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No. 8

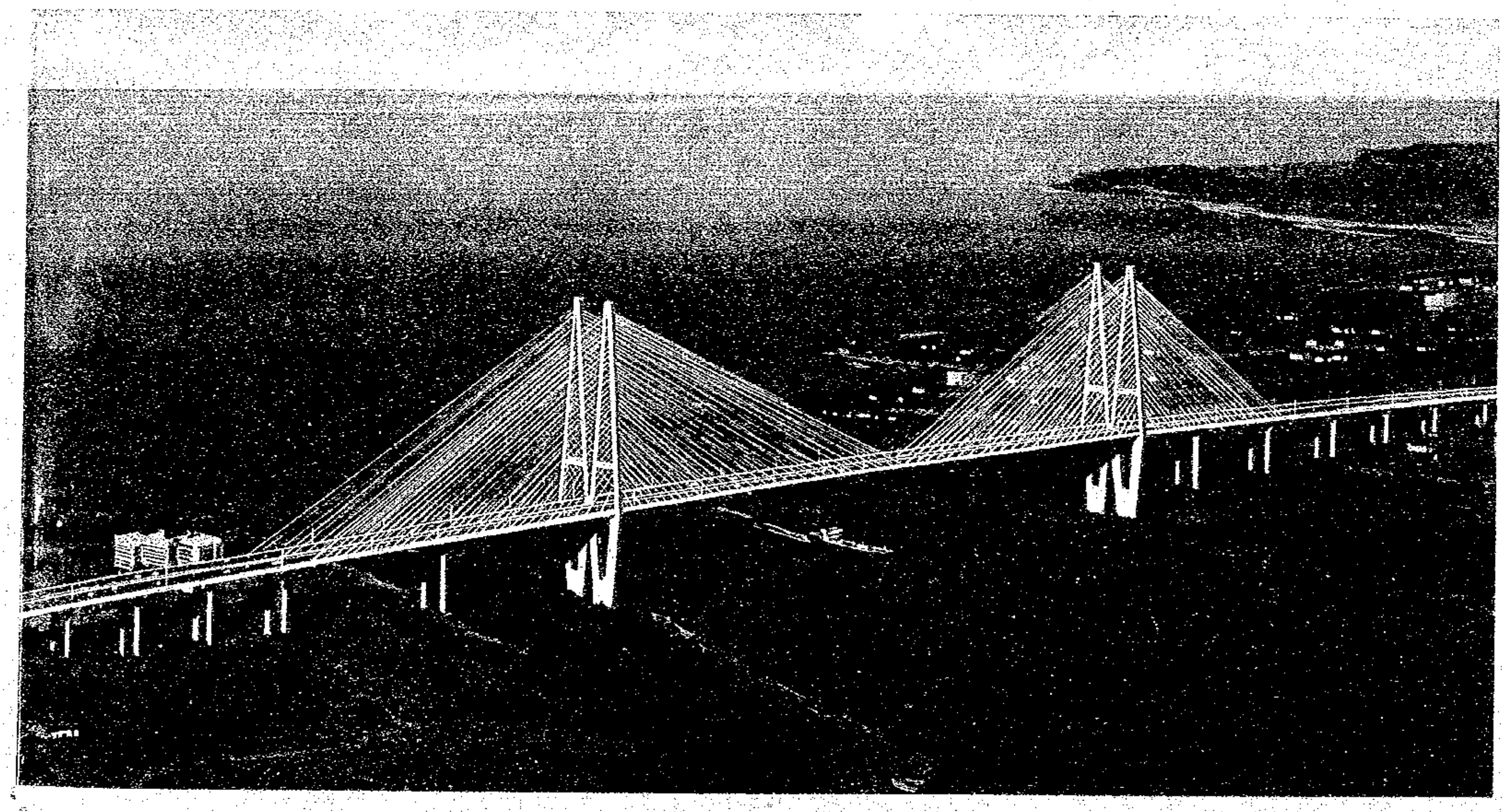
REPUBLIC OF KENYA

MINISTRY OF TRANSPORT AND COMMUNICATIONS

FEASIBITY STUDY ON LIKONI CROSSING CONSTRUCTION PROJECT

FINAL REPORT

VOL. II APPENDIX



APRIL 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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CONTENTS

Appendix A TRAFFIC INDUCED BY NO WAITING FERRY

On the replacement of existing ferry by a fixed crossing traffic service without waiting time will be realized.

Due to the increment of the service, some additional traffic will be induced. Generally the rate of induced traffic is given by the following formula.

