concrete pylons with two rectangular columns will be constructed on both banks of the Canal. The steel box deck girder will span the canal and provide the required navigation height clearance of 70 m.

Table 6.5.6 Project Cost Summary of 4 Lane Alternative

Location	Gradient	Basic Cost (million US$) = A					Physical Contingency	Price Contingency	Subtotal
		Main Bridge	Approach Bridge		Access Road	Sub Total			
			East B	West B		(A)	(A x 10 %)	(A x 9 %)	(B)
Qantara	4.0%	32.7	20.6	23.3	2.9	79.5	8.0	7.2	94.7
	3.3%	32.7	25.1	28.6	3.1	89.5	9.0	8.1	106.6
Ferdan	4.0%	30.9	18.4	23.5	3.1	75.9	7.6	6.8	90.3
	3.3%	30.9	23.1	29.5	3.1	86.6	8.7	7.8	103.1
Ismailiya	4.0%	30.9	13.4	20.1	3.3	67.7	6.8	6.1	80.6
	3.3%	30.9	18.6	24.3	3.2	77.0	7.7	6.9	91.6
Srabuiom	4.0%	30.9	13.9	20.9	1.6	67.3	6.7	6.1	80.1
	3.3%	30.9	18.9	25.7	1.4	76.9	7.7	6.9	91.5

		Subtotal (B)	Indirect C./Overhead C. (B x 20 %)	Engineering C. (B x 10 %)	Land Acquisition Compensation C.	Grand Total (million US$)
Qantara	4.0%	94.7	18.9	9.5	0.3	123.4
	3.3%	106.6	21.3	10.7	0.3	138.9
Ferdan	4.0%	90.3	18.1	9.0	0.4	117.8
	3.3%	103.1	20.6	10.3	0.4	134.4
Ismailiya	4.0%	80.6	16.1	8.1	0.4	105.2
	3.3%	91.6	18.3	9.2	0.4	119.5
Srabuiom	4.0%	80.1	16.0	8.0	0.1	104.2
	3.3%	91.5	18.3	9.2	0.1	119.1

Source: Study Team

Table 6.5.7 Project Cost Summary of 2 Lane Alternative

Location	Gradient	Basic Cost (million US$) = A					Physical Contingency	Price Contingency	Subtotal
		Main Bridge	Approach Bridge		Access Road	Sub Total			
			East B	West B		(A)	(A x 10 %)	(A x 9 %)	(B)
Qantara	4.0%	25.1	15.8	17.8	2.0	60.7	6.1	5.5	72.3
	3.3%	25.1	15.4	17.6	2.2	60.3	6.0	5.4	71.7
Ferdan	4.0%	22.5	14.1	18.0	2.2	56.8	5.7	5.1	67.6
	3.3%	22.5	14.2	18.1	2.2	57.0	5.7	5.1	67.8
Ismailiya	4.0%	22.5	10.3	15.4	2.3	50.5	5.1	4.5	60.1
	3.3%	22.5	11.4	14.9	2.2	51.0	5.1	4.6	60.7
Srabuiom	4.0%	22.5	10.6	16.0	1.1	50.2	5.0	4.5	59.7
	3.3%	22.5	11.6	15.8	1.0	50.9	5.1	4.6	60.6

		Subtotal (B)	Indirect C./Overhead C. (B x 20 %)	Engineering C. (B x 10 %)	Land Acquisition Compensation C.	Grand Total (million US$)
Qantara	4.0%	72.3	14.5	7.2	0.2	94.2
	3.3%	71.7	14.3	7.2	0.2	93.4
Ferdan	4.0%	67.6	13.5	6.8	0.3	88.2
	3.3%	67.8	13.6	6.8	0.3	88.5
Ismailiya	4.0%	60.1	12.0	6.0	0.3	78.4
	3.3%	60.7	12.1	6.1	0.3	79.2
Srabuiom	4.0%	59.7	11.9	6.0	-	77.6
	3.3%	60.6	12.1	6.1	-	78.8

Source: Study Team

2) New Radar System and Bridge Locations

The installation of the new Suez Canal Vessel Traffic Management System (SCVTMS) has been completed by SCA, and vessel management using this system has been operated since early on 1996. There are six tracking radar stations at the locations shown in Fig. 6.5.8 which also shows the potential site of the proposed bridge.

Therefore, in the planning of the construction of the bridge, considerations should be given to the effects of the bridge on the SCVTMS from a navigation safety point of view.

The proposed bridge at Qantara, Ferdan and Ismailiya is located within the area covered by both the Qantara and Ismailiya Radar Stations, whilst the Srabuiom bridge site is covered by both the Ismailiya and Great Bitter Lake Radar Stations.

3) Radar Functioning

It is anticipated, but will require confirmation by SCA after selection of the bridge site location, that as a vessel leaves one radar area and passes under bridge into the next radar area, that the tracking information will be satisfactorily transmitted to the Operation Center.

However, it is quite possible that the tracking information may be interrupted by the bridge structure due to the shadow image created by the bridge. It will be difficult now to verify the effects of the bridge construction on the radar system by field trials at the proposed sites, because the new radar system is already operating.

4) Proposed Solution

In the mean time, due to the importance of navigation safety, some countermeasures will need to be considered to resolve the above issues. One solution would be to provide additional radar stations on both banks of the Canal in the vicinity of the proposed bridge. This would be the most suitable and practical solution for overcoming the potential problem created by the proposed bridge structure. The additional radar stations should be installed before commencement of the bridge construction works.

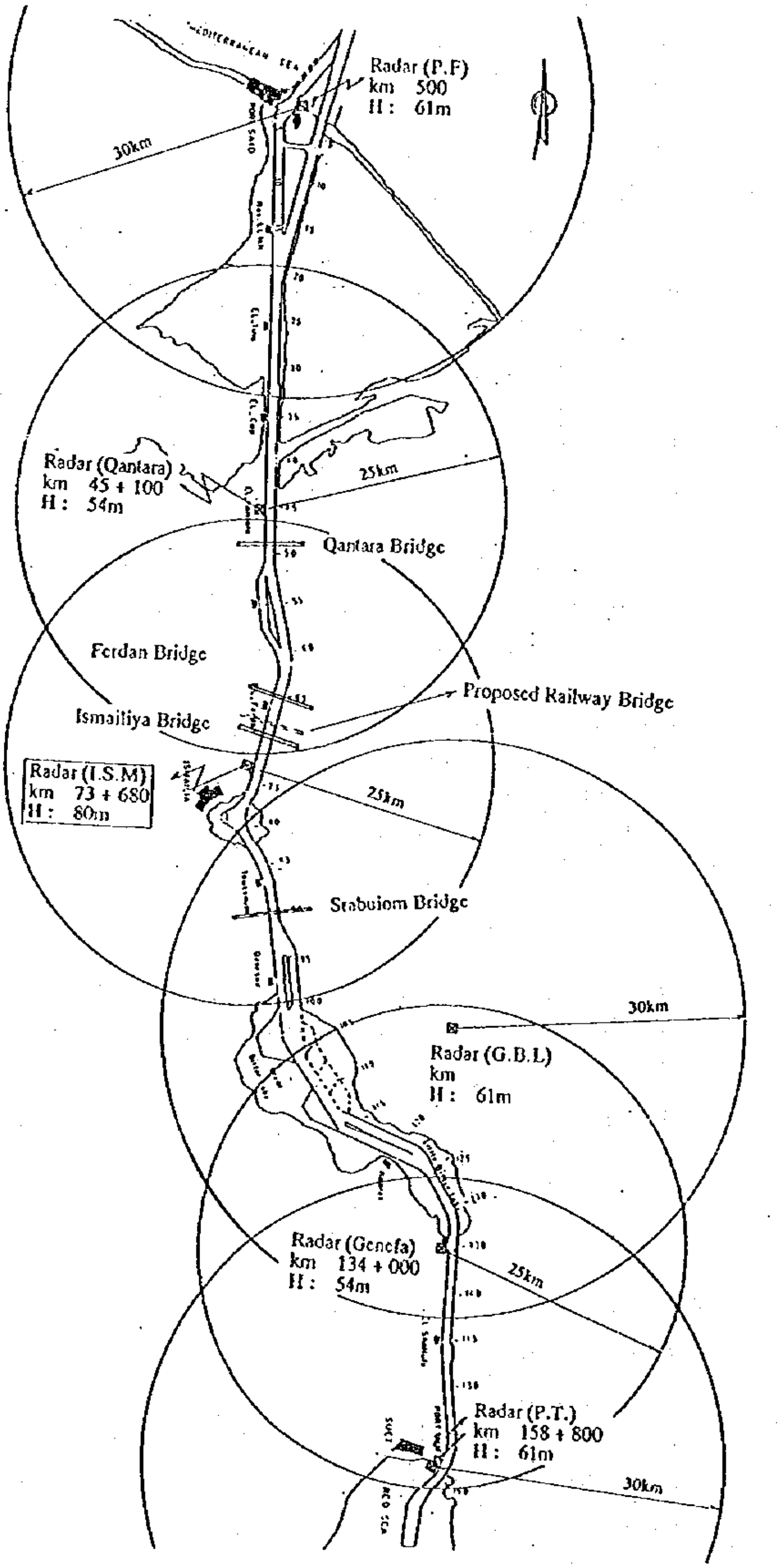


Fig. 6.5.8 **Location of Radar Stations and Proposed Bridge**

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

It should be added that as the shadow image induced by the proposed bridge must be fixed, improvement to the computer system of SCVTMS should be studied and implemented. This would help to reduce the costs of the countermeasures as well as improving the maintenance of the system to resolve the problems of continuous tracking of vessels.

(2) Risk Management and Countermeasures

1) Ship Collision

The following cases of ship collision with the piers of main bridge have been reviewed.

- Possibility of ship collision incidents
- The type of possible ship collision
- Calculation of ship collision force
- Protection against ship collision

It is considered that the possibility of the ship collision incidents with the bank of the Canal will be very low. In addition, as caisson foundation have been proposed for the pylons of the cable-stayed bridge, and the distance between the edge of the navigable channel and face of the caisson in more than 15 m, a direct ship collision with the pylon can not occur.

According to the results of the case study, inspite of the low probability of ship collision, the effects of the collision force are not significant on the design of the pylon caisson foundation.

The collision force anticipated as a result of the case study is shown in Appendix, Chapter 6, 6.5.

2) Prevention of shipping accidents

From the risk forecast due to the construction of the proposed bridge, additional safety measures to ensure the safe navigation of vessels passing along the Canal may be required. It is considered that there are four types of risk relating to the navigation safety of vessels on the Canal, as a result of the bridge construction.

a) Accident Prevention During Construction:

At all times during construction, when there are water borne activities a guard boat will be in attendance in the channel. In addition lookouts will be posted on both of the Canal banks to give early warning of the approach of ships.

The underside of the bridge deck will be fully decked in with false work, and the sides fully enclosed with wire safety netting to prevent any small falling objects from dropping through, and to ensure safety for the construction work at all times. The constructed section of the deck will also have guard rails installed on both sides to maintain safety of the works during construction.

b) Vehicle Containment and Control

The following traffic safety devices will be installed on the deck;

- Suitable crash barriers and curbstones.
- Lane marking by use of highly reflective paint.
- Painting of the curbstones.
- Installing colored reflectors on curbstones or in the pavement.

In addition to these safety devices, the following measures should be taken or enforces;

- No vehicle overtaking on the bridge
- No vehicle parking on the bridge

However, it is impossible to fully prevent accidents caused by reckless drivers even with the best engineering traffic safety measures taken from an engineering aspect. The traffic safety will be further increased by implementing the necessary by temporary physical controls, combined with education of the drivers and rigid enforcement of the safety rules.

c) Protection from Falling Items in Normal Service

To prevent an accident due to fragments or articles falling from the bridge deck, the simplest solution will be to provide tall fences or barricades on both sides of the deck.

However, the provision of this type of protection, even if it is made from wire netting is very difficult to successfully achieve when incorporated into cable stayed type of bridges.

It is also very difficult to prevent the arbitrary throwing of objects from vehicles on the bridge deck unless the traffic can be kept away from the bridge deck or the bridge deck is enveloped by wire netting or similar protection.

However, the installation of these physical type barriers can be detrimental to the aero dynamic profile of the bridge structure. To ensure stability against wind action, a static analysis of the bridge, as well as a study of the dynamic phenomena induced by wind action, on flexible structures like suspension bridges, cable-stayed bridges and tall towers should be made.

The quantitative evaluation, by analysis only, of the dynamic phenomena resulting from wind action is very complicated and difficult to achieve. Therefore, the verification of the aero-dynamic stability of the bridge will be made by wind tunnel tests for effects such as vortex oscillation, galloping, torsional flutter, etc.

For cable-stayed bridges, the aero-dynamic stability is the most important issues, and a large number of the aero-dynamic tests have been done to date. Based on these results, and on experience, a stable deck section will be selected for the cable-stayed bridge. Tests to confirm the sectional features of the deck structure will be necessary.

Therefore, based on the above, the provision of tall fences is not recommended, as it could be determined to the stability and security of the bridge structure against the wind forces.

A possible solution to this problem would be the installation of CCTV cameras along both sides of the bridge with appropriate monitoring and police control to forestall any such incidents occurring.

d) Navigation Lighting

To ensure the safe navigation for vessels using the Canal, navigation lights will be installed along the under side of the deck girder of the bridge, indicating the navigation width of 270 m for Qantara or 250 m for the other three locations respectively. The lighting will also be installed at the deck level and at the pylons bases if required.

6.6 Tunnel Crossing

(1) General

Regardless of whether two or four lanes are selected as the recommended solution, or if the gradients are 4 % or 3.3 %, the total tunnel structure arrangements will be similar.

Thus in the following description, unless stated otherwise the commentary applies to all the options.

The four preferred route alignment options at each crossing location are briefly identified in 5.6.1 below at the selected SCA kilometer chainages.

6.6.1 Alignment and Profile

(1) Qantara Km.48 + 650

The route alignment is effectively perpendicular to the Canal and the portal and approach cuttings will be located in the low lying are. (ground level less than 2.5 m)

To avoid potential flooding problems the ground will be built up to + 2.5 m above datum in these areas.

(2) Ferdan Km.65 + 020

The route alignment is effectively perpendicular to the Canal and the portal and approach cuttings will be located in the low lying areas (ground level less than 2.5 m). The ground will be built up to + 2.5 m above datum in these areas.

(3) Ismailiya Km.69 + 775

This route alignment is also perpendicular to the Canal, but the portal and approach cuttings will be located in the higher level ground areas (ground level greater than 5.0 m). To avoid unnecessary additional tunnel length being constructed the ground will be reduced to + 5.0 m above datum in these areas.

(4) Srabuiom Km.89 + 850

This route alignment is also perpendicular to the Canal, and the portal and approach cuttings will be located in the higher level ground areas (ground level greater than 5.0 m).

The ground level on the West Bank will require relatively minor grading to reduce it to the required level, but on the East bank, more extensive ground reduction will be required. The same situation prevails for the tunnel crossing beneath either the single (existing) channel or the dual (future bypass) channels.

(5) Summary

In general at all of the selected locations, the tunnel and access road will have the same horizontal alignment as the bridge routes. The length of the tunnel will depend on the ground levels surrounding the portal structure, which have been discussed above in this Section.

The shorter tunnel routes (ground level at +2.5 m) will be around 1,800 m long between the portal headwall faces, and the longer routes (ground level at +5.0 m) about 1,910 m. See Fig. A6.2.33 in the Appendix).

The access road at Qantara on the West Bank, connecting to the Post Said - Ismailiya divided highway will differ from the bridge solution here, as it will junction directly with this highway at the rotary, without the need for the elevated spiral connection proposed for the bridge.

In the case of a 3.3 % gradient at this location however, the access route would have to swing to the south of the military area and junction with a rotary on the Port Said - Ismailiya road to Suez.

6.6.2 Tunnel Structure

(1) Tunnelling Methods

1) Option Selected

As described in Section 6.2.2 the geology has been confirmed as being predominantly saturated sands and gravel with occasional silt/clay layers.

Therefore the selection of a slurry type TBM is the recommended method for excavating and constructiing this tunnel. This type of TBM has already been well demonstrated in the recent successful tunnelling of the El Salaam Siphon and the Greater Cairo Metro tunnels. In both of these projects very similar ground conditions exist and the TBMs, have performed very well, with high advance rates (GCMC achieved 565 m advance in December 1995, of an 8.35 m i.d concrete segmental tunnel.)

(2) Tunnel Lining

1) Alternative Solutions

Two options were discussed here:

a) Primary Segmental Lining, and
b) Primary Segmental plus in-situ Secondary Lining

The benefits of each are further discussed below:

2) Primary Segmental Lining

This option would result in a slightly smaller diameter tunnel, and would also achieve a shorter and more economic construction time. This will be demonstrated below.

The lining will consist of 9 segments plus a key stone produced from high quality very dense concrete (fc = 480 kg/cm" cylinder) to very precise dimension tolerances.

The segments will each include a continuous EPDM gasket, designed to withstand the full water pressure, and allow for construction errors, located in the outer area of the segment section.

As a backup to this, in the event of tunnel lining deflection during Canal deepening an inner hydrophilic (expands in contact with water) type continuous gasket will also be fitted.

The proposed detail is shown in Fig. 6.6.1.

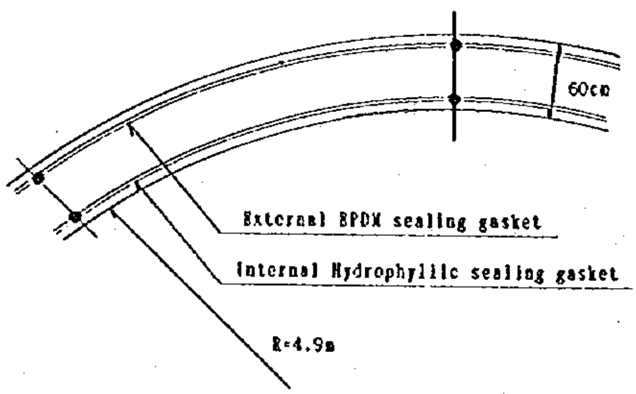


Fig. 6.6.1 Primary Tunnel Lining only, Double Sealing Gasket System

The segments will have an internal diameter of 9.8 m and be a nominal 1.2 m wide (along tunnel axis) and 60 cm, thick. The reinforcement will be epoxy coated to prevent corrosion by exposure to the saline water, should any damage be sustained to the concrete during handling and erection.

A complete ring will weigh approximately 56.5 Tonnes and each segment 6.1 Tonnes maximum. This will be well within the normal handling capacities of large diameter TBMs.

3) Primary Lining plus Secondary Lining

This option will require a larger diameter primary lining to maintain the roadway clearances. The primary lining will be similar to that described in Section 6.6.2 (2) above but will include only the external EPDM gasket and will be a nominal 50 cm thick with an internal diameter of 10.4 m.

The primary lining ring will weigh approximately 47.0 Tonnes and each segment a maximum of 5.1 Tonnes.

The secondary lining will be cast in-situ reinforced and unreinforced concrete using steel forms, but will be fully enveloped with a continuous PVC membrane in conjunction with a layer of geotextile (fleece) material fixed to the primary lining.

The concrete will be 30 cm thick and reinforced, where required to resist any deformation of the tunnel lining which may be induced by the future deepening of the Canal.

This is the preferred technical solution for long term durability of the structure, but the additional costs and time for construction will require consideration when selecting the best solution for the Tunnel Crossing. The proposed detail is shown in Fig. 6.6.2.

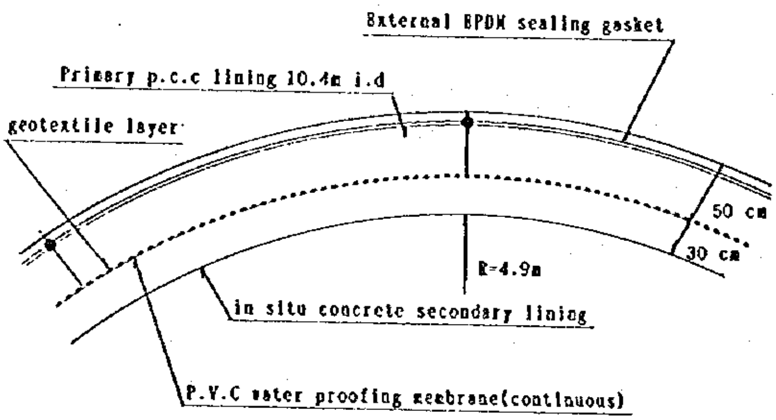


Fig. 6.6.2 Primary and Secondary Lining, Single Sealing Gasket System Plus Continuous P.V.C Membrane

The general tunnel section arrangements for these options are shown in Fig. 6.6.3 and 6.6.4, respectively.

6.6.3 Portal Structures

(1) General Requirements

The Portal Structure is the ground support structure at the interface between the tunnel and the approach cutting. It provides ground support to the vertical faces required to facilitate the commencement of the tunnel construction, and provides a suitable structure within which the facilities control building, drainage sump and electrical and mechanical rooms can be constructed.