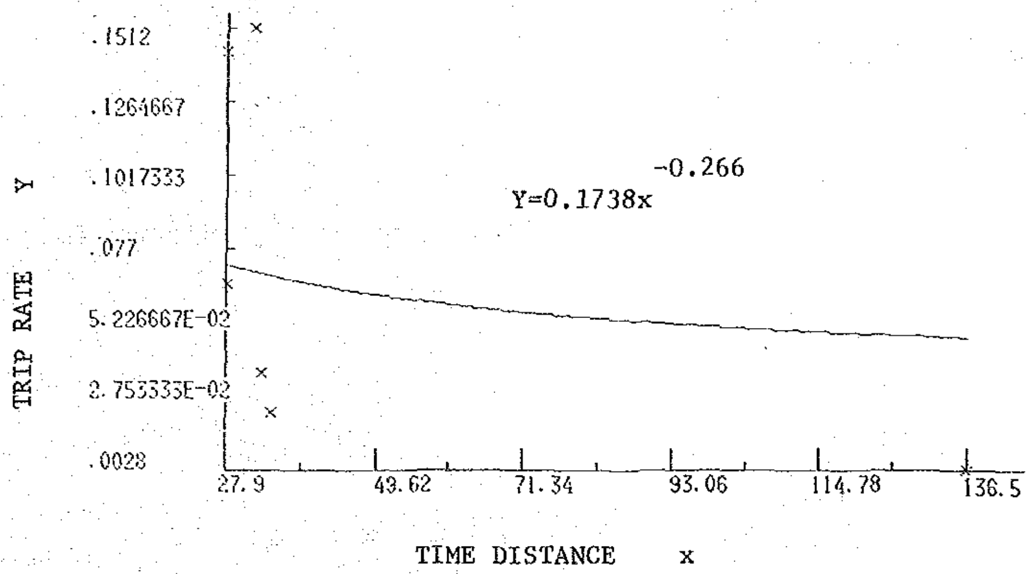
$$R_{ij} = \left(\frac{D'_{ij}}{D_{ij}}\right)^{\beta} - 1$$

where

- R_{ij} : Induced traffic ratio between i and j zones
- D_{ij} : Induced traffic ratio between i and j zones in case of "Without Project"
- D'_{ij}: Time distance between i and J zones in case of "With Project"
- β : Parameter

The parameter β is Caluculated by the regession analysis using the trip rate and time distance surveyed in the April 1983 as shown below.

Y=ALPHA*X^BETA ALPHA=.1737572 BETA=-.266
R2=.1484041 F=.6970633 R=0.37



The time distance with and without project are caluculeted as the weighted avarege of time distance between 6 zonal pairs as shown in the following Table.

Zones From Likoni, Kwale	Present Traffic Potential (ADT in 1983) Tij	Present Time Distance (Min. 1983) Dij	Time Distance With Project D'ij	Zonal Perir Gravity Pi x Pj (Population in 1979, 1000)	Trip Rate R= Tij÷ (PixPj)
Island North	609	33.1	12.7	329x 52=17,108	0.0356
Island South	193	28.1	10.7	329x 9= 2,961	0.0652
Port Industry	1,492	31.9	12.5	329x 30= 9,870	0.1512
Town Center	2,263	27.9	7.5	329x 48=15,792	0.1433
West Mainland	593	34.5	14.5	329x 82=26,978	0.02198
North Mainland	471	136.5	116.1	329x511=168,119	0.00280
Weighted average	(5,621)	39.33	19.34	-	-

Based on the above, the induced traffic ratio (Rij) is obtained as 20.8% as follow.

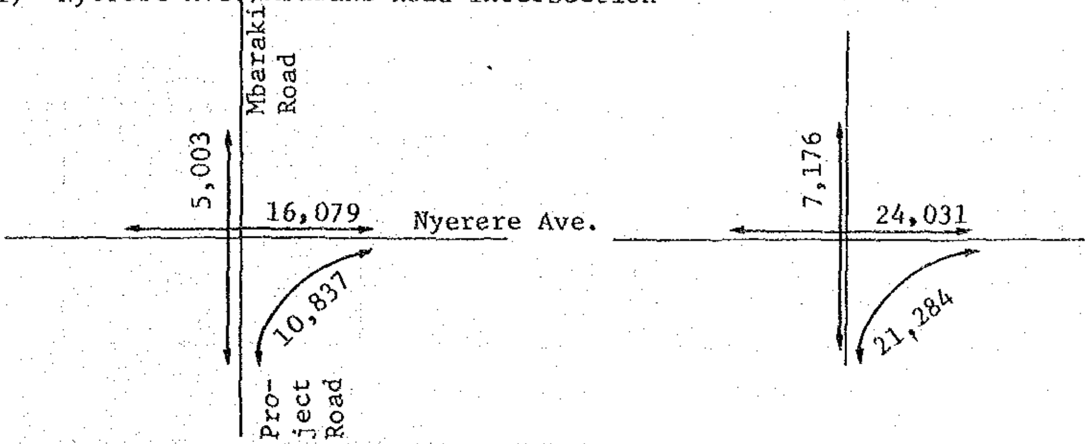
$$Rij = \left(\frac{19.34}{39.33}\right)^{-0.266} -1 = 0.208$$