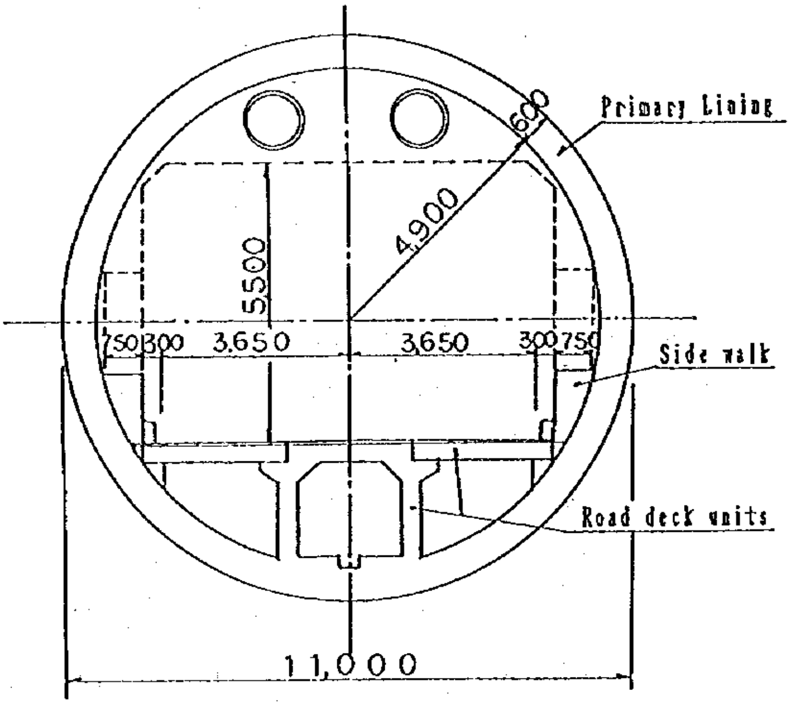


Fig. 6.6.3 Tunnel Section Showing Primary Lining only

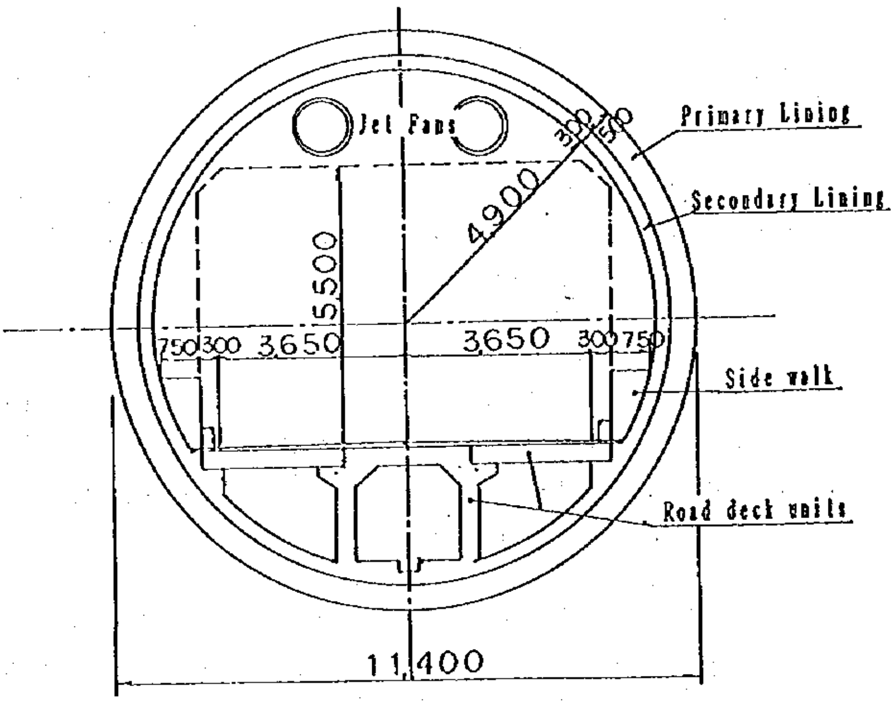


Fig. 6.6.4 Tunnel Section Showing Primary and Secondary Lining

(2) Portal Structure

1) Temporary Structure

To provide adequate clearances for assembly and dismantling of the TBM (one such activity for each tunnel) the internal free width required will be approximately 37 metres.

The maximum clear standing height at the tunnel face during construction will be approximately 23 metres. The structure will be formed using interlocking low strength bored piles, as this method is considered the most economic in this situation.

The side walls will be restrained using steel walings in conjunction with ground anchors and H shape steel sections within the alternate piles.

The headwall will require a more complex restraint arrangement to facilitate the TBM entry and exit i.e.two 11.9 m circular areas of unreinforced weak concrete will be required. Within these areas long fibreglass dowel ground anchors will be placed to provide restraint, whilst not impeding the TBM's ability to excavate through the headwall face.

The remaining head wall areas will be restrained in the same manner as the side walls.

Adequate toe-in will be provided to ensure stability of the structure during excavation to full depth, prior to construction of the heavy duty base slab upon which the TBM will be assembled and launched.

This slab will be designed to accommodate the full weight of the TBM, and also to resist any uplift from the ground. It is anticipated that dewatering will be required prior to excavation of the approaches and portal area, and in addition full ground treatment will be undertaken for a distance of about 20 m from the headwall to facilitate TBM launch and reception.

A suitable thrust block comprising tunnel rings encased in reinforced concrete, to enable the TBM thrust rams to propel the machine forward into the ground through the headwall will also be installed within the portal structure. This arrangement is shown in Fig. 6.6.6.

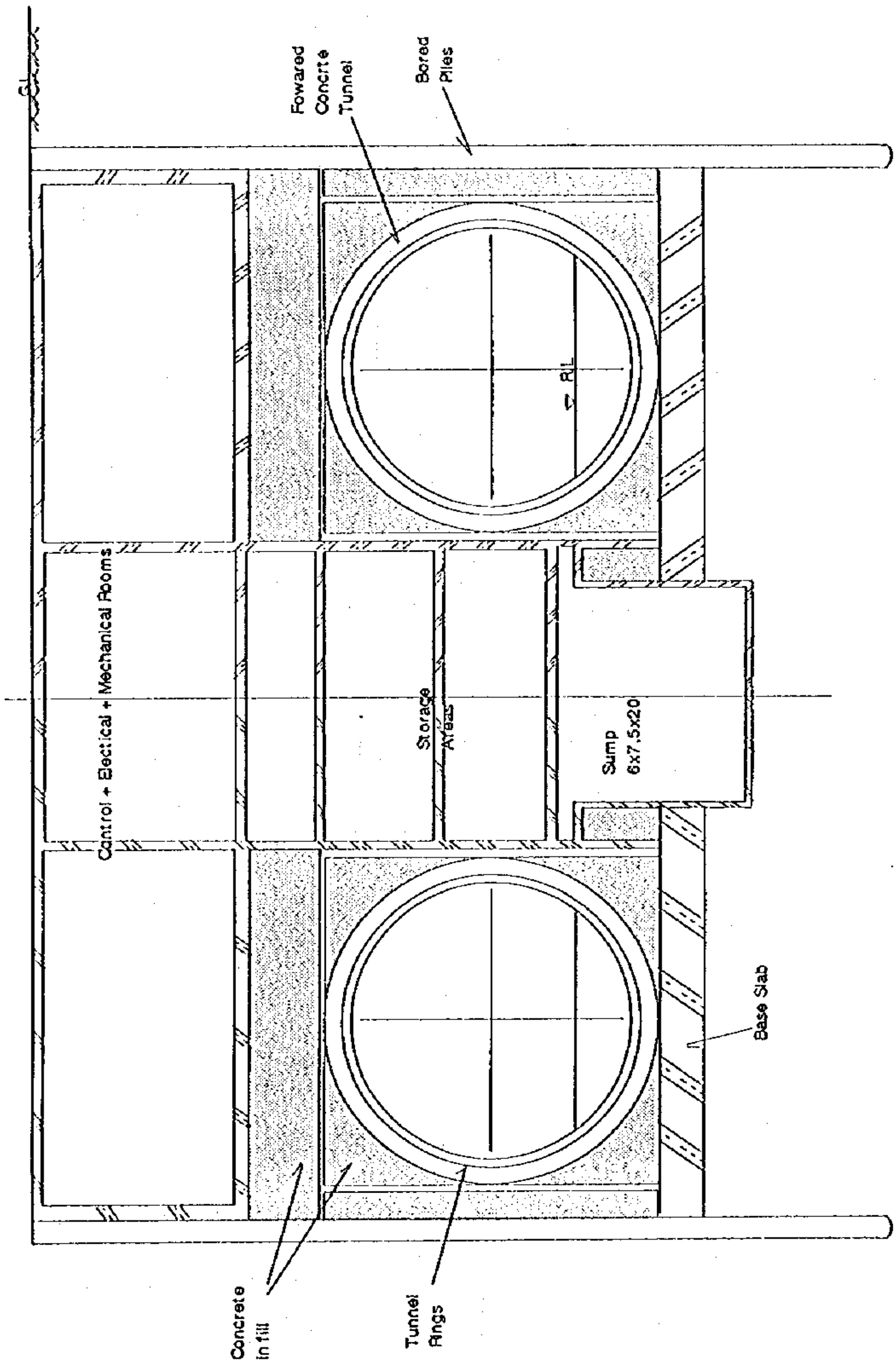


Fig. 6.6.5 Section Through Portal Structure

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

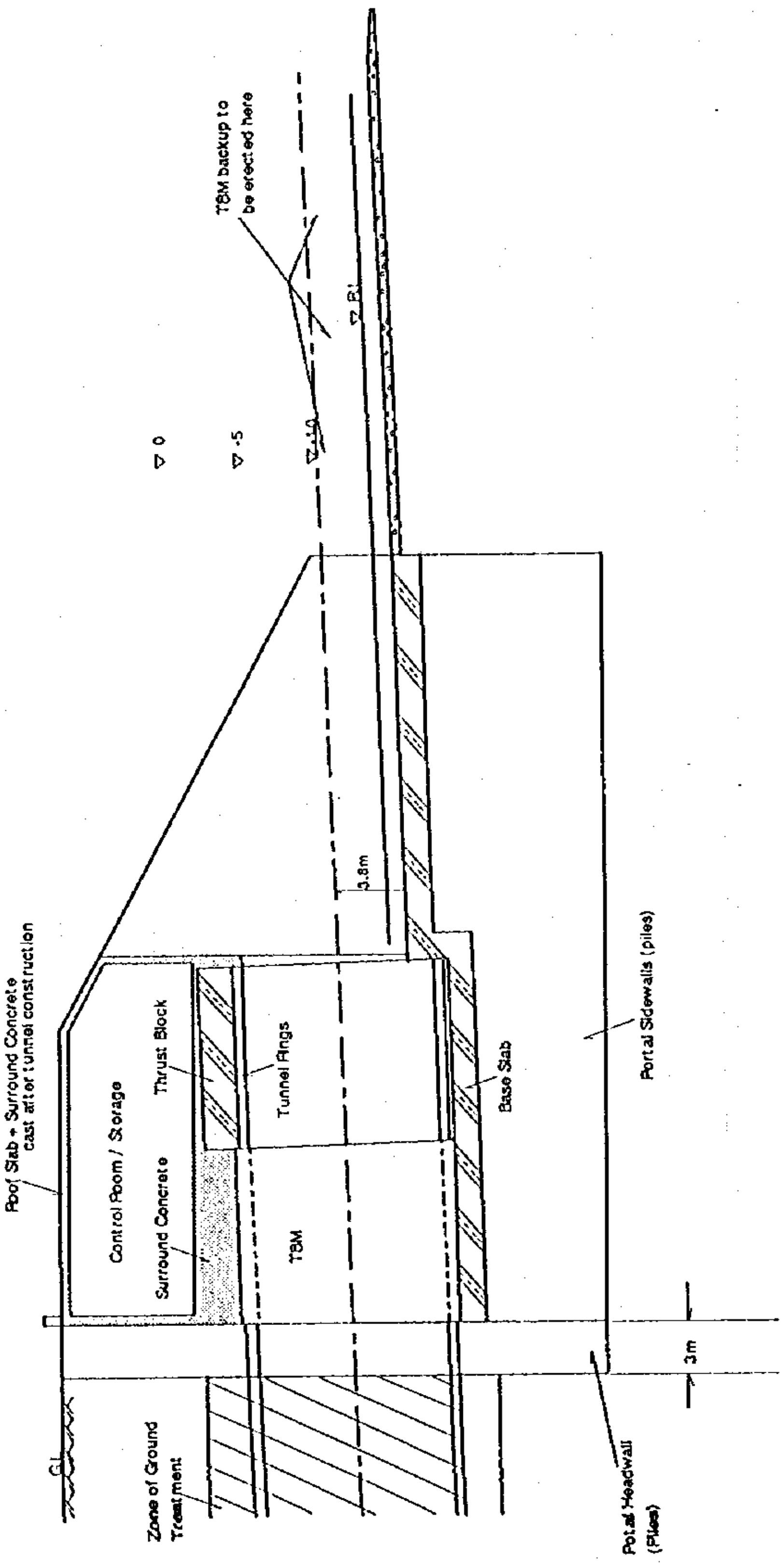


Fig. 6.6.6 Sectional Elevation Through Portal

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

The remaining space within the potal structure, above the tunnel lining can be used to accommodate the main control room and associated equipment and welfare rooms.

The main collector sump for rainwater run off and any seepage water from the approaches will be located beneath the tunnel invert level between the two roadways as shown in Fig. 6.6.5.

6.6.4 Approach Cuttings

(1) General

The cutting provides the means of access for the roads to the tunnel portal.

(2) Principal Features

It is anticipated that dewatering will be required to permit the excavation to the appropriate depths. The side slopes will be constructed with a batter of 1:1.5 (V:H) and incorporate horizontal berms at 7 m vertical height intervals.

6.6.5 Construction Methods and Schedule

(1) Early Ordering Key Materials and Equipment

Early ordering of the TBM and tunnel lining segments will be essential to ensure that the construction sequence is not disrupted or delayed. This should be done immediately upon award of the construction contract.

A description of the construction sequence and construction method can be found in Appendix A 6.5.2.

(2) Schedule

1) General

The schedules for constructing the Tunnel crossing have been prepared for the following alternatives using the twin tunnel with secondary lining as the base case:

- Twin Tunnels - Primary and Secondary Lining
- Twin Tunnels - Primary Lining only
- Single Tunnel - Primary and Secondary Lining

The schedules for the Twin Tunnels solution are shown below in Fig. 6.6.7 to 6.6.9. The times for completion of the principal tunnelling activities are as follows.

2) Twin Tunnels - Primary and Secondary Lining

- TBM Preparation and Assembly - 16 months
- Completion of Primary Tunnel Lining - 36 months
- Completion of Secondary Lining and Road and Deck - 53 months
- Completion of construction - 59 months

3) Twin Tunnels Primary Lining only
(Road deck constructed during tunnel construction)

- TBM Preparation and Assembly - 16 months
- Completion of Tunnel Lining plus Road Deck - 36 months
- Completion of Construction - 42 months

These two alternatives show that the crossing will be completed after approximately 5 years and 3.5 years respectively.

4) Single Tunnel - Primary Lining and Secondary lining

- TBM Preparation and Assembly - 16 months
- Completion of Primary Tunnel Lining - 25 months
- Completion of Secondary Tunnel Lining and Road Deck 42 months.
- Completion of Construction - 48 months

This shows that a single road crossing can be completed in 4 years.

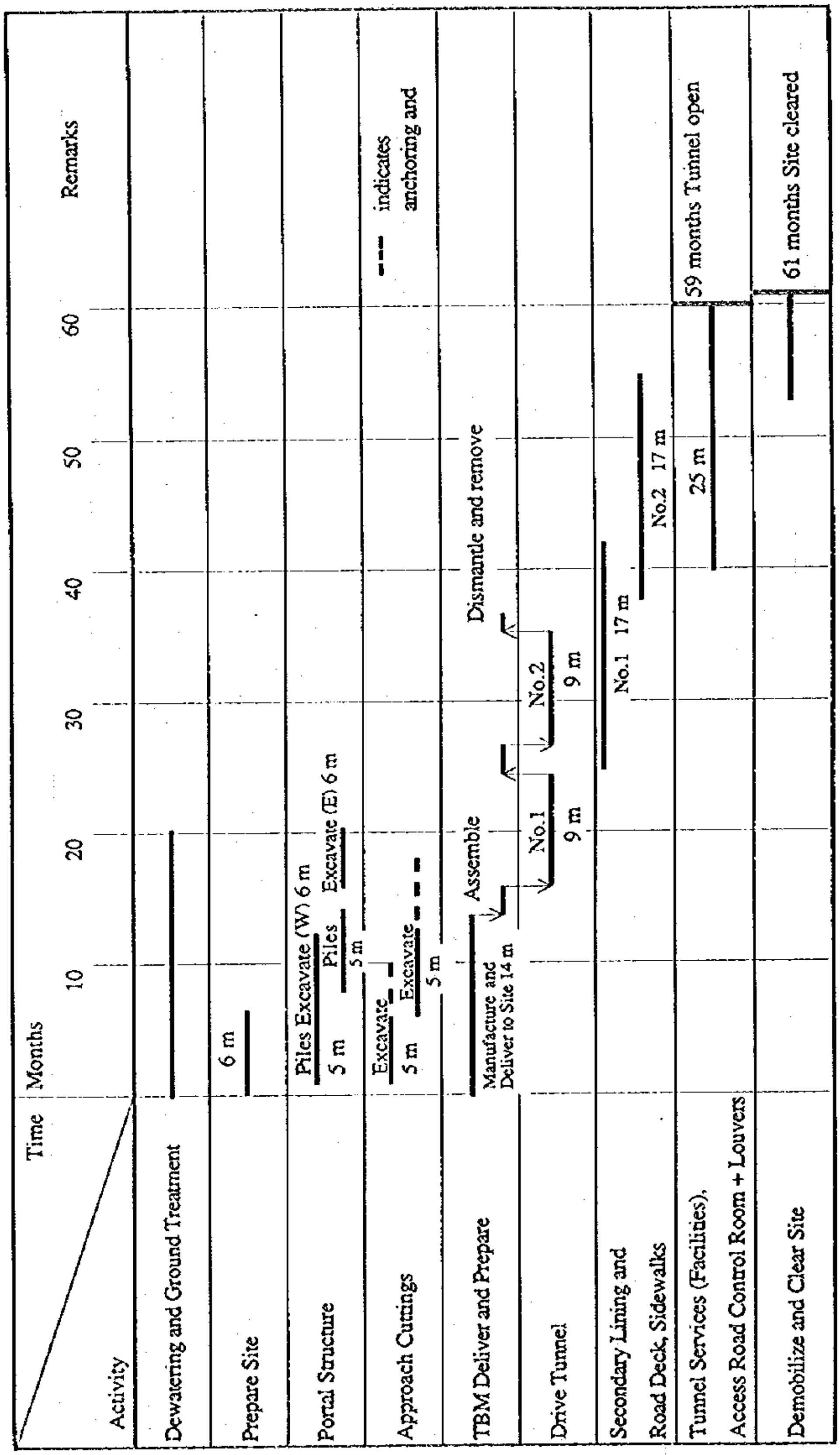


Fig. 6.6.7 Construction Schedule for Twin Tunnel - Primary Lining + Secondary Lining

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

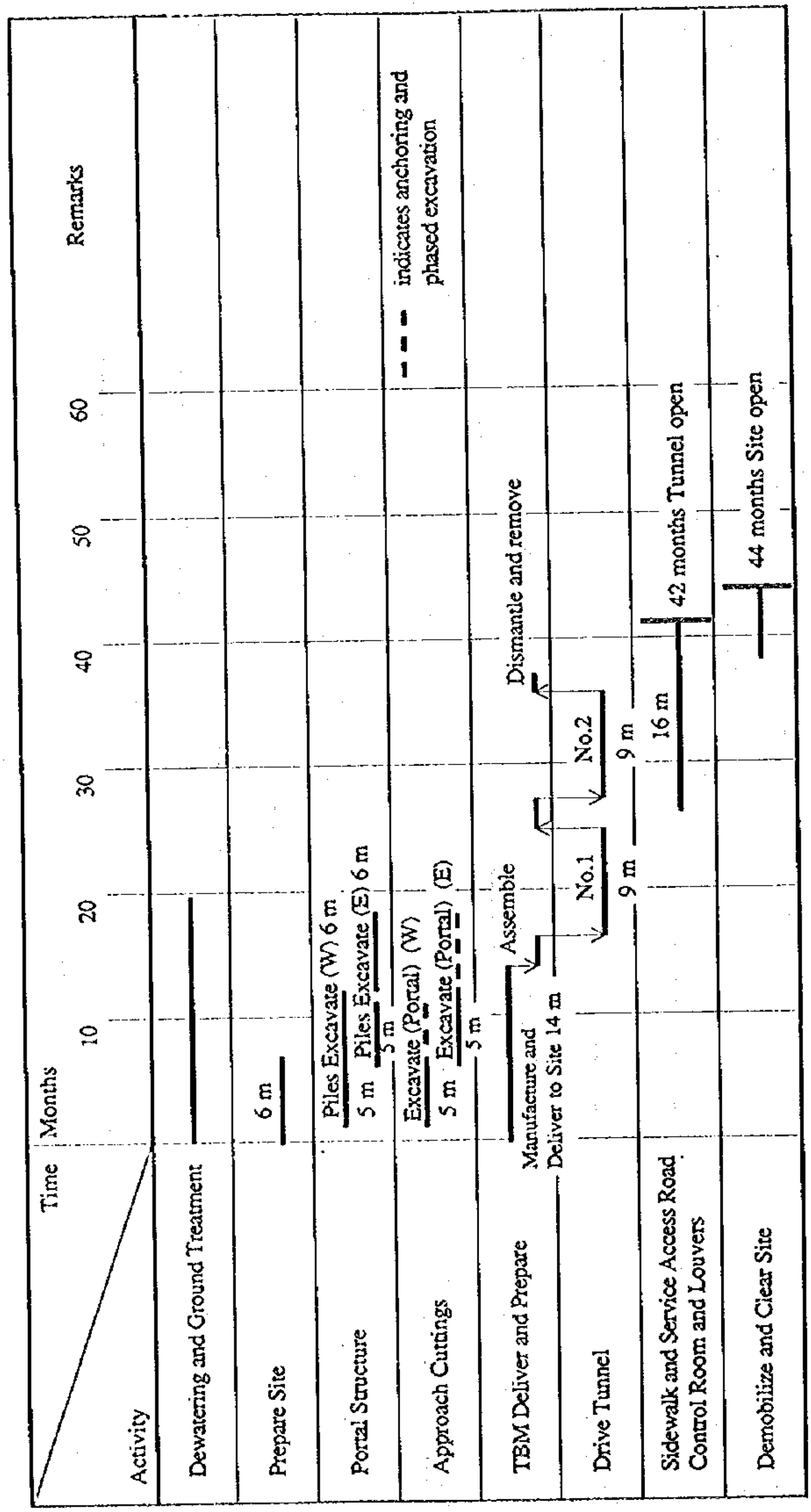


Fig. 6.6.8 **Construction Schedule for Twin Tunnel - Primary Lining Only**

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

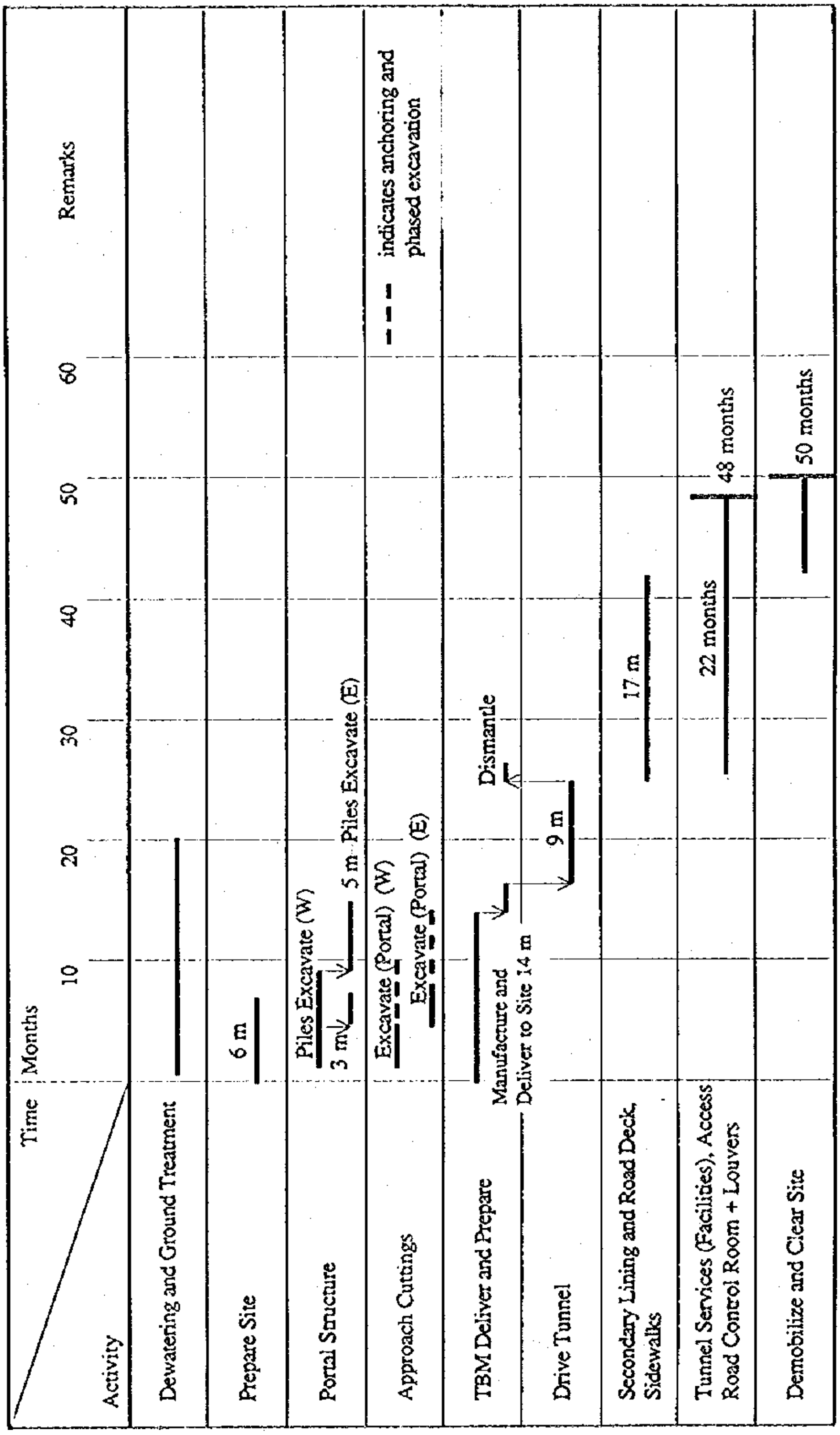


Fig. 6.6.9 Construction Schedule for Single Tunnel - Primary + Secondary Linig

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

6.6.6 Temporary Facilities

(1) General

For the tunnel construction option two job sites will be required. The main one would be located on the West Bank whilst the secondary site would be on the East Bank.

1) West Bank Facility

This would be established at the very start of the construction contract. The future tunnel access road, connecting the crossing to the existiing highway, should be set out and a temporary site access route prepared. The site facility should be located adjacent to the top of the approach cutting ramp with the access route forming one boundary. The site area can be divided into three distinct areas:

- Segment Storage
- Work and Storage area
- Welfare area

The whole area should be enclosed within a security fence with full time security guards in attendance.

The principal features of the work site will include the following facilities:

- Segment storage area with access ways
- Equipment Yard
- Slurry separation plant
- Concrete and Mortar Batching Plant + Aggregate Bins
- General Materials storage area
- Generators and Compressor Sheds
- Workshops, Stores and Fuel Tanks
- Canteen, Changing and Medical Rooms
- Offices and Car Parking Areas
- Motor Launch for Cross Canal usage

It is estimated that:	Segment Storage	= 1 Hectare
	Main Site	= 2 Hectares
	Total	= 3 Hectares

2) East Bank Facility

The establishment of this facility will be required early in the construction contract, prior to the portal piling and approach cutting excavation work commencing on the East Bank. The preparation of the future tunnel access road will only be required at this stage if no existing roads exist. The main access to the site, apart from the segment supply will be across the Canal using the nearest SCA ferry service.

It is envisaged that the segments would be delivered via the AH Tunnel route. The site should again be similarly located to the West Band Site and will have a similar but smaller area layout.

The facilities will be similar to those on the West Bank except that the generators and compressors will not be required, apart from mobile types, as the supply for tunnel driving can be routed through the previously constructed No. 1 Tunnel. The Batching Plant facility will only be required for the Portal piling works and the tunnel lining grouting mortar, and will have much less capacity than the West Bank.

It is estimated that: Segment Storage = 1 Hectare
Main Site = 1 Hectare
Total = 2 Hectares

(1) Principal Temporary Facility Items

The main items and their capacities are listed below in Table 6.6.1.

Table 6.6.1 Main Facility Items

Item	Capacity	Remarks
Generators	5,000 KW and 11 KV	Total Project Demand
Slurry Separation Plant	2,000 m^3/hr	West Bank-move to East Bank
Concrete Batcher	50 m^3/hr 25 m^3/hr	West Bank East Bank
Tunnel Ventilation	2,400 m^3/hr	Minimum Capacity
Water Supply		Pump from Sweet Water Canal

Source: Study Team

6.6.7 Tunnel Facilities

(1) General

In order to provide a safe and smooth traffic flow, various supplementary tunnel facilities are to be provided. These include such facilities as buildings and mechanical, electrical and communication equipment.

These tunnel facilities are generally classified as shown in Fig. 6.6.10.

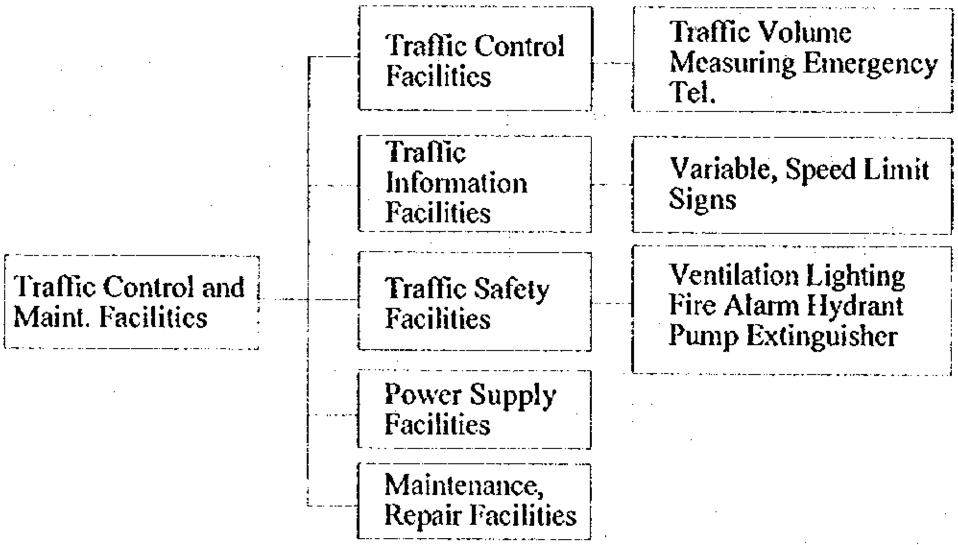


Fig. 6.6.10 Traffic Control and Management Facilities

(2) Facilities Installation

The provision and installation of the tunnel facilities requires specialist input, and this is normally provided in the form of sub-contractors to the main contractor.

The installation of the facilities would commence after installation of the basic tunnel structure, ie, the secondary lining, road deck and walkway.

Where possible the activities within the tunnel should progress from one portal to the other, to avoid conflict with the other activities, and follow in sequence from one tunnel to the other.

In some cases these works will precede the tunnel finishes, whilst in others they will work in parallel with or follow on.

Finally all the system will be connected to the control room area, tested and commissioned . Further information on the type of the facilities proposed can be found in Appendix A.6.2.8.

6.6.8 Cost Estimation

(1) General

The cost estimation has been compiles using information gained from the current tunneling activities in Egypt (Cairo Metro and El Salaam Siphon Tunnels) in conjunction with experience of the requirements for this type of work.

1) Labor Costs

For the specialist works, ie., the tunnel driving, portal structures and secondary lining activities, the supervisory and key personnel have been allocated to expatriate staff. It has been assumed that during the course of the work Egyptian personnel will benefit from the experience and Technology transfer, and for the construction of the No. 2 tunnel the expatriate involvement has been reduced.

2) Materials

Where possible the local products have been used for costing, based on local rates. However for specialist products, in particular tunnel waterproofing materials , tunnel facilities equipment and TBM special oils and lubricants which are not obtainable in Egypt, imported prices in US currency have been used.

3) Equipment

All standard equipment used in construction is generally available in Egypt, and local currency prices have been used. The specialist items manufactured abroad, i,e, the TBM and associated equipment, plus the secondary lining special formwork comprise the majority of foreign currency costs.

(2) Costing Philosophy

Quotations were requested from specialist manufacturers both in Europe and Egypt for specific items and services, and these were incorporated into the costing build up. The associated works and activities were calculated using the normal procedures of quantities and durations.

(3) Other Costs

1) Contingencies

A physical risk contingency of 10 % of the basic estimated construction cost has been allowed to cover unforeseen construction events. This is normal procedure in the industry.

A price escalation contingency of 3 % per annum has been assumed based on the US currency inflation rate.

2) Indirect/Overhead Costs

The indirect cost/overhead cost includes all costs necessary for preparatory works including a work camp, construction of contractor/consultant's office, laboratory and welfare facilities, transportation cost of materials and equipment, site office management and maintenance cost, and contractor's general overhead costs. A figure of 20 % of the sum of the basic construction and contingency cost has been assumed for these costs.

3) Engineering Cost

A sum of 8.4 % has been added to the total cost, including the above contingencies and indirects, to allow for consultants design and site supervision costs. This value has been selected to reflect the higher degree of site supervision required or those types of large diameter TBM.

4) Land Acquisition and Compensation Cost

A unit price of 15,000 LE per 0.4 ha has been used for the cultivated areas on the West Bank only, with no cost being allowed forth East bank desert areas.

A resettlement allowance has been included based on resettlement of 3 houses per one kilometer of access road.

(4) Summary

The costs were calculated for a "base case" condition using the primary and secondary lining proposal and primary lining only.

The costs for each location using a 4 % and 3.3 % road gradient were then developed, and the additional costs due to the future Canal development at Srabuiom projected. A single tunnel "base case" option was also costed. The summary of all these options is shown in Table 6.6.2.

The cost savings envisaged using the double gasketted preliminary tunnel lining only solution were less significant than anticipated, and whilst there is a considerable saving in time for constuction, the overall long term benefits to the Canal crossing structure do not merit the use of this option. Therefore the cost detail for this option have not been included Table 6.6.2 Summary of Tunnel Costs.

The cheapest twin tunnel which provide 4 traffic lanes option is at Qantara with Ferdan marginally more expensive. Therefore Qantara Canal crossing is the recommended solution for the tunnel option on the basic of price only.

Table 6.6.2 Summary of Tunnel Costs

Location	Gradient	Basic Cost (million US$) = A				Physical Contingency (A x 10 %)	Price Contingency (A x 13 %)
		Tunnel	Approach Road	Access Road	Sub Total		
Qantara	4.0%	124.0	6.2	2.6	132.8	13.3	17.3
	3.3%	135.0	6.6	2.4	144.0	14.4	18.7
Ferdan	4.0%	124.0	6.3	2.8	133.1	13.3	17.3
	3.3%	135.0	6.8	2.6	144.4	14.4	18.8
Ismailiya	4.0%	128.4	8.5	2.9	139.8	14.0	18.2
	3.3%	141.8	9.3	2.6	153.7	15.4	20.0
Srabuiom	4.0%	128.4	9.1	0.8	138.3	13.8	18.0
	3.3%	141.8	10.1	0.4	152.3	15.2	19.8
Ferdan *	4.0%	90.4	7.3	1.9	99.6	10.0	12.9
Srabuiom (widening)	4.0%	151.9	10.8	0.5	163.2	16.3	21.2

		Subtotal (B)	Indirect Cost (B x 20 %)	Engineering C. (B x 8.4 %)	Land Acquisition Compensation C.	Grand Total
Qantara	4.0%	163.4	32.7	13.7	0.3	210.1
	3.3%	177.1	35.4	14.9	0.3	227.7
Ferdan	4.0%	163.7	32.7	13.8	0.4	210.6
	3.3%	177.6	35.5	14.9	0.4	228.4
Ismailiya	4.0%	172.0	34.4	14.4	0.4	221.2
	3.3%	189.1	37.8	15.9	0.4	243.2
Srabuiom	4.0%	170.1	34.0	14.3	0.1	218.5
	3.3%	187.3	37.5	15.7	0.1	240.6
Ferdan *	4.0%	122.5	24.5	10.3	0.1	157.4
Srabuiom (widening)	4.0%	200.7	40.1	16.9	0.1	257.8

Note: * Tunnel with 2 lanes carriageway - single tunnel only. All other cases with 4 lane carriageway - twin tunnels.
Source: Study Team

CHAPTER 7

EVALUATION OF ALTERNATIVES

CHAPTER 7 EVALUATION OF ALTERNATIVES

7.1 Evaluation of Crossing System Alternatives

(1) Crossing System Alternatives

1) Traffic Demand and Capacity

In accordance with the results of the analyses presented in Chapters 4 and 5, the relationship between future traffic demand and road capacity is summarized as shown in Fig. 7.1.1.

2) Crossing System

This results of the analysis which has been undertaken in Chapter 5, Sction 5,1 are as follows;

a. Limitation of Ferry Transport

There are major limitations to the ferry boat system in meeting future traffic demand in any of the socio-economic cases.

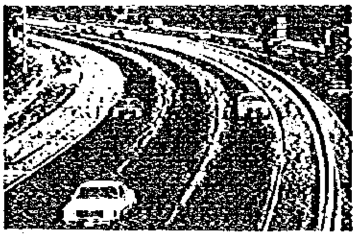
b. Construction Method

- A Four Lane Capacity Structure is required. This can be provided either by constructing a single four lane crossing structure or a double two lane crossing structure.

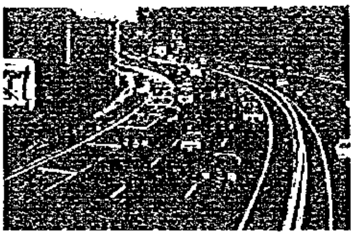
It would be necessary to construct a double two lane crossing structure in adjacent locations and operate one way traffic flow on each two lane crossing. This makes the capacity of the double two lane structures equivalent to a single structure.

c. Ferry Transport

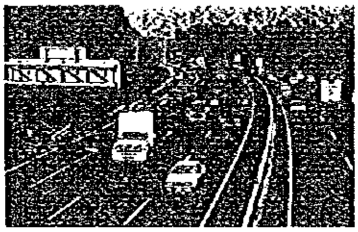
Regardless of the location or type of the crossing structures constructed, the ferry facilities will have to remain at the current ferry locations, although the ferry service may change due to fluctuations of traffic at the ferry stations, in particular at the station where the crossing structure has not been constructed.



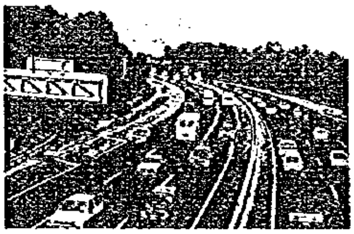
(1) Level Of Service A



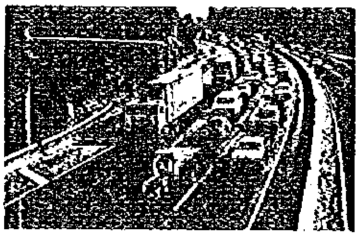
(2) Level Of Service B



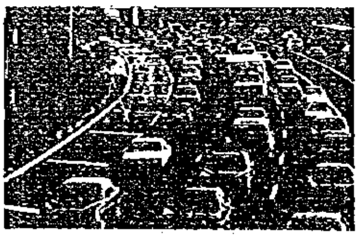
(3) Level Of Service C



(4) Level Of Service D

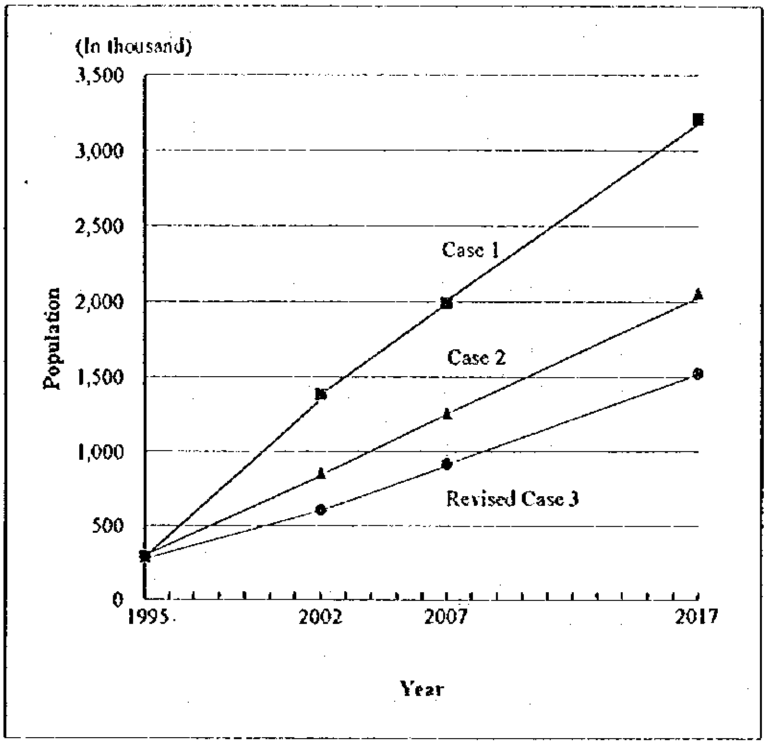


(5) Level Of Service E

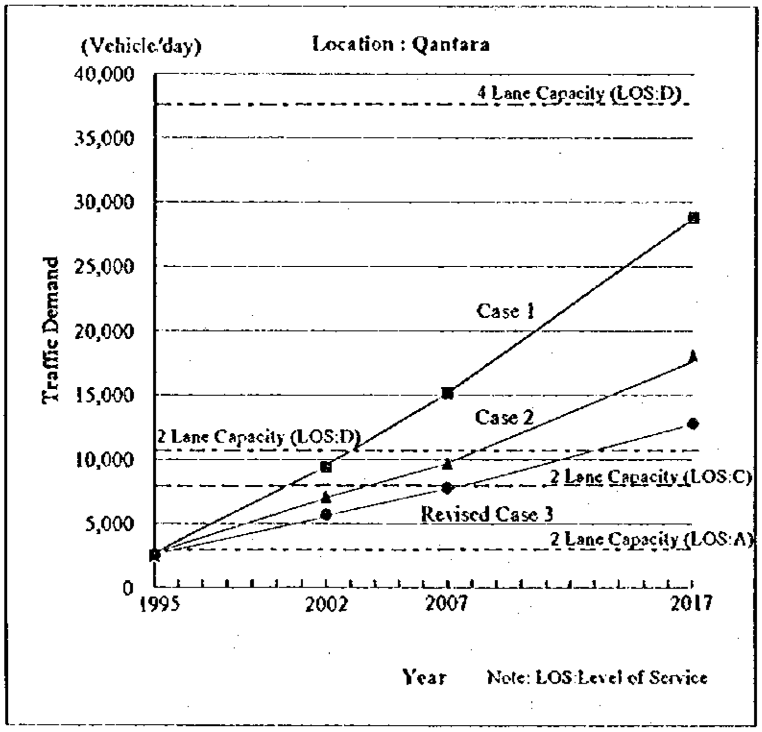


(6) Level Of Service F

Source : Highway Capacity Manual 1985



Future Population by Development Case



Traffic Demand and Capacity of the Crossing Structure

Fig. 7.1.1 Relationship between Traffic Demand and Capacity

THE FEASIBILITY STUDY ON A BRIDGE OVER NORTHERN PART OF THE SUEZ CANAL

3) Alternatives for Evaluation

Taking the above results into consideration, two alternatives crossing structures have been selected for evaluation.