Appendix B INTERSECTION TRAFFIC ANALYSIS

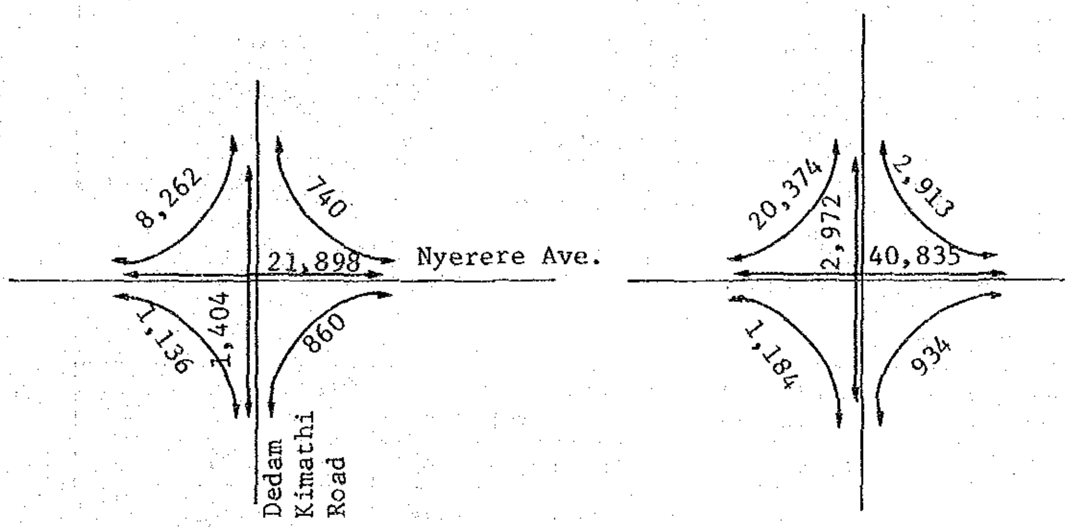
Fig. B-1 TRAFFIC DEMAND FOR INTERSECTION

Year 2000 (PCU/Day) Year 2010 (PCU/Day)

(1) Nyerere Ave./Mbaraki Road Intersection



(2) Nyerere Ave./Dedan Kimathi Ave. Intersection



(3) Lunga Lunga Road/Mtongwe Road Intersection

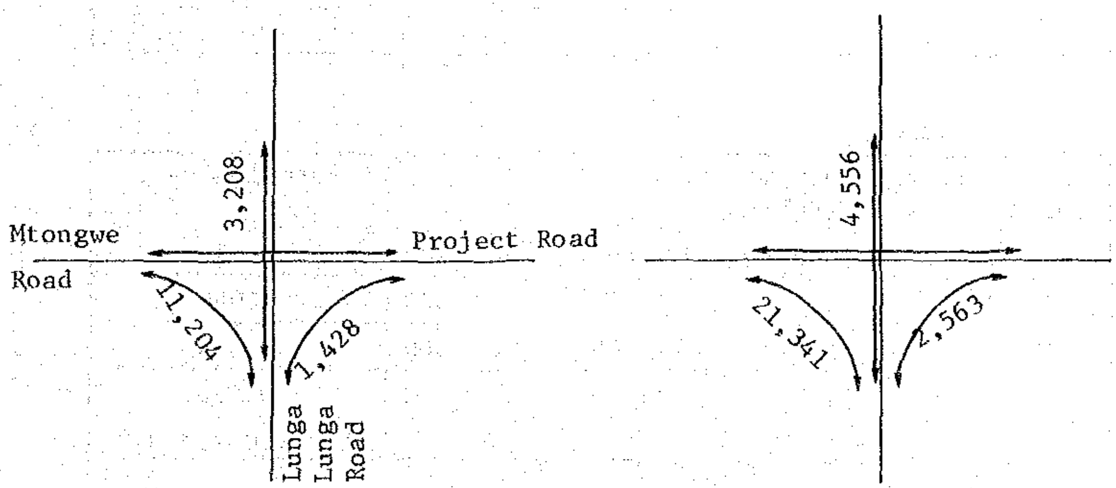


Table B-2 INTERSECTION TRAFFIC ANALYSIS

(1) Nyerere Ave./Mbaraki Road Intersection

Year 2000

Signal Phase	Traffic Demand: V (Veh./hr)	Capacity: C (Veh./hr)	Saturation Rate V/C
I	1,061	1,800 x 2 = 3,600	0.295
II	330	1,800 x 1 = 1,800	0.183
III	715	1,200 x 2 = 2,400	0.298
			Σ = 0.776 < 0.9