- Construction of a four lane crossing structure or
- Construction of a two lane crossing structure initially and then a later stage, another two lane crossing structure is added when the traffic demand exceeds the first two lane capacity (so called staged construction). After completion of both, each two lane crossing structure will be used for one way operations. This approach will make it possible to provide full four lane capacity required.

Fig. 7.1.2 shows the schematic of the alternative crossing systems evaluated.

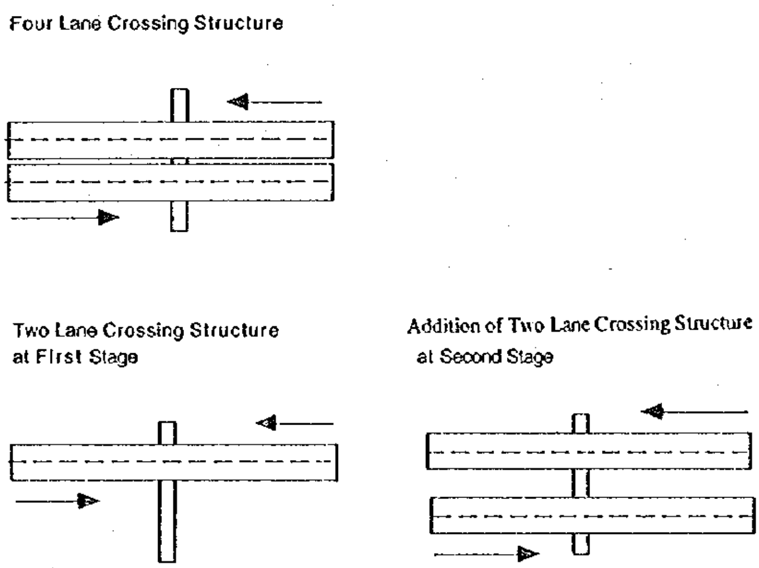


Fig. 7.1.2 Schematic of Construction Alternatives

(2) Evaluation

The following conditions have been used for evaluating the alternatives.

- The traffic demand of case 2 and the revised case 3 at Qantara have been used for comparison of the alternatives, because the staged construction alternative cannot be considered for case of 1. This is due to the fact that the future traffic demand under case 1 will exceed the two lane capacity in 2002 under the condition of Level of Service C.
- It is assumed that the crossing structure will be opened to the public in the year 2002.

- For the double two lane crossing structure alternative, the second two lane structure is assumed to be constructed in the year 2001 for case 2, and in the year 2009 for the revised case 3, as indicated by the projected future traffic demand under the condition of Level of Service C. (refer to Fig. 7.1.1)

- Only a vertical grade 3.3% has been used for cost comparison. Likewise, only construction and maintenance costs have been discounted at a 12% rate.

- Only the bridge alternative is subject to this evaluation.

Discounted costs for each case are tabulated in Table 7.1.1.

Table 7.1.1 Net Present Value

Case	Construction Stage	Cost (M. USD)	Remarks
Case 2	Four Lanes	99.5	2002 opened
Case 2	Double Two Lanes	114.7	2002 and 2005 opened
Revised Case 3	Double Two Lanes	95.6	2002 and 2009 opened

Note : Discount rate of 12% is used

The results of the discounted value indicate that the double two lane crossing structure for the revised case 3 shows the lowest value in the comparison ,followed by the four lane crossing structure. This means that if the initial volume and growth in traffic demand is small, the staged construction becomes the most attractive investment alternative. Also, under given assumptions, this investment alternative is the most preferable, when the second two lane bridge is constructed after the year 2008 (this critical year is obtained by calculation using the proportional method).

However, a major factor to be considered in this conclusion on the staged construction is that it depends mainly on a small future traffic volume and low growth rate. Another point is that the second two lane bridge has to be constructed at an adjacent location ,which will enable the required one way operations to use double two lane crossings. Otherwise this alternative would not make any sense at all. This is also assumed as indicated by the results of the four lane crossing structure for case 2 with a higher traffic demand. For this alternative the staged construction approach has no merit due to the high traffic volume and its growth rate. This is attributable to the higher construction cost for the double two lane crossing structure in comparison to that for the four lane crossing structure.

7.2 Evaluation of Structure Alternatives

7.2.1 Financial Cost Comparison

(1) Result of Construction Costs Comparison

As shown in Table 7.2.1 the lowest construction cost in market price is US$ 104.2 million for Srabuiom bridge (4% vertical grade), and the highest cost is US$ 242.4 million for Ismailiya tunnel (3.3% vertical grade). The bridge construction period is estimated to be 5 years between 1997 and 2001. The tunnel construction period is estimated to be 6 years between 1997 and year 2002.

Table 7.2.1 Comparison of Financial Cost and Prioritiy Rating

Unit: 1,000US$

Alternatives	Approximate Cost		Priority Rating
	4% V.Grade	3.3% V.Grade	
Qantra Bridge	123,400	138,900	4
Ferdan Bridge	117,800	134,400	3
Ismailiya Bridge	105,200	119,500	2
Srabuiom Bridge	104,200	118,500	1
Qantara Tunnel	209,200	227,000	5
Ferdan Tunnel	209,800	227,700	6
Ismailiya Tunnel	220,600	242,400	8
Srabuiom Tunnel	217,800	239,800	7

Note: Maintenance cost is not included

Ref.: Appendix Table 7.2.1 Yearly allocation of construction cost

(2) Result of Discounted Cost for Project Life to Market Price

Table 7.2.2 shows cost comparison of the different alternatives. Cost comparison was conducted up till year 2027. The average long term interest rate of 14% was used for the discount rate to obtain the present value. The left half of the table shows the market price composition, and right half the discounted present value composition.

Table 7.2.3 shows the summary of the discounted the present value of Table 7.2.2 for comparison. The least cost was found to be US$ 61.58 million for Srabuiom Bridge (4% vertical grade) and the highest cost US$ 133.40 million for Ismailiya Tunnel (3.3% vertical grade).

Table 7.2.2 Comparison of Discounted Present Value of Financial Costs

(4 Lanes, 4% Vertical Grade) Unit: US$ 1000

	Year	Construction and Maintenance Costs								Discount	Discounted Construction and Maintenance Costs							
		Bridge				Tunnel					Bridge				Tunnel			
		Qantra	Ferdan	Ismaili	Srabuio	Qantra	Ferdan	Ismaili	Srabuio	14.00%	Quantra	Ferdan	Ismaili	Srabuiom	Quantra	Ferdan	Ismaili	Srabuiom
1	1996	0	0	0	0	0	0	0	0	0.877	0	0	0	0	0	0	0	0
2	1997	2,468	2,356	2,104	2,084	4,184	4,196	4,412	4,356	0.769	1,899	1,813	1,619	1,604	3,219	3,229	3,395	3,352
3	1998	29,616	28,272	25,248	25,008	37,656	37,764	39,708	39,204	0.675	19,990	19,083	17,042	16,880	25,417	25,490	26,802	26,462
4	1999	43,190	41,230	36,820	36,470	41,840	41,960	44,120	43,560	0.592	25,572	24,411	21,800	21,593	24,773	24,844	26,123	25,791
5	2000	40,722	38,874	34,716	34,386	43,932	44,058	46,326	45,738	0.519	21,150	20,190	18,030	17,859	22,817	22,882	24,060	23,755
6	2001	7,404	7,068	6,312	6,252	43,932	44,058	46,326	45,738	0.456	3,373	3,220	2,876	2,848	20,015	20,072	21,106	20,838
7	2002	255	273	283	78	37,656	37,764	39,708	39,204	0.400	102	109	113	31	15,049	15,092	15,869	15,667
8	2003	255	273	283	78	1,500	1,510	1,620	1,470	0.351	89	96	99	27	526	529	568	515
9	2004	255	273	283	78	1,500	1,510	1,620	1,470	0.308	78	84	87	24	461	464	498	452
10	2005	255	273	283	78	1,500	1,510	1,620	1,470	0.270	69	74	76	21	405	407	437	397
11	2006	255	273	283	78	1,500	1,510	1,620	1,470	0.237	60	64	67	18	355	357	383	348
12	2007	255	273	283	78	1,500	1,510	1,620	1,470	0.208	53	57	59	16	311	313	336	305
13	2008	955	973	983	778	1,500	1,510	1,620	1,470	0.182	174	177	179	142	273	275	295	268
14	2009	255	273	283	78	1,500	1,510	1,620	1,470	0.160	41	44	45	12	240	241	259	235
15	2010	255	273	283	78	1,500	1,510	1,620	1,470	0.140	36	38	40	11	210	212	227	206
16	2011	2,555	2,573	2,583	2,378	1,500	1,510	1,620	1,470	0.123	314	316	317	292	184	186	199	181
17	2012	255	273	283	78	1,500	1,510	1,620	1,470	0.108	27	29	30	8	162	163	175	158
18	2013	255	273	283	78	1,500	1,510	1,620	1,470	0.095	24	26	27	7	142	143	153	139
19	2014	255	273	283	78	1,500	1,510	1,620	1,470	0.083	21	23	23	6	124	125	134	122
20	2015	955	973	983	778	1,500	1,510	1,620	1,470	0.073	69	71	71	57	109	110	118	107
21	2016	255	273	283	78	1,500	1,510	1,620	1,470	0.064	16	17	18	5	96	96	103	94
22	2017	255	273	283	78	1,500	1,510	1,620	1,470	0.056	14	15	16	4	84	85	91	82
23	2018	255	273	283	78	1,500	1,510	1,620	1,470	0.049	13	13	14	4	74	74	80	72
24	2019	255	273	283	78	1,500	1,510	1,620	1,470	0.043	11	12	12	3	65	65	70	63
25	2020	255	273	283	78	1,500	1,510	1,620	1,470	0.038	10	10	11	3	57	57	61	56
26	2021	2,555	2,573	2,583	2,378	1,500	1,510	1,620	1,470	0.033	85	85	86	79	50	50	54	49
27	2022	955	973	983	778	1,500	1,510	1,620	1,470	0.029	28	28	29	23	44	44	47	43
28	2023	255	273	283	78	1,500	1,510	1,620	1,470	0.026	7	7	7	2	38	39	41	37
29	2024	255	273	283	78	1,500	1,510	1,620	1,470	0.022	6	6	6	2	34	34	36	33
30	2025	255	273	283	78	1,500	1,510	1,620	1,470	0.020	5	5	6	2	29	30	32	29
31	2026	255	273	283	78	1,500	1,510	1,620	1,470	0.017	4	5	5	1	26	26	28	25
32	2027	255	273	283	78	1,500	1,510	1,620	1,470	0.015	4	4	4	1	23	23	24	22
	Total	136,730	131,588	119,248	112,918	246,700	247,550	261,100	254,550		73,344	70,132	62,814	61,585	115,409	115,756	121,803	119,902

Table 7.2.3 Comparison of Total Discounted Construction & Maintenance Costs for Project Life and Priority Rating in Market Price

Unit: 1,000US$

Alternatives	Approximate Cost		Priorities
	4% V.Grade	3.3% V.Grade	
Qantra Bridge	73,344	82,386	4
Ferdan Bridge	70,132	79,816	3
Ismailiya Bridge	62,814	71,155	2
Srabuiom Bridge	61,585	69,927	1
Qantara Tunnel	115,409	124,878	5
Ferdan Tunnel	115,756	125,278	6
Ismailiya Tunnel	121,803	133,401	8
Srabuiom Tunnel	119,902	131,605	7

Ref.: Appendix Table 7.2.2 maintenace and repairing unit cost of canal crossing facilities

Ref.: Appendix Table 7.3.3 Comparison of Discounted Present Value of Financial Cost of 3.3% V. Grade

(3) Conclusion

The least cost crossing facility over the Suez canal is Srabuiom Bridge. However the cost estimated reflects the market price, which is reasonable in the case when a private enterprise implements the project. When a government undertakes the project, it should be compared by the economic cost in which the affects on users (benefit) is considered. Thus low financial cost does not necessarily indicate the best priority rating.

7.2.2 Economic Cost Comparison

(1) Introduction

Comparison is made after an accurate evaluation of resources for different alternatives is expressed in economic values. Thus the financial cost arrived at in paragraph of 7.2.1 needs to be corrected to economic cost. The reason why correction need be made is summarized in Table 7.2.4. It makes comparison possible of the optimum use of national resources for the different alternatives.

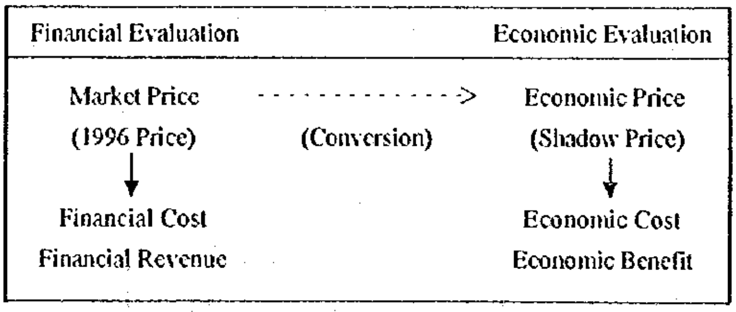


Fig. 7.2.1 Relationship Between Financial Cost and Economic Cost

Table 7.2.4 Items and Contents for Conversion to Economic Value of Market Price

Items	Price	Contents
1) Deletion of cost not related to project	Market Price Distortion:	Miscellaneous costs are not related to the project resource consumption, such as taxes and subsidies.
	Correction by Economic Price:	To be deleted because not related to competitive market economic activities
2) Foreign Materials	Market Price Distortion:	Official foreign exchange rate and tariffs are distorted.
	Correction by Economic Price:	To use US$ of international price determined by international competitive market.
3) Domestic materials	Market Price Distortion:	Price is distorted by regional difference, monopoly and by partial competition.
	Correction by Economic Price:	To remove influence of tax imposed on export, to make price closer to international free competitive
4) Labors	Market Price Distortion:	Wage is distorted by minimum wage low, number of jobless, and labor union
	Correction by Economic Price:	To apply shadow wage rate to unskilled labors to make the wage closer to real value of workers
5) Right of Way	Market Price Distortion:	Land price is distorted by speculation, social dignities, and by long term lent.
	Correction by Economic Price:	To calculate marginal productivity in order to make the price closer to free competition
6) Capital Market	Market Price Distortion:	Unsuitability of interest rate and financing a certain enterprise with good condition limits selection of optimum capital investment.
	Correction by Economic Price:	To allocate optimum investment resources by applying cost - benefit analysis to the capital opportunity cost.

Actual work for conversion is conduct according to the following steps.

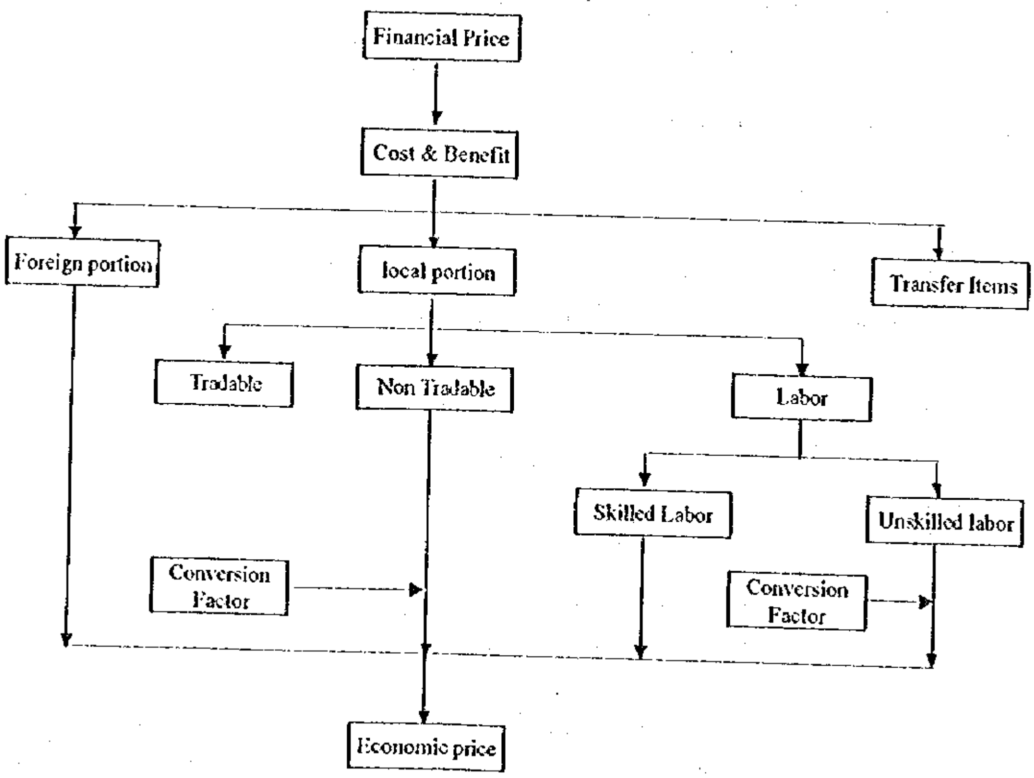


Fig. 7.2.2 Conversion Procedure Chart of Economic Price

In general, all the costs and benefits are divided into three categories; tradable goods, non-tradable goods and labor. Labor is further divided into skilled and unskilled labor. The cost of skilled labor is obtained by multiplying its market price by the Conversion Factor for Consumption (CFC), and the cost of unskilled labor is calculated by multiplying its market price by a rate of the Shadow Wage Rate and the CFC. Tradable goods are expressed by the CIF value for imports and by the FOB forexports. Asfornon-tradable goods, the economic price is obtained by multiplying their market price by the Standard Conversion Factor (SCF).

(2) Correction to Economic Price

Table 7.2.5 shows the corrected economic price of the financial cost. For each alternative the construction cost is divided into five cost items. Then each item is divided into the following six categories. 1) Foreign portion, 2) local tradable goods, 3) non tradable goods, 4) skilled labor, 5) unskilled labor, and 6) tax composition ratio. The financial costs are converted by adopting the following assumptions:

1) The tax portion is 5%, which is deducted from the financial cost to give the correct to economic price.

2) For the foreign and local tradable goods portions, the financial and economic cost is the same.

3) For the local non tradable goods, financial cost is corrected to economic cost by deducting 3 %, ie the market price SCF= 0.97.

4) For the skilled labor the market price is multiplied by the CFC=0.98 to correct to international price.

5) For the unskilled labor the market price is multiplied by the SWR=0.27 to obtain the international value.

Table 7.2.6 Comparison between Financial and Economic Cost of Construction

Unit: million US$

Alternatives	4% Vertical Grade		3.3%Vertical Grade	
	Financial	Economic	Financial	Economic
Qantra Bridge	123.4	105.6	138.9	118.9
Ferdan Bridge	117.8	100.8	134.4	115.0
Ismailiya Bridge	105.2	89.9	119.5	102.2
Srabuiom Bridge	104.2	89.3	118.5	101.6
Qantara Tunnel	209.2	166.3	227.0	180.5
Ferdan Tunnel	209.8	166.8	227.9	181.0
Ismailiya Tunnel	220.6	175.1	242.4	192.5
Srabuiom Tunnel	217.8	173.0	239.8	190.5

Ref. Appendix Table 7.2.4 Conversion to Economic Cost from Financial Cost (3.3 % Vertical Grade)

Table 7.2.5 Conversion to Economic Cost from Financial Cost

4 lanes, 4% Vertical Grade, Tunnel and Bridge — Unit: US$ 1,000

ternativ & Work	Investment Costs n Market Prices	Foreign Portion	Local Portion: Tradable Goods	Local Portion: Non-trada Goods	Local Portion: Skilled Labor	Local Portion: Unskilled Labor	Local Portion: Transfer (Tax)	Overall Conversio Factor	Investment Costs in Economic Prices
		1.000	1.000	0.97	0.98	0.27	0		
Qantara Tunnel									
Tunnel &	152,520	48%	4%	3%	24%	16%	5%	78%	118,584
Access R	10,680	16%	5%	3%	43%	28%	5%	69%	7,328
Indirect	32,600	80%	3%	3%	5%	4%	5%	87%	28,326
Engineer	13,100	87%			8%		5%	90%	11,769
Land Acq	300			100%				97%	291
Total	209,200								166,298
Ferdan Tunnel									
Tunnel &	152,520	48%	4%	3%	24%	16%	5%	78%	118,584
Access R	11,080	16%	5%	3%	43%	28%	5%	69%	7,602
Indirect	32,700	80%	3%	3%	5%	4%	5%	87%	28,413
Engineer	13,100	87%			8%		5%	90%	11,769
Land Acq	400			100%				97%	388
Total	209,800								166,756
IsmailiyaTunnel									
Tunnel &	157,932	48%	4%	3%	24%	16%	5%	78%	122,792
Access R	14,068	16%	5%	3%	43%	28%	5%	69%	9,652
Indirect	34,400	80%	3%	3%	5%	4%	5%	87%	29,890
Engineer	13,800	87%			8%		5%	90%	12,398
Land Acq	400			100%				97%	388
Total	220,600								175,120
Srabuiom Tunnel									
Tunnel &	157,932	48%	4%	3%	24%	16%	5%	78%	122,792
Access R	12,168	16%	5%	3%	43%	28%	5%	69%	8,348
Indirect	34,000	80%	3%	3%	5%	4%	5%	87%	29,543
Engineer	13,600	87%			8%		5%	90%	12,218
Land Acq	100			100%				97%	97
Total	217,800								172,998
Qantara Bridge									
Main&Acc	91,154	73%	5%	3%	8%	6%	5%	85%	77,818
Access R	3,546	26%	9%	4%	34%	22%	5%	73%	2,594
Indirect	18,900	28%	40%	18%	5%	4%	5%	86%	16,337
Engineer	9,500	87%			8%		5%	90%	8,535
Land Acq	300			100%				97%	291
Total	123,400							86%	105,575
Ferdan Bridge									
Main&Acc	86,632	73%	5%	3%	8%	6%	5%	85%	73,958
Access R	3,668	26%	9%	4%	34%	22%	5%	73%	2,683
Indirect	18,100	28%	40%	18%	5%	4%	5%	86%	15,646
Engineer	9,000	87%			8%		5%	90%	8,086
Land Acq	400			100%				97%	388
Total	117,800							86%	100,760
IsmailiyaBridge									
Main&Acc	76,636	73%	5%	3%	8%	6%	5%	85%	65,424
Access R	3,964	26%	9%	4%	34%	22%	5%	73%	2,899
Indirect	16,100	28%	40%	18%	5%	4%	5%	86%	13,917
Engineer	8,100	87%			8%		5%	90%	7,277
Land Acq	400			100%				97%	388
Total	105,200							86%	89,905
Srabuiom Bridge									
Main&Acc	78,183	73%	5%	3%	8%	6%	5%	85%	66,745
Access R	1,917	26%	9%	4%	34%	22%	5%	73%	1,402
Indirect	16,000	28%	40%	18%	5%	4%	5%	86%	13,830
Engineer	8,000	87%			8%		5%	90%	7,187
Land Acq	100			100%				97%	97
Total	104,200							86%	89,262

The economic cost is lower than the financial cost in all alternatives. The maintenance and repair cost is multiplied by a shadow rate of 0.84 to correct to economic cost. Economic costs for Qantara Tunnel and Ferdan Tunnel are found to be about the same.

(3) Results of Discounted Cost Comparison for Project Life in terms of Economic Price

Table 7.2.7 shows comparison of construction and maintenance costs for the project life of the alternatives after correcting to economic price in the case of 4% vertical grade. The left hand culumns indicate the total economic cost for 31 years. The right, the total of discounted present value discounted at 12% of capital opportunity cost.

Table 7.2.8 shows priority ratings of each alternative. The alternatives which uses the least national resources are Ismailiya and Srabuiom bridges. Financial and economic costs analyses give the same priority rating. Therefore, the next step is to compare the economic costs and benefits.

Table 7.2.8 Comparison of Total Construction & Maintenance Costs for Project Life and Priority Rating in Economic Price

Unit: million US$

Alternatives	Cost in Economic Price		Priority Rating
	4% V.Grade	3.3% V.Grade	
Qantra Bridge	67.7	76.0	4
Ferdan Bridge	64.7	73.6	3
Ismailiya Bridge	57.9	65.7	2
Srabuiom Bridge	56.8	64.6	1
Qantara Tunnel	100.6	108.8	5
Ferdan Tunnel	100.9	109.2	6
Ismailiya Tunnel	106.1	116.1	8
Srabuiom Tunnel	104.4	114.5	7

Ref. Appendix Table 7.2.5 Yearly Allocation of construction Cost
Ref. Appendix Table 7.2.6 Comparison of Discounted Value of Economic Costs (3.3% vertical Grade)

Table 7.2.7 Comparison of Discounted Present Value with Economic Cost

(4 Lanes, 4% Vertical Grade, Bridge and Tunnel)

Unit: US$ 1000

	Year	Construction and Maintenance Costs								Discount	Discounted Construction and Maintenance Costs							
		Bridge				Tunnel					Bridge				Tunnel			
		Qantara	Ferdan	Ismaili	Srabuio	Qantara	Ferdan	Ismaili	Srabuio	12.00%	Qantara	Ferdan	Ismaili	Srabuiom	Qantara	Ferdan	Ismaili	Srabuiom
1	1996	0	0	0	0	0	0	0	0	0.893	0	0	0	0	0	0	0	0
2	1997	2,112	2,015	1,798	1,784	3,326	3,335	3,502	3,460	0.797	1,683	1,607	1,433	1,422	2,651	2,659	2,792	2,758
3	1998	25,338	24,182	21,577	21,408	29,934	30,016	31,522	31,140	0.712	18,035	17,213	15,358	15,238	21,306	21,365	22,436	22,165
4	1999	36,951	35,266	31,467	31,221	33,260	33,351	35,024	34,600	0.636	23,483	22,412	19,998	19,841	21,137	21,195	22,258	21,989
5	2000	34,840	33,251	29,669	29,437	34,923	35,019	36,775	36,330	0.567	19,769	18,867	16,835	16,703	19,816	19,871	20,867	20,614
6	2001	6,335	6,046	5,394	5,352	34,923	35,019	36,775	36,330	0.507	3,209	3,063	2,733	2,712	17,693	17,742	18,631	18,406
7	2002	214	229	237	65	29,934	30,016	31,522	31,140	0.452	97	104	107	29	13,540	13,578	14,259	14,086
8	2003	214	229	237	65	1,260	1,268	1,361	1,235	0.404	87	92	96	26	509	512	550	499
9	2004	214	229	237	65	1,260	1,268	1,361	1,235	0.361	77	83	86	23	454	457	491	445
10	2005	214	229	237	65	1,260	1,268	1,361	1,235	0.322	69	74	76	21	406	408	438	398
11	2006	214	229	237	65	1,260	1,268	1,361	1,235	0.287	62	66	68	19	362	365	391	355
12	2007	214	229	237	65	1,260	1,268	1,361	1,235	0.257	55	59	61	17	323	326	349	317
13	2008	802	817	825	653	1,260	1,268	1,361	1,235	0.229	184	187	189	150	289	291	312	283
14	2009	214	229	237	65	1,260	1,268	1,361	1,235	0.205	44	47	48	13	258	260	278	253
15	2010	214	229	237	65	1,260	1,268	1,361	1,235	0.183	39	42	43	12	230	232	249	226
16	2011	2,146	2,161	2,169	1,997	1,260	1,268	1,361	1,235	0.163	350	352	354	326	206	207	222	201
17	2012	214	229	237	65	1,260	1,268	1,361	1,235	0.146	31	33	35	9	184	185	198	180
18	2013	214	229	237	65	1,260	1,268	1,361	1,235	0.130	28	30	31	8	164	165	177	161
19	2014	214	229	237	65	1,260	1,268	1,361	1,235	0.116	25	27	28	8	146	147	158	143
20	2015	802	817	825	653	1,260	1,268	1,361	1,235	0.104	83	85	86	68	131	131	141	128
21	2016	214	229	237	65	1,260	1,268	1,361	1,235	0.093	20	21	22	6	117	117	126	114
22	2017	214	229	237	65	1,260	1,268	1,361	1,235	0.083	18	19	20	5	104	105	112	102
23	2018	214	229	237	65	1,260	1,268	1,361	1,235	0.074	16	17	17	5	93	94	100	91
24	2019	214	229	237	65	1,260	1,268	1,361	1,235	0.066	14	15	16	4	83	84	90	81
25	2020	214	229	237	65	1,260	1,268	1,361	1,235	0.059	13	13	14	4	74	75	80	73
26	2021	2,146	2,161	2,169	1,997	1,260	1,268	1,361	1,235	0.053	113	113	114	105	66	67	71	65
27	2022	802	817	825	653	1,260	1,268	1,361	1,235	0.047	38	38	39	31	59	59	64	58
28	2023	214	229	237	65	1,260	1,268	1,361	1,235	0.042	9	10	10	3	53	53	57	52
29	2024	214	229	237	65	1,260	1,268	1,361	1,235	0.037	8	9	9	2	47	47	51	46
30	2025	214	229	237	65	1,260	1,268	1,361	1,235	0.033	7	8	8	2	42	42	45	41
31	2026	214	229	237	65	1,260	1,268	1,361	1,235	0.030	6	7	7	2	38	38	41	37
32	2027	214	229	237	65	1,260	1,268	1,361	1,235	0.027	6	6	6	2	34	34	36	33
Total		116,768	112,343	101,697	96,521	197,798	198,466	209,140	203,868		67,676	64,717	57,946	56,817	100,614	100,909	106,072	104,398

7.2.3. Benefits

(1) Introduction

Table 7.2.9 Construction Effects of Canal Crossing Facility

Items	Contents
Forward effects	Increase of demand for construction materials and equipment, progress of engineering, profits of project-related contractors.
Saving effects of direct users	Saving time effects, running cost saving effects, and increase of comfortability
Capital saving effects	Saving of ferries, and saving of number of trucks and buses for effective turnovers.
Avoiding loss effects	Decrease of traffic accidents, and decrease of spoiling vegetables and fruits
Development enhancement effects	Development of neighboring areas, enhancement of sightseeing development, enhancement of mining development, effective use of natural resources, and expansion of local and international economic market zones.
Socio-economic effects	Enhancement of immigrants, increase of employment opportunities, uniting local regions, correction of regional differences, promoting international fellowship, and expansion of peace and safety.
Minus effects	(In the case of a bridge) Falling of dangerous things, and limitation on large size vessels for pass.

Note: 1) Not included here because of the lack of Input/Ooutput table.
2) Included 100 % in the comparison.
3) Benefits of Saving cost of ferries is included 100%. Increase effects of turnover of buses and trucks is included as the driving time cost saving.
4) Not included here because the amount is small. It will be considered in the Feasibility Study.
5) Included in the calculation for traffic volume calculation.
6) Included in step 7, evaluation and comparison
7) Falling of dangerous goods is not included. Limitation of large sized vessels is included 100%.

(2) Summary of Benefits Calculation

The benefits, from the effects of the project, can be calculated using the following three factors:

Saving of running costs

- Running costs per vehicle per kilometer without the project, minus running costs with the project, equals to amount saved per vehicle per kilometer. Running cost per vehicle per kilometer is calculated in "Traffic Assignment " of Chapter 4, Traffic Demand Projection.
- Saving of running costs per vehicle per kilometer multiplied by thevehicle operating cost per kilometer equals the saving of running costs.

Saving of running time

- Running time without the project, minus running time with the project, equals the saving of running time. This is also calculated in "Traffic Assignment " of Chapter 4.

- Saving of running time, multiplied by the time value of vehicles, equals the benefits of time saving of vehicles. Saving of running time, multiplied by the time value of passengers, equals the benefits of time saving of passengers.

Saving benefits of capital costs of ferries

- Traffic volume of ferry users, multiplied by the waiting time without the project, minus traffic volume of ferry users, multiplied by the waiting time with the project,equals the saving in time of waiting for ferries.

- Saving of waiting time, multiplied by the time value of vehicles, equals the time saving of vehicles, and is equal to the capital cost saving of the ferries. Saving of waiting time, multiplied by the time value of passengers, equals the time saving of passengers, and is equal to the capital saving cost of the ferries.

(3) Unit Cost Estimation

For estimation the unit cost benefit of the following three items were calculated; 1) unit cost of operating vehicle, 2) the value of vehicle unit cost, and 3) unit cost of passengers time value.

1) Estimation of Vehicle Operating Unit Cost

The Table 7.2.10 shows unit vehicle operating cost per km of base speed. These figures are calculated based upon Appendix 7.2.7. These tables are estimated using Egyptian national economic conditions in 1991.

Base speed is taken as: 70k/h for passenger cars, 60k/h for taxis, 50k/h for small buses, 45k/h for large buses, 50k/h for mini trucks, and 40k/h for heavy trucks.

Buses and trucks are calculated at weighted average according to vehicle types based upon the OD survey of the Canal crossing traffic.

The following unit cost is used for cost benefits calculation.

Table 7.2.10 Unit Vehicle Operating Cost per Km by Base Speed

Unit: LE

	Passenger Car	Peugeot	Pick-up-car	Medium Bus (Seats)	Large Bus (Seats)	Super Dx. Bus (AirCondition)	Medi. Truck (8 Ton)	Hvy. Truck (15 Ton)	Semitrailer (25 Ton)	T-Trailer (20 ton)	T-Trailer (30 Ton)	TrailerWagon (25 Ton)
Basic Financial Running Costs												
Fuel Costs	0.0736	0.0828	0.0638	0.0692	0.0940	0.1400	0.0660	0.1116	0.2356	0.1564	0.2852	0.1080
Lubricant Costs	0.0095	0.0105	0.0122	0.0214	0.0329	0.0474	0.0154	0.0291	0.0392	0.0291	0.0392	0.0291
Tyre Costs	0.0160	0.0160	0.0217	0.0195	0.0269	0.0394	0.0613	0.1197	0.1626	0.1470	0.1457	0.1548
Maintenance Spares Costs	0.0017	0.0016	0.0013	0.0031	0.0043	0.0095	0.0012	0.0020	0.0021	0.0017	0.0020	0.0004
Maintenance Labor Costs	0.0073	0.0091	0.0110	0.0548	0.0548	0.0548	0.0438	0.0548	0.0548	0.0548	0.0548	0.0548
Depreciation Costs	0.0833	0.0809	0.0854	0.1870	0.3358	1.1475	0.0949	0.1976	0.2134	0.1512	0.1956	0.0413
Total Costs/vehicle-km	0.1913	0.2009	0.1954	0.3550	0.5486	1.4384	0.2826	0.5147	0.7077	0.5402	0.7225	0.3883
Basic Financial Fixed Costs												
Capita. Costs(Depreciation-Time relate	2.5000	4.0455	1.8298	1.6500	2.9625	10.1250	2.0344	4.2350	4.5734	3.2400	4.1923	1.1498
Long Term Interest Costs	7.8000	6.7964	9.5150	13.2000	23.7000	81.0000	13.0200	20.3280	20.1231	16.8480	20.1231	5.0592
Overhead Cost	0.3660	0.5051	1.0732	11.5122	15.3672	33.9349	13.0978	22.8107	26.1342	18.2163	26.2967	10.0393
Crew Costs	0.0000	3.6603	10.2487	9.3644	11.4200	17.0421	22.3597	24.5969	25.6774	21.6248	25.6774	0.0000
Registration Fee(Licenses)	0.1100	0.0500	0.1600	0.1900	0.2200	0.0990	0.4600	0.9300	0.3800	0.4600	0.7700	0.0600
Registration Fee(Insurance)	0.0400	0.0300	0.0800	0.0600	0.0900	0.0600	0.1200	0.2200	0.2600	0.1000	0.1700	0.0000
Fixed Costs, All	10.7760	15.0573	22.8267	35.9166	53.6697	142.2010	50.9719	72.9006	76.8881	60.3791	77.0595	16.3084
Factor	0.3000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000
Total Costs/Vehicle-hour	3.2328	10.5401	15.9787	25.1416	37.5688	99.5407	35.6804	51.0304	53.8217	42.2654	53.9416	11.4158
Costs/Vehicle-km	0.0462	0.1622	0.2663	0.4571	0.7514	1.9908	0.6487	1.2758	1.3455	1.0566	1.3485	0.2537
Total Financial Cost/Vehicle-km	0.2375	0.3630	0.4617	0.8121	1.2999	3.4292	0.9314	1.7905	2.0532	1.5968	2.0710	0.6420
Basic Economic Running Costs												
Fuel Costs	0.0774	0.0870	0.0823	0.1080	0.1466	0.2184	0.1030	0.1741	0.3675	0.2440	0.4449	0.1685
Lubricant Costs	0.0086	0.0095	0.0111	0.0195	0.0299	0.0431	0.0140	0.0265	0.0356	0.0265	0.0356	0.0265
Tyre Costs	0.0176	0.0175	0.0238	0.0215	0.0295	0.0433	0.0674	0.1317	0.1788	0.1617	0.1603	0.1702
Maintenance Spares Costs	0.0015	0.0015	0.0011	0.0028	0.0034	0.0070	0.0011	0.0018	0.0017	0.0014	0.0015	0.0003
Maintenance Labor Costs	0.0073	0.0091	0.0110	0.0548	0.0548	0.0548	0.0438	0.0548	0.0548	0.0548	0.0548	0.0548
Depreciation Costs	0.0757	0.0736	0.0689	0.1700	0.2644	0.8500	0.0863	0.1797	0.1654	0.1260	0.1517	0.0242
Total Costs/vehicle-km	0.1881	0.1982	0.1981	0.3764	0.5286	1.2165	0.3156	0.5684	0.8038	0.6143	0.8488	0.4546
Basic Economic Fixed Costs												
Capita. Cost(Depreciation-time related)	2.2724	3.6777	1.4754	1.5000	2.3325	7.5000	1.8494	3.8500	3.5452	2.7000	3.2498	0.9540
Opportunity Cost of Capital	7.0900	6.1786	7.6720	12.0000	18.6600	60.0000	11.8364	18.4800	15.5991	14.0400	15.5991	4.1976
Overhead Cost	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000
Crew Costs	0.0000	3.6603	10.2487	9.3644	11.4200	17.0421	22.3597	24.5969	25.6774	21.6248	25.6774	0.0000
Registration (Licenses)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Registration (Insurance)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fixed Costs, All	12.3624	16.5165	22.3961	25.8644	35.4125	87.5421	39.0455	49.9269	47.8217	41.3648	47.5263	8.1516
Factor	0.3000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000
Total Costs/Vehicle-hour	3.7087	11.5616	15.6773	18.1051	24.7887	61.2795	27.3319	34.9488	33.4752	28.9553	33.2684	5.7061
Cost/Vehicle-km	0.0530	0.1779	0.2613	0.3292	0.4958	1.2256	0.4969	0.8737	0.8369	0.7239	0.8317	0.1268
Total Economic Costs/Vehicle-km	0.2411	0.3761	0.4594	0.7056	1.0244	2.4421	0.8125	1.4421	1.6407	1.3382	1.6805	0.5813

Table 7.2.11 Vehicle Running Cost by Vehicle Types (Economic price)

Passenger Car	Taxi	Bus	Truck
0.1881LE/km	0.1982LE/km	0.3677LE/km	0.600LE/km

Ref. Appendix Table 7.2.7 Data Sheet for V.O.C. Calculation.

2) Unit Cost of Running Time of Vehicles

This is shown in the Table 7.2.12, along with VOC estimation. Time value of vehicles is determined by costs which are not related to running distance; (1) depreciation, (2) interests, (3) overhead cost, and (4) crew cost.

Time cost by vehicles used for benefits and costs calculation is as follows.

Table 7.2.12 Time Unit Cost by Vehicle Types

Passenger Car	Taxi	Bus	Truck
3.71LE/hr	11.56LE/hr	19.35LE/hr	30,52LE/hr

Waiting time of ferries is not calculated by vehicle types. Therefore, average time value per vehicle was calculated according to OD survey of the vehicle type composition at the point of river-crossing. Time value of a vehicle at crossing points is as Table 7.2.13.

Table 7.2.13 Unit Time Cost of Vehicles at Crossing Points

Unit: LE / Vehicle /h

R.E. Esh	Qantara	Ferdan	No.6	Srabuiom	Shatt	A.H. Tunnel
18.308	13.808	30.026	11.962	17.7	31.049	20.387

Ref.: Appendix Table 7.2.8 Average Time Value by Vehicle Types by Crossing Points

(3) Unit Time Cost of Passengers

Time value of a person is calculated from income of labor. (Estimated at the growth rate of the past 5 years.)

The total wage of laborers in 1996	39,418 LE million /year
The total labor population in 1996	14,317,000
Average wage per laborer	2,753 LE/year

Time value of passengers of bus, car, and taxi.

Vehicle Type	Unit	Average Income (LE)		Remark
		per year	per hour	
Bus	a passenger	2,753	1.45	
Car	a person	12,388	6.52	4.5 times
Taxi	a passenger	7,571	3.98	in-between

Time value of a vehicle by vehicle types.

Bus	1.45 LE/h	x	18.01 person	=	26.11 LE/Vehicle
Passenger Car	6.52 LE/h	x	2.74 person	=	17.86 LE/Vehicle
Taxi	3.98 LE/h	x	3.77 person	=	15.00 LE/Vehicle

Time Value of car, bus and taxi Traffic.

When the trip purpose is in relation to production, the saved time of leisure trips as such, is not considered as a benefit. Therefore the ratio of that portion is detracted. Trip purposes differ according to crossing points.

Table 7.2.14 Unit Time Cost of Passengers by Crossing points and Types of Vehicles

Unit: LE/Vehicle

Location and Efficiency		Qantara	Ferdan	No.6	Srabuiom	Shatt	A.H. Tunnel
	of time Saved	62%	71%	60%	66%	59%	70%
Bus	26.11	16.84	18.41	15.67	17.21	15.41	18.38
Passenger Car	17.86	11.52	12.60	10.72	11.77	10.54	12.58
Taxi	15.00	9.68	10.58	9.00	9.89	8.85	10.56
Average per vehicle		13.64	16.31	13.09	15.90	13.43	15.29

Note: Average per vehicle is calculated at weighted average, according to vehicle types composition.
Ref. Appendix 7.2.9 Composition of Vehicle Type & Trip Purpose by Crossing Points

7.2.4 Estimation of Benefits

(1) Saving of Capital Costs of Ferries

Table 7.2.15 shows the traffic volume and number of ferry boats needed at the crossing points in order to compare the benefits with costs at Ferdan, both with and without the project. In the year 2017 with project for instance, 4,612 vehicles will still use the ferry at El Esh, and 38 vehicles at Qantara.

Thus the waiting time saving at Ferdan will be calculated as detracting the total waiting time of 4,650 vehicles (4,612 + 38 = 4,650) in the case of with project, from the total waiting time of 36,206 vehicles (4,819 + 18,940 + 4,952 + 4,190 + 3,305 = 36,206) in the case of without the project. The figures for Qantara,, Ismiliya and Srabuiom were calculated in the same method.

Table 7.2.15 Traffic Volume and Ferry Number at Crossing points to Compare the Benefits (Case 1:Year 2017, Ferdan Example)

Unit: Vehicles/day

Crossing Points	Without Project		With Ferdan Project	
	Traffic	No. of Boats	Traffic	No. of Boats
Port Said	0	0	0	0
El Esh	4,819	10	4,612	10
Qantara	18,940	27	38	2
Ferdan	4,952	21	(33,282)	Project
No.6	4,190	11	0	0
Srabuiom	3,305	11	0	0
Total	36,206	80	4,650	12

l) Waiting Time for Ferries in the Case Without project

Table 7.2.16 assumes that no canal crossing facility is constructed (Without the project). In this case the ferryies will be used up till year 2027. The first column shows the traffic volume conveyed by ferry by year, according to Chapter 5.

The second column shows the total waiting time of ferries at each point. Waiting time is assumed to be the same as at present up till the year 2027. Unless the ferry system transport is improved, the waiting time will be huge. However, This is not realistic. If the ferry system transport is to be improved to meet the demand, it has been assumed present waiting time will not increase up till year 2027.

Thus the present waiting time is multiplied by the traffic volume to calculate the future waiting time, assuming that ferries are to be increased in the future. Thus the cost to increase ferries equals the increased waiting time cost. The third column is the waiting time cost of vehicles at each ferry point. The fourth column is the waiting time cost of people at each ferry point.

In Table 7.2.17 (with project at Ferdan), the first column "Traffic Volume with Project" shows 0, in several culumns because the ferry users will use the new crossing facility.

Table 7.2.16 Time Cost Waiting Ferry of Vehicles and Passengers Without Project

Case - 1

Unit. 1000LE

	Traffic Volume Without Project					Ferry Waiting Time					Vehicle Waiting Cost						Passenger Waiting Cost					
Year	R. E. Esh	Qantara	Ferdan	No. 6	Srabuiom	R. E. Esh	Qantara	Ferdan	No. 6	Srabuiom	R. E. Esh	Qantara	Ferdan	No. 6	Srabuiom	Total	R. E. Esh	Qantara	Ferdan	No. 6	Srabuiom	Total
						0.37	0.339	0.536	0.331	0.234	18.308	13.808	30.026	11.962	17.700	Year	12.644	13.642	16.307	13.090	15.897	Year
2002	1,910	7,900	0	3,765	40	697	2,678	0	1,246	9	12,763	36,979	0	14,907	166	23,658	8,815	36,535	0	16,313	149	22,561
2003	2,046	8,477	20	3,791	120	747	2,874	11	1,255	28	13,670	39,679	322	15,012	497	25,250	9,441	39,202	175	16,427	446	23,977
2004	2,191	9,095	60	3,818	360	800	3,083	32	1,264	84	14,640	42,575	966	15,117	1,491	27,298	10,111	42,063	524	16,542	1,339	25,762
2005	2,346	9,759	180	3,845	1,080	856	3,308	96	1,273	253	15,680	45,683	2,897	15,222	4,473	30,644	10,829	45,134	1,573	16,658	4,017	28,547
2006	2,513	10,472	540	3,872	2,592	917	3,550	289	1,281	607	16,793	49,018	8,691	15,329	10,736	36,707	11,598	48,429	4,720	16,775	9,642	33,274
2007	2,686	11,248	986	3,889	1,690	980	3,813	528	1,287	395	17,949	52,651	15,869	15,398	7,000	39,736	12,396	52,018	8,618	16,850	6,287	35,102
2008	2,847	11,844	1,159	4,161	1,807	1,039	4,015	621	1,377	423	19,026	55,441	18,646	16,476	7,483	42,731	13,140	54,775	10,126	18,030	6,720	37,519
2009	3,018	12,472	1,361	4,453	1,931	1,102	4,228	730	1,474	452	20,167	58,380	21,909	17,629	7,999	46,021	13,928	57,678	11,898	19,292	7,184	40,143
2010	3,199	13,133	1,600	4,764	2,065	1,168	4,452	857	1,577	483	21,378	61,474	25,743	18,863	8,551	49,643	14,764	60,735	13,981	20,642	7,680	42,998
2011	3,391	13,829	1,879	5,098	2,207	1,238	4,688	1,007	1,687	516	22,660	64,732	30,248	20,184	9,141	53,642	15,650	63,954	16,427	22,087	8,210	46,110
2012	3,594	14,562	2,208	5,455	2,359	1,312	4,936	1,184	1,805	552	24,020	68,163	35,541	21,597	9,772	58,069	16,589	67,343	19,302	23,633	8,776	49,510
2013	3,810	15,334	2,595	5,836	2,522	1,391	5,198	1,391	1,932	590	25,461	71,775	41,761	23,109	10,446	62,981	17,584	70,913	22,680	25,288	9,382	53,234
2014	4,039	16,146	3,049	6,245	2,696	1,474	5,474	1,634	2,067	631	26,989	75,580	49,069	24,726	11,167	68,448	18,639	74,671	26,649	27,058	10,029	57,322
2015	4,281	17,002	3,582	6,682	2,882	1,563	5,764	1,920	2,212	674	28,608	79,585	57,656	26,457	11,937	74,549	19,757	78,629	31,313	28,952	10,721	61,321
2016	4,538	17,903	4,209	7,150	3,081	1,656	6,069	2,256	2,367	721	30,324	83,803	67,745	28,309	12,761	81,374	20,943	82,796	36,792	30,978	11,461	66,784
2017	4,819	18,940	4,952	4,190	3,305	1,759	6,421	2,654	1,387	773	32,203	88,656	79,697	16,590	13,689	84,255	22,240	87,591	43,283	18,154	12,294	67,000
2018	5,108	19,944	5,819	4,483	3,533	1,864	6,761	3,119	1,484	827	34,135	93,355	93,644	17,751	14,633	92,534	23,574	92,233	50,858	19,425	13,143	72,720
2019	5,415	21,001	6,837	4,797	3,777	1,976	7,119	3,665	1,588	884	36,183	98,303	110,032	18,994	15,643	101,891	24,989	97,121	59,758	20,785	14,049	79,096
2020	5,740	22,114	8,033	5,133	4,037	2,095	7,497	4,306	1,699	945	38,354	103,513	129,287	20,323	16,722	112,493	26,488	102,269	70,216	22,240	15,019	86,224
2021	6,084	23,286	9,439	5,492	4,316	2,221	7,894	5,059	1,818	1,010	40,655	108,999	151,913	21,746	17,876	124,534	28,077	107,689	82,503	23,797	16,055	94,214
2022	6,449	24,520	11,091	5,877	4,614	2,354	8,312	5,945	1,945	1,080	43,094	114,776	178,498	23,268	19,109	138,242	29,762	113,396	96,941	25,462	17,163	103,195
2023	6,836	25,820	13,032	6,288	4,932	2,495	8,753	6,985	2,081	1,154	45,680	120,859	209,735	24,897	20,428	153,884	31,548	119,406	113,906	27,245	18,347	113,315
2024	7,246	27,188	15,312	6,728	5,272	2,645	9,217	8,207	2,227	1,234	48,421	127,265	246,438	26,640	21,838	171,770	33,441	125,735	133,840	29,152	19,613	124,750
2025	7,681	28,629	17,992	7,199	5,636	2,803	9,705	9,644	2,383	1,319	51,326	134,010	289,565	28,505	23,344	192,264	35,447	132,399	157,262	31,193	20,966	137,702
2026	8,142	30,146	21,141	7,703	6,025	2,972	10,220	11,331	2,550	1,410	54,406	141,113	340,239	30,500	24,955	215,792	37,574	139,416	184,782	33,376	22,413	152,410
2027	8,630	31,744	24,840	8,242	6,441	3,150	10,761	13,314	2,728	1,507	57,670	148,592	399,780	32,635	26,677	242,854	39,828	146,805	217,119	35,712	23,960	169,150

Table 7.2.17 Time Cost Waiting Ferry of Vehicles and Passengers With Project

Case 1. Ferdan

Unit:1000LE

	Traffic Volume with Project					Time Ferry Waiting					Vehicle Waiting Cost						Passenger Waiting Cost					
	R. E. Esh	Qantara	Ferdan	No. 6	Srabuion	R. E. Esh	Qantara	Ferdan	No. 6	Srabuion	R. E. Esh	Qantara	Ferdan	No. 6	Srabuion	Total	R. E. Esh	Qantara	Ferdan	No. 6	Srabuion	Total
						0.37	0.34	0.54	0.33	0.23	18.308	13.808	30.026	11.962	17.700	Year	12.644	13.642	16.307	13.090	15.897	Year
2002	1,845	0	0	0	0	673	0	0	0	0	12,329	0	0	0	0	4,500	8,515	0	0	0	0	3,108
2003	1,987	0	0	0	0	725	0	0	0	0	13,278	0	0	0	0	4,847	9,170	0	0	0	0	3,347
2004	2,140	0	0	0	0	781	0	0	0	0	14,301	0	0	0	0	5,220	9,877	0	0	0	0	3,605
2005	2,305	0	0	0	0	841	0	0	0	0	15,402	0	0	0	0	5,622	10,637	0	0	0	0	3,883
2006	2,482	0	0	0	0	906	0	0	0	0	16,588	0	0	0	0	6,055	11,456	0	0	0	0	4,181
2007	2,668	0	0	0	0	974	0	0	0	0	17,829	0	0	0	0	6,507	12,313	0	0	0	0	4,494
2008	2,817	0	0	0	0	1,028	0	0	0	0	18,827	0	0	0	0	6,872	13,003	0	0	0	0	4,746
2009	2,975	0	0	0	0	1,086	0	0	0	0	19,881	0	0	0	0	7,257	13,731	0	0	0	0	5,012
2010	3,142	0	0	0	0	1,147	0	0	0	0	20,995	0	0	0	0	7,663	14,500	0	0	0	0	5,292
2011	3,318	0	0	0	0	1,211	0	0	0	0	22,170	0	0	0	0	8,092	15,312	0	0	0	0	5,589
2012	3,504	0	0	0	0	1,279	0	0	0	0	23,412	0	0	0	0	8,545	16,169	0	0	0	0	5,902
2013	3,700	0	0	0	0	1,350	0	0	0	0	24,723	0	0	0	0	9,024	17,074	0	0	0	0	6,232
2014	3,907	0	0	0	0	1,426	0	0	0	0	26,108	0	0	0	0	9,529	18,031	0	0	0	0	6,581
2015	4,126	0	0	0	0	1,506	0	0	0	0	27,570	0	0	0	0	10,063	19,040	0	0	0	0	6,950
2016	4,357	0	0	0	0	1,590	0	0	0	0	29,114	0	0	0	0	10,626	20,107	0	0	0	0	7,339
2017	4,612	38	0	0	0	1,683	13	0	0	0	30,819	178	0	0	0	11,314	21,285	176	0	0	0	7,833
2018	4,870	40	0	0	0	1,778	14	0	0	0	32,545	187	0	0	0	11,947	22,477	185	0	0	0	8,272
2019	5,143	42	0	0	0	1,877	14	0	0	0	34,368	197	0	0	0	12,616	23,735	195	0	0	0	8,735
2020	5,431	44	0	0	0	1,982	15	0	0	0	36,292	208	0	0	0	13,323	25,064	205	0	0	0	9,223
2021	5,735	47	0	0	0	2,093	16	0	0	0	38,325	219	0	0	0	14,068	26,468	216	0	0	0	9,740
2022	6,056	49	0	0	0	2,211	17	0	0	0	40,471	230	0	0	0	14,856	27,950	228	0	0	0	10,285
2023	6,395	52	0	0	0	2,334	18	0	0	0	42,737	242	0	0	0	15,688	29,516	240	0	0	0	10,861
2024	6,754	55	0	0	0	2,465	18	0	0	0	45,131	255	0	0	0	16,566	31,168	252	0	0	0	11,469
2025	7,132	57	0	0	0	2,603	19	0	0	0	47,658	269	0	0	0	17,493	32,914	266	0	0	0	12,110
2026	7,531	60	0	0	0	2,749	21	0	0	0	50,327	283	0	0	0	18,473	34,757	280	0	0	0	12,788
2027	7,953	64	0	0	0	2,903	22	0	0	0	53,145	298	0	0	0	19,507	36,703	295	0	0	0	13,504

2) Benefits from saving time of waiting ferries

Table 7.2.18 is the total cost of time saved waiting time for ferries at crossing points subtracting Table 7.2.16 and Table 7.2.17. In the case of Qantara the time saving cost will be 27,800,000 LE (14,202 vehicles + 13,635 passengers) in the year 2002. In the case of Srabuiom, many will continue to use ferries, and the benefits will not be large. Saving time of vehicles and of passengers are about the same.

3) Relationship between Saving Benefits of Waiting Time and Ferry Saving Cost

With the project, the time saving benefits are expected to be generated as shown above, however these are the benefits of the crossing facility assuming strengthening ferry transport. That is, it presupposes the costs for increasing the number of ferries, necessary to maintain the present waiting time, ferry operating costs and the facility costs. Fig. 7.2.3 shows the relationship between additional waiting time and additional ferry investment.

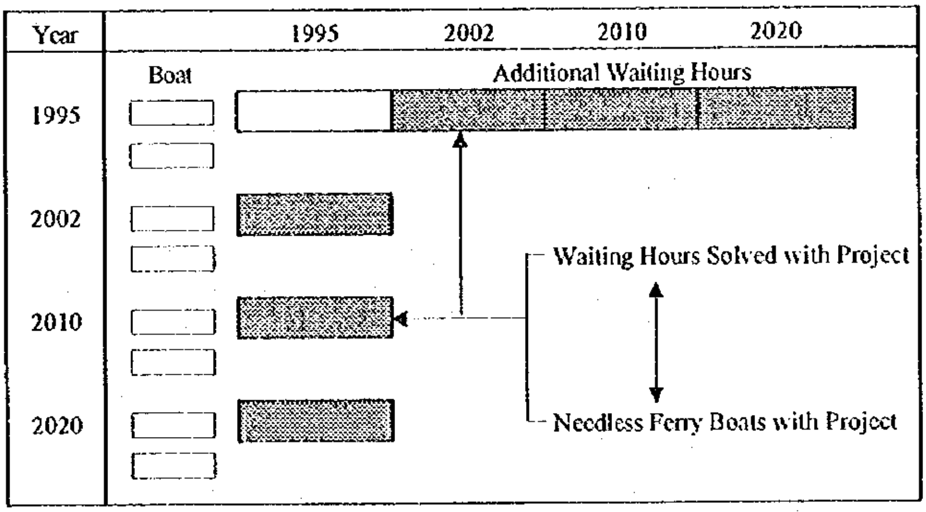


Fig. 7.2.3 Relationship between Additional Waiting Time and Additional Ferry Investment

Therefore, it is necessary to prove that the saving time benefits of waiting for ferries equals the above ferry costs. That means that the total discounted present value of waiting time saving benefits, equals the total discounted present value of additional costs of these ferries. This is the benefit and cost analysis of ferries.

Ferries will be gradually increased in stages, in accordance with traffic demand. Thus additional investment in ferries can be considered to be very close to realistic amount of ferry investment to match the time saving benefits. Time saving benefits with project, should thus be considered as ferry investment saving benefits.

Table 7.2.18 Time Cost Waiting Ferry Saving of Vehicles and Passengers by Crossing Point

(Case 1)

Unit: 1000LE

Year	Without Project		Time Cost With Project/Year								Saving Benefit/Year							
			Qantara		Fordan		Ismailiya		Srabuiom		Qantara		Ferdan		Ismailiva		Srabuiom	
	Vehicle	Passenge	Vehicle	Passeng	Vehicle	Passen	Vehicle	Passen	Vehicl	Passen	Vehicle	Passeng	Vehicle	Passeng	Vehicle	Passeng	Vehicle	Passenger
2002	23,658	22,561	9,455	8,926	4,500	3,108	4,948	3,550	16,931	15,342	14,202	13,635	19,158	19,453	18,710	19,011	6,727	7,219
2003	25,250	23,977	9,858	9,216	4,847	3,347	5,328	3,820	18,182	16,480	15,392	14,761	20,404	20,630	19,923	20,157	7,068	7,497
2004	27,298	25,762	10,301	9,534	5,220	3,605	5,737	4,111	19,526	17,702	16,997	16,228	22,078	22,157	21,561	21,651	7,772	8,059
2005	30,644	28,547	10,787	9,882	5,622	3,883	6,179	4,424	20,969	19,015	19,857	18,665	25,022	24,665	24,465	24,124	9,675	9,532
2006	36,707	33,274	11,322	10,263	6,055	4,181	6,654	4,760	22,519	20,425	25,385	23,011	30,652	29,093	30,053	28,514	14,188	12,849
2007	39,736	35,102	11,931	10,698	6,507	4,494	7,093	5,073	24,103	21,865	27,805	24,404	33,229	30,607	32,643	30,028	15,633	13,236
2008	42,731	37,519	12,557	11,191	6,872	4,746	7,478	5,345	25,308	22,943	30,175	26,328	35,859	32,773	35,253	32,174	17,423	14,576
2009	46,021	40,143	13,088	11,593	7,257	5,012	7,884	5,632	26,574	24,074	32,933	28,550	38,764	35,131	38,136	34,511	19,447	16,069
2010	49,643	42,998	13,663	12,029	7,663	5,292	8,313	5,934	27,903	25,261	35,980	30,968	41,980	37,705	41,330	37,063	21,740	17,737
2011	53,642	46,110	14,289	12,505	8,092	5,589	8,764	6,253	29,300	26,507	39,353	33,604	45,550	40,521	44,878	39,857	24,342	19,603
2012	58,069	49,510	14,974	13,028	8,545	5,902	9,241	6,589	30,768	27,815	43,094	36,482	49,523	43,608	48,827	42,921	27,301	21,695
2013	62,981	53,234	15,728	13,605	9,024	6,232	9,744	6,944	32,309	29,189	47,253	39,629	53,957	47,002	53,237	46,290	30,672	24,045
2014	68,448	57,322	16,564	14,248	9,529	6,581	10,275	7,318	33,929	30,630	51,885	43,073	58,919	50,741	58,174	50,004	34,519	26,691
2015	74,549	61,821	17,496	14,971	10,063	6,950	10,834	7,712	35,630	32,144	57,052	46,850	64,486	54,871	63,714	54,108	38,918	29,677
2016	81,374	66,784	18,546	15,791	10,626	7,339	11,425	8,128	37,418	33,733	62,828	50,994	70,748	59,445	69,949	58,656	43,956	33,052
2017	84,255	67,000	18,720	15,634	11,314	7,833	12,077	8,588	39,333	35,433	65,535	51,367	72,941	59,167	72,177	58,413	44,921	31,567
2018	92,534	72,720	20,048	16,683	11,947	8,272	12,736	9,051	41,476	37,351	72,486	56,037	80,587	64,448	79,798	63,669	51,059	35,369
2019	101,891	79,096	21,583	17,907	12,616	8,735	13,432	9,540	43,735	39,372	80,308	61,189	89,275	70,362	88,460	69,556	58,156	39,724
2020	112,493	86,224	23,376	19,352	13,322	9,223	14,165	10,056	46,117	41,504	89,117	66,872	99,171	77,001	98,328	76,168	66,376	44,721
2021	124,534	94,214	25,491	21,075	14,068	9,740	14,939	10,600	48,630	43,751	99,043	73,139	110,466	84,475	109,595	83,614	75,904	50,464
2022	138,242	103,195	28,011	23,149	14,856	10,285	15,756	11,174	51,280	46,119	110,231	80,046	123,386	92,910	122,487	92,021	86,963	57,075
2023	153,884	113,315	31,044	25,670	15,688	10,861	16,617	11,780	54,074	48,616	122,840	87,645	138,196	102,455	137,266	101,536	99,810	64,699
2024	171,770	124,750	34,727	28,761	16,566	11,469	17,527	12,418	57,021	51,249	137,042	95,989	155,204	113,281	154,243	112,332	114,749	73,501
2025	192,264	137,702	39,241	32,582	17,493	12,110	18,486	13,092	60,128	54,024	153,023	105,120	174,771	125,592	173,778	124,611	132,136	83,678
2026	215,792	152,410	44,815	37,340	18,473	12,788	19,498	13,802	63,405	56,950	170,977	115,070	197,320	139,622	196,294	138,608	152,387	95,460
2027	242,854	169,150	51,751	43,303	19,507	13,504	20,566	14,552	66,862	60,034	191,103	125,847	223,348	155,646	222,288	154,599	175,993	109,116

(2) Saving of Operating Costs

1) Vehicle km and vehicle hour

With the project the running cost of vehicles will be saved. However, the result of calculation shows at every crossing point the vehicle running distance with the project is more than in the case of without the project as shown in Table 7.2.19. With the crossing Qantara for instance, the road users must travel further than without the project.

But, vehicle hour is shortened at every crossing point with project than without project. Therefore, vehicle km is a minus benefit, while vehicle hour is a plus benefit.

Table 7.2.19 Saving of Vehicle-km and Vehicle-Hour by Crossing Points

Items		Vehicle - kirometer			Vehicle - hour		
		2002	2007	2017	2002	2007	2017
Without project of whole area		24,964,404	34,523,266	65,940,664	364,538	510,985	963,670
With project							
	Qantara	24,999,184	34,583,196	66,058,378	363,818	510,015	961,887
	Ferdan	25,014,064	34,593,106	66,057,604	363,633	509,636	961,198
	Ismailiya	25,012,324	34,590,646	66,051,764	363,615	509,605	962,240
	Srabuiom	24,957,594	34,515,586	65,929,364	364,149	510,309	962,240
Saving							
	Qantara	-34,780	-59,930	-117,714	720	970	1,783
	Ferdan	-49,660	-69,840	-116,940	905	1,349	2,472
	Ismailiya	-47,920	-67,380	-111,100	923	1,380	1,430
	Srabuiom	6,810	7,680	11,300	389	676	1,430

2) Saving of Vehicle-km Cost

Table 7.2.20 shows the total cost saving with the case of the crossing at Qantara . The left half of the table shows the difference of vehicle km with and without project by vehicle types. Vehicle km is based on the results of the calculation of traffic distribution in chapter 5. The right half of the table shows the saving of running costs by vehicle types. In the case of the crossing at Qantara, running costs increase to LE14,189,000 per year in year 2002.

Vehicle operating costs by vehicle types includes costs due to running, and cost generated by owning vehicles. For calculating the savings of vehicle kms the former is used, and for that of vehicle hours the latter is used.

Table 7.2.20 Vehicle Running Cost Saving (Increase)

Case 1

Year	Vehicles Ocrating Costs Increase by Crossing Points				Qantara Case as an Example										
					Year	Vehicle-Kilometers Increse				Vehicle Operating Costs Increase					
	Qantara	Ferdan	Ismailva	Srabuiom		Pass. Car	Taxi	Bus	Truck	Pass. Car	Taxi	Bus	Truck	Total/day	Total/Year
	1000Le					(Km)	(Km)	Km)	(Km)	0. 188Le	0. 198Le	0. 367Le	0. 601Le	(LE)	(1000LE)
2002	14,189	23,007	21,732	21,732	2002	34,780	16,270	7,201	44,030	6,539	3,225	2,648	26,462	38,873	14,189
2003	16,420	24,817	23,443	23,443	2003	38,780	18,987	8,152	51,471	7,291	3,763	2,997	30,934	44,985	16,420
2004	19,008	26,771	25,289	25,289	2004	43,239	22,158	9,228	60,170	8,129	4,392	3,393	36,162	52,076	19,008
2005	22,011	28,880	27,282	27,282	2005	48,212	25,858	10,446	70,338	9,064	5,125	3,841	42,273	60,303	22,011
2006	25,496	31,156	29,434	29,434	2006	53,756	30,177	11,824	82,226	10,106	5,981	4,348	49,418	69,853	25,496
2007	29,535	33,548	31,798	31,798	2007	59,930	35,150	13,387	96,110	11,267	6,967	4,922	57,762	80,918	29,535
2008	31,803	35,341	33,436	33,436	2008	64,125	38,278	14,043	103,703	12,056	7,587	5,164	62,325	87,131	31,803
2009	34,247	37,231	35,159	35,159	2009	68,614	41,685	14,731	111,895	12,899	8,262	5,417	67,249	93,827	34,247
2010	36,881	39,224	36,973	36,973	2010	73,417	45,395	15,453	120,735	13,802	8,997	5,682	72,562	101,043	36,881
2011	39,720	41,325	38,883	38,883	2011	78,556	49,435	16,210	130,273	14,769	9,798	5,960	78,294	108,821	39,720
2012	42,780	43,542	40,893	40,893	2012	84,055	53,835	17,004	140,565	15,802	10,670	6,253	84,479	117,204	42,780
2013	46,078	45,880	43,009	43,009	2013	89,939	58,626	17,838	151,669	16,908	11,620	6,559	91,153	126,240	42,078
2014	49,633	48,345	45,237	45,237	2014	96,234	63,844	18,712	163,651	18,092	12,654	6,880	98,354	135,980	49,633
2015	53,465	50,945	47,582	47,582	2015	102,971	69,526	19,629	176,579	19,359	13,780	7,217	106,124	146,480	53,465
2016	57,597	53,688	50,051	50,051	2016	110,179	75,714	20,590	190,529	20,714	15,007	7,571	114,508	157,799	57,597
2017	62,207	56,545	52,723	52,723	2017	117,710	82,620	21,590	206,300	22,129	16,375	7,939	123,986	170,430	62,207
2018	67,021	60,596	55,464	55,464	2018	125,950	89,973	22,648	222,598	23,679	17,833	8,328	133,781	183,620	67,021
2019	72,212	64,203	58,350	58,350	2019	134,766	97,981	23,758	240,183	25,336	19,420	8,736	144,350	197,841	72,212
2020	77,809	68,033	61,388	61,388	2020	144,200	106,701	24,922	259,157	27,110	21,148	9,164	155,734	213,175	77,809
2021	83,844	72,100	64,587	64,587	2021	154,294	116,197	26,143	279,631	29,007	23,030	9,613	168,058	229,708	83,844
2022	90,351	76,419	67,956	67,956	2022	165,094	126,539	27,424	301,722	31,038	25,080	10,084	181,335	247,536	90,351
2023	97,368	81,006	71,504	71,504	2023	176,651	137,801	28,768	325,558	33,210	27,312	10,578	195,660	266,761	97,368
2024	104,934	85,880	75,240	75,240	2024	189,017	150,065	30,177	351,277	35,535	29,743	11,096	211,117	287,492	104,934
2025	113,095	91,058	79,174	79,174	2025	202,248	163,421	31,656	379,028	38,023	32,390	11,640	227,796	309,848	113,095
2026	121,895	96,561	83,318	83,318	2026	216,405	177,966	33,207	408,971	40,684	35,273	12,210	245,791	333,959	121,895
2027	131,386	102,410	87,681	87,681	2027	231,553	193,805	34,834	441,279	43,532	38,412	12,809	265,209	359,962	131,386

3) Saving of Vehicle-hour Cost

Table 7.2.21 shows saving of vehicle-hour,s calculated by the same method as vehicle-kms. There are two kinds of saving of vehicle-hour. One is saving of time related cost in vehicle operating costs, and the other is time saving of passengers.

In general Time saving composition by vehicle types of car, taxi, bus, and truck shows that time saving of trucks amounts to more than half of the total. In the same way, time saving of passengers of cars amounts to more than half of the total.

(3) Minus Benefits due to restriction on Pasage of Large Vessels

There were two proposed of bridge heights; one is 65m and the other is 70m. Here we adopted 70m. In the case of 70m, impassable vessels per year may be as follows. (Ref. Chapter 3)

- Large Tanker : 4 vessels , 3 round trips every year (when fully laden, they take the detour of the cape of Good Hope)
- Oil rigs : 2 vessels
- Large carrier of vehicles Almost none

Without the project, they are all passable. With the project they cannot pass. Thus the difference is considered as the minus benefits.

Large size tankers mainly start from Restanura in Saudi Arabia, and terminate at Rotterdam. With the project these vessels will inevitably increase fuel cost, sailing time, the capital cost, and operating costs, which are considered to be minus benefits.

Operating costs of general vessels have certain standard (WS100) which take account of the sea route, region, type of vessel, fuel, crews and others. It remains the same whether fully loaded or unloaded. It is expressed per Net Weight Ton (NWT).

- By way of Suez Canal: US$ 11.55/ton
- By way of Cape of Hope: US$ 17.84/ton
- The difference is US$ 3.15/ton

In the case of a large sized tanker, scale merit of a large size makes the cost 45.1% less (1993). Accordingly the operating costs of a 500,000 ton tanker are as follows.

500,000 ton (Deadweight Ton) × 0.5 = 250,000 ton(NWT)
250,000 × 3.15 × 0.451 = $355,162

Thus the cost of minus benefits with the bridge project is calculated as below.
355,162 × 12 = $4,261,000/year

Oil Rigs will be unable to pass and the production areas will also move from Europe to Asia. This financially will decrease Canal revenue, but it does not increase operating costs of the Cape of Hope route. Cost factors of the change of production area will be affected by other factors as well, and are not included in the minus benefits.

Table 7.2.21 Driving Time Cost Saving of Vehicle and Passenger

Unit: 1000LE

Year	Time Cost Saving of Vehicle								Time Cost Saving of Pasenger							
	Case 1				Revised Case 3				Case 1				Revised Case 3			
	Qantara	Ferdan	Ismaili	Srabuio	Qantara	Ferdan	Ismaili	Srabuio	Qantara	Ferdan	Ismaili	Srabuio	Qantara	Ferdan	Ismaili	Srabuiom
2002	15,248	17,021	22,085	9,553	9,021	10,273	10,447	2,794	5,335	7,643	6,658	3,167	3,629	3,826	2,115	439
2003	16,589	18,517	24,348	10,608	9,812	11,183	11,426	3,075	5,704	8,176	7,257	3,557	3,878	4,084	2,170	470
2004	18,050	20,148	26,845	11,781	10,674	12,176	12,576	3,386	6,101	8,747	7,912	3,996	4,146	4,360	2,355	504
2005	19,642	21,924	29,600	13,085	11,613	13,258	13,845	3,728	6,526	9,359	8,626	4,490	4,433	4,655	2,557	540
2006	21,376	23,859	32,640	14,535	12,636	14,437	15,244	4,106	6,982	10,017	9,406	5,045	4,740	4,972	2,777	580
2007	23,294	35,018	35,994	18,116	12,610	15,207	15,473	4,478	7,471	11,755	10,259	5,682	4,723	5,241	2,886	626
2008	24,711	37,147	38,139	19,262	13,376	16,114	16,379	4,757	7,926	12,468	10,865	6,111	5,009	5,548	3,049	667
2009	26,215	39,412	40,415	20,482	14,188	17,079	17,340	5,017	8,408	13,231	11,509	6,573	5,313	5,875	3,222	699
2010	27,813	41,817	42,828	21,783	15,051	18,104	18,359	5,293	8,922	14,041	12,193	7,073	5,636	6,223	3,405	733
2011	29,509	44,371	45,389	23,171	15,968	19,192	19,440	5,584	9,468	14,904	12,919	7,613	5,979	6,594	3,600	768
2012	31,310	47,083	48,105	24,650	16,940	20,348	20,588	5,892	10,049	15,822	13,691	8,196	6,344	6,987	3,808	805
2013	33,222	49,963	50,986	26,227	17,973	21,576	21,805	6,218	10,666	16,798	14,512	8,827	6,733	7,406	4,028	844
2014	35,253	53,023	54,043	27,910	19,070	22,880	23,097	6,563	11,323	17,838	15,384	9,508	7,145	7,852	4,263	885
2015	37,410	56,273	57,286	29,705	20,235	24,265	24,468	6,927	12,023	18,944	16,311	10,245	7,585	8,327	4,512	929
2016	39,701	59,724	60,727	31,620	21,472	25,737	25,923	7,313	12,766	20,122	17,297	11,042	8,052	8,831	4,777	974
2017	42,133	63,546	64,429	38,635	21,517	26,002	26,451	8,556	13,639	21,265	18,289	11,890	8,009	8,924	4,900	1,144
2018	44,717	67,447	68,310	40,968	22,837	27,578	28,043	9,021	14,487	22,590	19,402	12,619	8,507	9,464	5,198	1,196
2019	47,462	71,598	72,429	43,601	24,239	29,255	29,734	9,516	15,389	24,008	20,587	13,610	9,037	10,041	5,515	1,251
2020	50,378	76,009	76,800	46,410	25,728	31,037	31,528	10,039	16,349	25,519	21,847	14,683	9,601	10,656	5,852	1,310
2021	53,475	80,695	81,438	49,407	27,310	32,931	33,431	10,592	17,372	27,127	23,187	15,843	10,201	11,310	6,210	1,372
2022	56,766	85,674	86,361	52,605	28,991	34,942	35,452	11,177	18,460	28,841	24,613	17,100	10,839	12,006	6,592	1,437
2023	60,261	90,964	91,586	56,019	30,776	37,080	37,596	11,796	19,618	30,667	26,130	18,460	11,520	12,748	6,997	1,505
2024	63,974	96,585	97,132	59,663	32,672	39,352	39,872	12,450	20,852	32,612	27,743	19,933	12,244	13,537	7,429	1,577
2025	67,919	102,558	103,018	63,554	34,687	41,766	42,287	13,142	22,165	34,685	29,461	21,528	13,015	14,378	7,888	1,653
2026	72,110	108,905	109,265	67,710	36,828	44,331	44,851	13,875	23,564	36,893	31,288	23,256	13,835	15,274	8,377	1,733
2027	76,563	115,650	115,897	72,148	39,102	47,058	47,573	14,649	25,054	39,247	33,233	25,128	14,710	16,228	8,896	1,818

7.2.5 Benefits and Costs Comparison

(1) Indicators Used for Comparison of Alternatives

By comparing economic costs and benefits of each alternative, the optimum location and facilities will be selected. As this is a comparison analysis of many alternatives, and not an investment feasibility analysis of a particular project, a sensitivity analysis has been not carried out.

There are three indicators as shown in Table 7.2.22:(a) Internal Rate of Return (IRR), (b) Net Present Value (NPV), and (c) Benefit Cost Ratio (B/C).

Table 7.2.22 Indicator of Benefits and Costs Analysis

Indicators	Contents
IRR	IRR is an indicator of benefit ratio to investment capital (cost). Higher the ratio is the better. That is to lead to the discounted rate of costs and benefits that makes total discounted present benefit become equal. However no matter the investment amount is greatly different, the rate may result in the same figure. For example, a project of 10 billion US$ scale and a project of 0.5 million US$ project scale could all show the same IRR of15%.
NPV	NPV indicator is usually used to analyze how much the benefit exceeds the investment cost. Differences is calculated by discounting costs and benefits with certain rate (capital opportunity cost). Higher the discounted present benefits is the better used.
B/C	On the other hand, even if NPV is small and project scale is small, some projects show high efficiency. It is expressed in benefit and cost ratio discounted at a certain rate (capital opportunity cost). That is, high B/C ratio means high benefit in relation to small investment cost. This is similar to IRR indicator.

NPV indicator and B/C indicator show different results depending upon which discount rate (= opportunity cost of capital) is to be used. In Egypt some say the opportunity cost of capital is 10% or others say 12%. IRR which can get the indicator (%) automatically by the calculation is used as project selection and priority indicator. Higher the IRR, the priority is higher, and any alternatives between 10 - 12% rate were considered feasible.

(2) Cost Benefit Comparison

Table 7.2.23 shows B/C analysis of the case of Ismailiya(Ferdan B) Bridge, Case 1, at 4% vertical grade. Table 7.2.24 is the summary of the result of Internal Economic Rate of Return calculation for each alternative.

Table 7.2.23 Cost Benefit Analysis with Ismailiya Project

(Case - 1, 4 Lanes, 4% Vertical Grade, Ismailiya Bridge)

	Year	1000 US$	Benefit								%	1000 US$	
		Cost	Time Waiting Ferry		V.O.C	Time Cost Saving		Total	Total	TunnerCost	Discount	Present Worth	
			Vehicle	Passenger	(Increase)	Vehicle	Passenger	1000LE	1000us$	1000us$	Factor	Cost	Benefit
1	1997	1,798									0.859	1,545	0
2	1998	21,577									0.739	15,936	0
3	1999	31,467									0.635	19,973	0
4	2000	29,669									0.545	16,184	0
5	2001	5,394									0.469	2,529	0
6	2002	237	18,710	19,011	22,732	22,085	6,658	43,732	12,513	4,261	0.403	96	3,325
7	2003	237	19,923	20,157	24,443	24,348	7,257	47,242	13,518	4,261	0.346	82	3,205
8	2004	237	21,561	21,651	26,289	26,845	7,912	51,679	14,787	4,261	0.298	71	3,132
9	2005	237	24,465	24,124	28,282	29,600	8,626	58,533	16,748	4,261	0.256	61	3,193
10	2006	237	30,053	28,514	30,434	32,640	9,406	70,179	20,081	4,261	0.220	52	3,477
11	2007	237	32,643	30,028	32,798	35,994	10,259	76,126	21,783	4,261	0.189	45	3,309
12	2008	825	35,253	32,174	34,436	38,139	10,865	81,995	23,462	4,261	0.162	134	3,117
13	2009	237	38,136	34,511	36,159	40,415	11,509	88,412	25,298	4,261	0.139	33	2,934
14	2010	237	41,330	37,063	37,973	42,828	12,193	95,441	27,309	4,261	0.120	28	2,763
15	2011	2,169	44,878	39,857	38,883	45,389	12,919	104,159	29,804	4,261	0.103	223	2,632
16	2012	237	48,827	42,921	40,893	48,105	13,691	112,651	32,233	4,261	0.089	21	2,477
17	2013	237	53,237	46,290	43,009	50,986	14,512	122,016	34,913	4,261	0.076	18	2,332
18	2014	237	58,174	50,004	45,237	54,043	15,384	132,368	37,875	4,261	0.065	15	2,198
19	2015	825	63,714	54,108	47,582	57,286	16,311	143,838	41,157	4,261	0.056	46	2,074
20	2016	237	69,949	58,656	50,051	60,727	17,297	156,578	44,803	4,261	0.048	11	1,958
21	2017	237	72,177	58,413	52,723	64,429	18,289	160,584	45,949	4,261	0.042	10	1,730
22	2018	237	79,798	63,669	55,464	68,310	19,402	175,715	50,278	4,261	0.036	8	1,642
23	2019	237	88,460	69,556	58,350	72,429	20,587	192,682	55,133	4,261	0.031	7	1,560
24	2020	237	98,328	76,168	61,388	76,800	21,847	211,755	60,591	4,261	0.026	6	1,484
25	2021	2,169	109,595	83,614	64,587	81,438	23,187	233,247	66,740	4,261	0.023	49	1,415
26	2022	825	122,487	92,021	67,956	86,361	24,613	257,525	73,687	4,261	0.019	16	1,351
27	2023	237	137,266	101,536	71,504	91,586	26,130	285,014	81,553	4,261	0.017	4	1,293
28	2024	237	154,243	112,332	75,240	97,132	27,743	316,210	90,479	4,261	0.014	3	1,239
29	2025	237	173,778	124,611	79,174	103,018	29,461	351,693	100,632	4,261	0.012	3	1,190
30	2026	237	196,294	138,608	83,318	109,265	31,288	392,138	112,205	4,261	0.011	3	1,146
31	2027	237	222,288	154,599	87,681	115,897	33,233	438,336	125,424	4,261	0.009	2	1,105
											16.36%	57,216	57,279

Table 7.2.24 Internal Rate of Return and Priority of Each Alternative

Alternatives	4 Lane, 4% Vertical Grade			4 Lane, 3.3%Vertical Grade		
	Case 1	Case 2	R. Case3	Case 1	Case 2	R. Case3
Qantra Bridge	12.13%	6.00%	1.59%	11.24%	5.22%	Not Estimated
Ferdan Bridge	15.32%	8.12%	3.90%	14.21%	7.07%	
Ismailiya Bridge	16.36%	8.60%	4.25%	15.26%	7.59%	
Srabuiom Bridge	8.15%	4.09%	<1.00%	7.52%	3.32%	
Qantara Tunnel	10.25%	5.81%	<1.00%	9.64%	5.24%	
Ferdan Tunnel	12.62%	7.25%	<1.00%	11.99%	6.66%	
Ismailiya Tunnel	12.21%	6.02%	2.85%	11.46%	5.92%	
Srabuiom Tunnel	6.41%	3.27%	<1.00%	5.88%	2.09%	

Note: For economic cost priorities, see Table 7.2.8

The prioritiy rating of alternatives was changed considerably, by adding benefits to economic costs. Benefits of each alternative are influenced by the following factors.

- Increase or decrease of traffic volume without project,
- Change of traffic volume with project by crossing points,
- Difference of vehicle type compositions by crossing points,
- Difference of running costs and time related fixed costs by type of vehicles,
- Time saving value of passengers by vehicles,
- Waiting time saving of ferries, and
- Non-passage of large sized vessels.

For internal rate of return, when 12% is applied, Ismailiya bridge has 16.36%, Ferdan bridge 15.32%, and Ferdan tunnel 12.62%. Reasons for high IRR of Ismailiya bridge are;

- The total discounted present value of economic cost is US$ 118.24 million which is 6% lower than average economic cost of bridges,
- Estimated traffic volume is high.

Reasons for high IRR at Ferdan are;

- Truck is estimated to amount to 72.14% of the total traffic which means large time saving benefits,
- Time saving benefits of passengers is a high estimate, because business trip amounts to 52.3% of the total trip purposes,
- Traffic volume estimation is high, and
- Waiting time for ferry is high and the resulting time saving benefits of vehicles and passengers is also high.

(3) Conclusion

1) Comparison by Construction Costs

Table 7.2.25 lists priority order of the total amount of construction and maintenance costs for 31 years discounted at present value of 12% of opportunity cost of capital.

The lowest cost is US$ 56.8 million for Srabuiom bridge (4% V. grade) and the highest cost is US$ 116.1 million for Ismailiya tunnel (3.3% V. grade). This shows that there is a difference of twice the cost in the use of national resources such as the land, imported materials, domestic resources and labor for a canal crossing project at different crossing points. When discounted at 10% of capital opportunity cost, the conclusion was the same.

Table 7.2.25 Comparison of Total Construction & Maintenance Costs for Project Life using Ecomnomic Price and Priority Rating

Unit: million US$

Alternatives	Cost in Economic Price		Priority
	4% V.Grade	3.3% V.Grade	
Srabuiom Bridge	56.8	64.6	1
Ismailiya Bridge	57.9	65.7	2
Ferdan Bridge	64.7	73.6	3
Qantra Bridge	67.7	76.0	4
Qantara Tunnel	100.6	108.8	5
Ferdan Tunnel	100.9	109.2	6
Srabuiom Tunnel	104.4	114.5	7
Ismailiya Tunnel	106.1	116.1	8

2) Comparison between Costs and Benefits

In the case of capital opportunity cost at 10%, 11 alternatives were found feasible out of 16 alternatives for canal crossing facilities. The project should be implemented as soon as possible as delay of implementation will incur greater loss of national resources.

According to the priority rating in the Table 7.2.26, Ismailiya bridge (4% V. grade) has the highest economic IRR of 16.36%, and this alternative should be given the top priority.

It should be remembered, however, this calculation asumes Case 1 of development case for Sinai (The population is assumed to grow to 3.2 million in year 2017). For Case 2 (2 million population) and Revised Case 3 (1.5 million), IRR of all alternatives shows less than 10%, and thus they are considered unfeasible.

Table 7.2.26 Priority Order of the Investment Feasibility Project

Alternatives	V. Grade	IRR	Priority
Ismailiya Bridge	4.00%	16.36%	1
Ferdan Bridge	4.00%	15.32%	2
Ismailiya Bridge	3.30%	15.26%	3
Ferdan Bridge	3.30%	14.21%	4
Ferdan Tunnel	4.00%	12.62%	5
Ismailiya Tunnel	4.00%	12.21%	6
Qantara Bridge	4.00%	12.13%	7
Ferdan Tunnel	3.30%	11.99%	8
Ismailiya Tunnel	3.30%	11.46%	9
Qantara Bridge	3.30%	11.24%	10
Qantara Tunnel	4.00%	10.25%	11

3) Final Economic Conclusion

Above 11 investment feasible alternatives of low economic costs and high IRR achieved by adding all benefits, can be considered in three distinct groups (Table 7.2.27).

The first group with low construction costs and high IRR has the highest priority rating. The first and second groups are based on the construction of a bridge, while the third group is a tunnel. On this basis a bridge is clearly preferable to a tunnel as the choice for the canal crossing facility.

The financial cost analysis using market price has been based on 1996 prices, and not use d for the priority rating comparison.

The final decision of the feasibility priority rating will be made taking into account the above economic analysis together with the engineering and other factors.

Table 7.2.27 Result of Combination of Construction Costs and IRR

Unit: million US$

Canal Crossing Facility	V. Grade	Economic Cost	IRR
(1) Low construction cost with high IRR			
Ismailiya Bridge	4.00%	57.9	16.36%
Ferdan Bridge	4.00%	64.7	15.32%
Ismailiya Bridge	3.30%	65.7	15.26%
(2) Low construction cost with relatively high IRR			
Ferdan Bridge	3.30%	73.6	14.21%
Qantara Bridge	4.00%	67.7	12.13%
Qantara Bridge	3.30%	76.0	11.24%
(3) High construction cost with relatively low IRR			
Ferdan Tunnel	4.00%	100.9	12.62%
Ismailiya Tunnel	4.00%	106.1	12.21%
Qantara Tunnel	4.00%	100.6	10.25%
Ferdan Tunnel	3.30%	109.2	11.99%
Ismailiya Tunnel	3.30%	116.1	11.46%

CHAPTER 8

THE BEST ALTERNATIVE

CHAPTER 8 THE BEST ALTERNATIVE

(1) Crossing System

1) Future Traffic Demand

Three scenarios of socio-economic development have been considered in this study in order to analyze an appropriate crossing structure for the Suez Canal. Case 1 has been taken as the basic case and the Revised Case 3 indicates the minimum socio-economic framework even under the worst case condition.

Future traffic demand can therefore be estimated as ranging from 6,000 to 33,000 vehicles per day at the crossing locations, in 2017, excluding Port Said and Ras El Esh, depending on the socio-economic framework cases.

2) Number of Lanes

A two lane crossing structure would only meet the future traffic demand in 2017, but only at Srabuiom in the socio-economic framework of Case 2 and Revised Case 3, under the condition of Level of Service C of the Highway Capacity Manual. Conversely, a four lane crossing structure will have to be provided at Srabuiom in 2017 using Case 1, the basic socio-economic framework case.

It will be necessary to provide a four lane crossing structure at either Qantara, Ferdan or Ismailiya in 2017 under each socio-economic framework case, even under the condition of Level of Service D which has a higher two lane traffic capacity than that of Level of Service C.

3) How to Provide the Four Lane Crossing Structure

There are two possible methods available of providing a four lane capacity crossing structure. One is to construct a four lane crossing and the other is to construct one two-lane crossing initially, and at a later stage to construct another two-lane crossing at an adjacent location, in order to meet the traffic increase. This is the so- called staged construction method. Using the stage construction method, it should be noted that after completion of the second structure, it will be necessary to revert to a one way flow system on each structure.

This is necessitated by the need to rationalize the crossing approach or access road layout, and to ensure a safe efficient and uninterrupted traffic flow pattern.

From the results of the evaluation presented in Paragraph 7.1, Evaluation of Crossing System Alternatives, it is preferable to construct one four lane crossing structure. If two two-lane structures are selected, the second two lane crossing structure has to be opened up in 2009 even under the condition in the Revised Case 3.

(2) Structural Alternatives

Structural alternatives (bridge/tunnel, location and physical configuration) have been compared and the best alternative (cable-stayed bridge with four lanes and 3.3% vertical grade) has been selected for the following reasons.

1) Bridge or Tunnel

From the viewpoint of economic viability, a bridge at the locations of Qantara, Ferdan or Ismailiya, or a tunnel at the locations of Ferdan and Ismailiya can be demonstrated to be viable with respected to the Economic Internal Rate of Return of these alternatives.

The estimated costs of the tunnels are much higher than the costs of the bridge alternatives, but the EIRRs of the former are only 1-2 % higher than the latter. Taking account of the massive anticipated financial expenditures for the Sinai Development in the coming two decades, it is essential to minimise expenditure on the infrastructures as much as possible.

Comparing the results of economic and financial factors between these two alternatives, it can be said that the bridge alternatives are more favorable than the tunnel alternatives.

2) Crossing Location

The four possible bridge location alternatives has been compared: Qantara, Ferdan, Ismailiya and Srabuiom, and the results of these comparisons are as follows;

a. Traffic Flow and Sinai Development

Comparing the projected future traffic flows of these four locations, Qantara, Ferdan and Ismailiya are expected to have the greatest traffic volumes and to become the most important components of the arterial road network connecting Sinai to the rest of Egypt. Expected traffic volumes at Qantara, Ferdan and Ismailiya in the year 2017 are 28,800, 33,300 and 32,900 vehicles respectively.

b. Engineering Aspect

From the engineering aspect, no significant difference in engineering difficulties can be observed between these four alternative locations.

c. Financial Cost / Economic Evaluation

From the results of the EIRR, they rank in the following order of preference,

1. Ismailiya
2. Ferdan,
3. Qantara, and
4. Serabuiom.

d. Navigational Safety

Egyptian National Railways have decided that the new railway swing bridge is to be constructed at Ismailiya, and consequently SCA has required that the road bridge be constructed at a different location. The new crossing bridge must be located at least 3 km away from the end of the curve of the channel and the new railway bridge, to ensure that there is sufficient stopping distance for the maximum sized vessels in transit on the Canal to avoid the risk of colliding with the bridges. This distance of 3 km, which is six to seven times the length of the maximum sized vessel (about 450 m length), has been confirmed as reasonable by the Study Team.

Taking this constraint into consideration, only Qantara and Serabuiom will satisfy this navigational safety requirement.

e. Future Development of the Canal

SCA has a plan to construct second channel to by-pass the channel at Srabuiom in the near future, and this will cause a considerable increase in the construction cost of the bridge at Srabuiom.

As a results of all these comparisons, Qantara has been selected as the best crossing location due to the navigational safety being the main factor dictating the selection of the crossing location.

3) Vertical Grade

When considering the forecast traffic volume for the target year of the plan, a vertical grade of 4 % for the bridge would appear to suffice with reference to the international design standards. It should be noted, however, that many of the vehicles currently used in Egypt are overloaded and aged trucks, and these vehicles will make up a large percentage of the vehicles crossing the bridge. These factors indicate that it is desirable to design vertical grade of 3.3 % for the bridge. In addition, as the heavy vehicle ratio is about 20% of the road crossing traffic, the effect on the environment around the crossing including noise and air pollution especially by heavy vehicles will be considerable and hence providing a vertical grade of 3.3% for the bridge should be considered.

(3) Best Alternative

Based on the above discussion, the following option will be recommended.

Crossing location	:	Qantara
Type of crossing structure	:	Bridge
Number of lanes	:	4 lanes
Vertical grade	:	3.3 %

CHAPTER 9

DESIGN CRITERIA FOR PRELIMINARY DESIGN

CHAPTER 9 DESIGN CRITERIA FOR PRELIMINARY DESIGN

9.1 General

The design criteria for the preliminary design will be determined based on the results of the study for the design requirements in Chapter 6 in this report.

9.2 Design Criteria

9.2.1 Geometric Design Criteria

(1) Road Classification and Design Speed

1) Road Classification

The road crossing the Canal should be classified as a Primary Rolling Desert Road.

2) Design Speed

The design speeds of the road crossing the Canal will be 80 km/hr.

(2) Design Geometry

1) General

As a rule, the Egyptian standards will be used for the geometric design of the road crossing. However, the geometric design criteria in this standards of other countries, such as America, Britain and Japan will be used for some of the design to complement the Egyptian standards.

2) Vertical Grade

The Study Team has examined the vertical grade for the road crossing the Suez Canal in this phase. A vertical grade of 3.3%has been selected based on the results of the studies and discussions with the Egyptian counterparts.
(Refer to Paragraph A10.14 in Appendix)

3) Other Design Criteria

Other criteria proposed for the geometric design of the road crossing the Canal are summarized in Table 9.2.1.

Table 9.2.1 Geometric Design Criteria

Item	Unit	Figure	Remarks
Design Speed	km/hr	80	Primary Rolling Desert Road
Lane Width	m	3.65	
Shoulder Widths for ;			
1) Bridge or Tunnel Section : 4 Lanes	m	0.60	
2) Earthwork Section : Elevated	m	1.25	Approach Section
3) Earthwork Section : Level	m	2.25	Access Road
Hard Strip Width	m	0.25	
Median Width	m	1.50	
Crossfall	%	2.0	
Maximum Superelevation	%	6.0	
Maximum Vertical Grade	%	3.3	Rolling Desert Road
Minimum Stopping Sight Distance	m	105	
Minimum Passing Sight Distance	m	140	
Minimum Horizontal Curve Radius	m	250	
Minimum Horizontal Curve Radius without Transition Curve	m	2,000	
Minimum Vertical Curve Radius for ;			
1) Crest Curve	m	3,000	
2) Sag Curve	m	2,000	
Nose Taper	m	12.3	
Taper Length	m	150	

Source : Study Team

(3) Cross Section

1) Number of Lanes

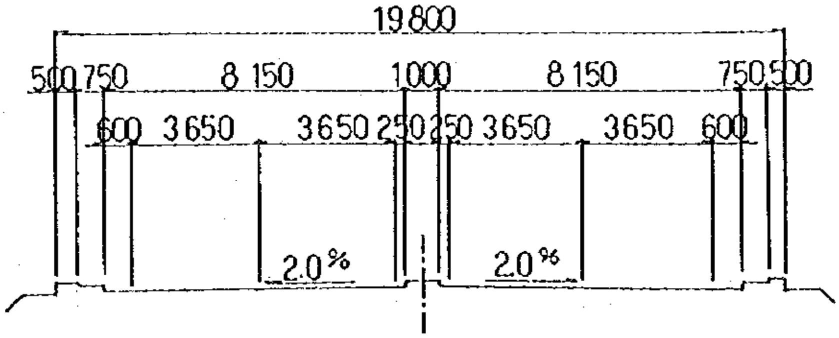
4 lanes as shown in Fig. 9.2.1 will be provided for the road crossing the Canal.

2) Lane Width

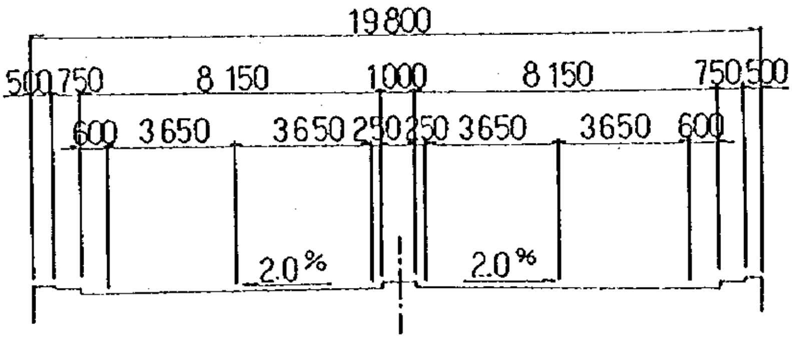
A lane width of 3.65 m will be provided for the road crossing the Canal.

3) Shoulder

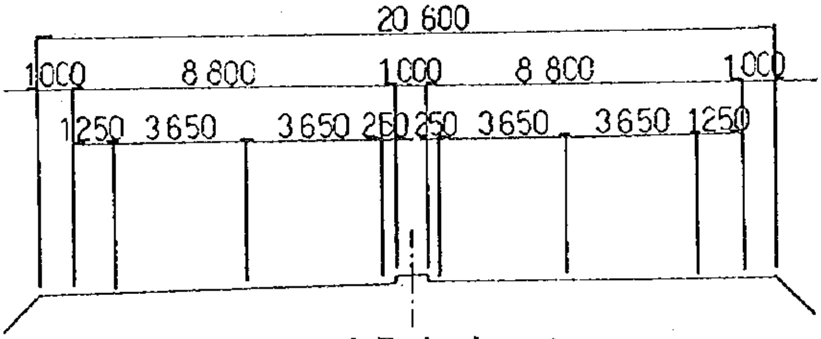
A shoulder width of 0.60 m for a 4 lane bridge and approach viaducts, 1.25 m for the approach embankment sections and 2.25 m for the access roads will be provided.



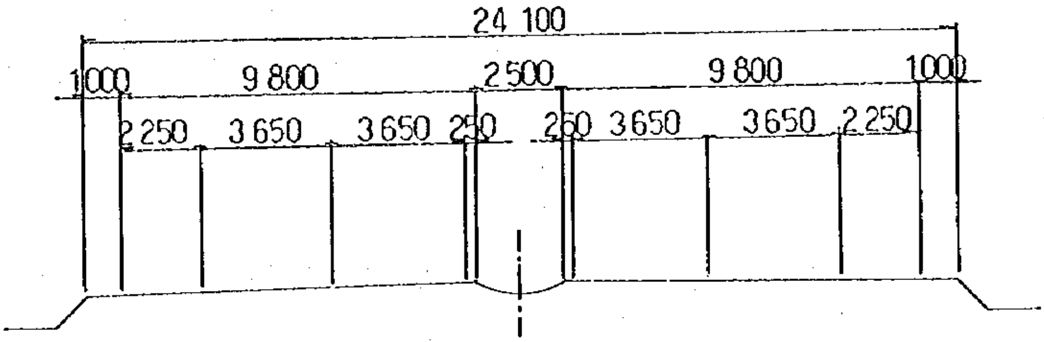
Main Bridge



Approach Viaduct



Approach Embankment



Access Road

Fig. 9.2.1 Cross Section for Bridge (4 Lane Road)

4) Median

A median width of 1.5 m, including hard strips of 0.5 m, should be provided to the bridges and approach embankments and 3.0 m for the access roads.

(4) Navigation Clearance

Based on the results of the study done by the Study Team (Refer to Paragraph 3.2.3) and in the discussions with SCA, a horizontal clearance of 384 m at Qantara and a vertical clearance of 70 m above H.H.W.L are required. This arrangement is shown in Fig. 9.2.2 below.

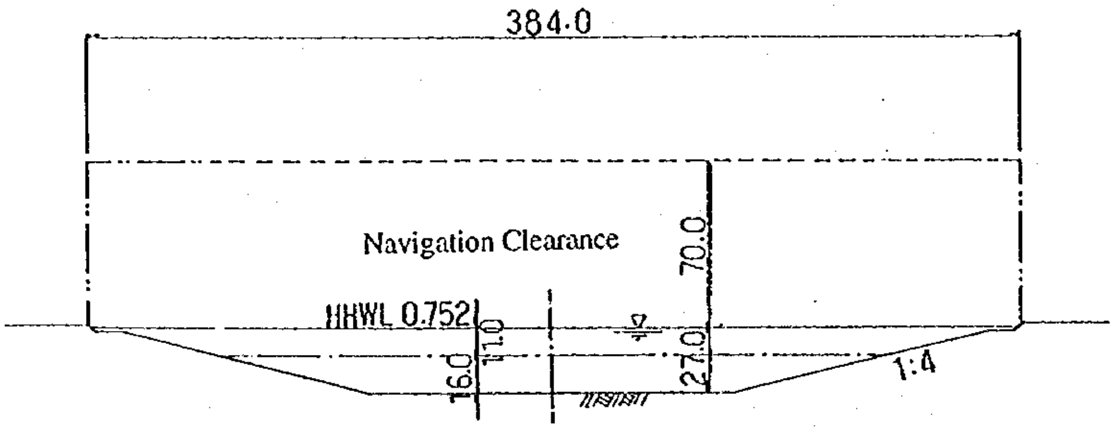


Fig. 9.2.2 Navigation Clearance at Qantara

(5) Structural Clearance

1) Road Clearance

A vertical structural clearance (headroom) of 5.5m and a horizontal structural clearance of the carriageway width based on the Egyptian standards will be provided for this study.

2) Construction Gauge of Railways

The railway construction gauge together with the proposed Canal railway crossing of the Ismailiya - Port Said Railway, will be allowed for in the design of the road crossing.
The headroom of the railway appears to be 5.5m based on the Egyptian standards as shown in Fig. 6.1.7.