Year 2010

Signal Phase	Traffic Demand: V (Veh./hr)	Capacity: C (Veh./hr)	Saturation Rate V/C
I	1,586	1,800 x 2 = 3,600	0.441
II	474	1,800 x 2 = 3,600	0.132
III	1,405	1,200 x 3 = 3,600	0.390
			Σ = 0.963 > 0.9

(2) Nyerere Ave./Dedan Kimathi Ave. Intersection

Year 2000

Signal Phase	Traffic Demand: V (Veh./hr)	Capacity: C (Veh./hr)	Saturation Rate V/C
I	1,445	1,800 x 2 = 3,600	0.401
II	75	1,200 x 1 = 1,200	0.063
III	93	1,800 x 1 = 1,800	0.053
IV	575	1,200 x 2 = 2,400	0.240
			Σ = 0.76 < 0.9

Year 2010

Signal Phase	Traffic Demand: V (Veh./hr)	Capacity: C (Veh./hr)	Saturation Rate V/C
I	2,695	1,800 x 4 = 7,200	0.374
II	192	1,200 x 2 = 2,400	0.080
III	192	1,800 x 2 = 3,600	0.053
IV	1,345	1,200 x 2 = 2,400	0.560
			Σ = 1,067 > 0.9

(3) Lunga Lunga Road/Mtongwe Road Intersection

Year 2000

Signal Phase	Traffic Demand: V (Veh./hr)	Capacity: C (Veh./hr)	Saturation Rate V/C
I			
II	212 + 94 = 306	1,800 x 0.615 = 1,107	0.276
III	739	1,200 x 1 = 1,200	0.616
IV	94*	1,200 x 1 = 1,200	0.078*
			Σ = 0.896 < 0.9

Note: * Traffic is treated by an additional lane.

APPENDIX C WIND AND EARTHQUAKE

1. Wind

1) Average Monthly Wind Speed

The average monthly velocity of the wind is in the range of 4 ∿ 5 m/sec. The daily on-shore wind prevails with a greater velocity in the afternoon reaching 15 m/sec, averaging 8 ∿ 10 m/sec as shown below:

Mombasa Town

Latitude 04° 03' S
Longitude 39° 39' F
Altitude 52 feet (16 m)

Mouth	Average Wind Speed (Knots)	
	06:00 G.M.T.	12:00 G.M.T.
January	5	11
February	4	10
March	3	9
April	3	8
May	4	8
June	5	10
July	5	9
August	5	9
September	5	9
October	5	9
November	3	9
December	4	9
Year	4	9

Note: Kenya Standard Time = G.M.T. plus three hours.
1 m/sec = 2.237 Knots
1 Knots = 0.447 m/sec
The wind speed is measured at 10 meters above ground level.

The wind directions is mainly from the east in November, December, January, February and March, while the south wind blows mainly from April through October.

2) Wind Gusts

The following are the average for 3 seconds gust wind once in 25, 50 and 100 years.

Station Name	Ras Serani at East End of Mombasa Is.	
No. of Years of Record		5(1967 ∿ 71)
Return Period (Years)	25	25.9 m/sec
"	50	28.1 m/sec
"	100	30.3 m/sec

The highest value was taken as the design value and the coefficient for the structure height was also considered.

2. Earthquake

1) Earthquake record and zone classification

Earthquake occurs in the study area based on "A Catalogue of Felt Earthquakes in Kenya (1982 ∿ 1969)" by Prof. I.S. Loupekine of the Geology Department of the University of Nairobi.

Mombasa locates in the zone of VI and 28 times earthquake in the period of 1982 ∿ 1969 as shown below:

Number of Earthquake

	Maximum intensities observed						
Zone	IX	VIII	VII	VI	V	IV	III-II
1892 - 1969	1*	0	3**	28	128	382	Numerous

* The Subukia Valley a earthquake on 6th January 1928

** The Suguta River earthquake in 1924

The local earthquake in Nairobi in 1933

Toro earthquake with episentre in Uganda 1956.

The zone map is shown in Fig. C-1 and their effects are described as follows:

Possible effects on buildings and other structures in the various zones are as follows (information extracted from the Modified Mercalli Scale, pp. 12-13) in Prof. Loupekine's report.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Underground pipes broken. (These effects are believed to obtain only locally in Zone VIII-IX, shown in the seismic Zoning map).

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildigs with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columes, monuments, walls.

VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken.

VI. A few instances of fallen plaster or damaged chimneys. Damage slight.

V. A few instance of cracked plaster.

Intesity V is taken as the threshold of damage and it is to be noted that this is the lowest intesity value assigned to Kenya.

The Modified Mercalli Scale of 1931 (Wood and Neumann, 1931), supplemented by Richter's version (1956) as shown in Table C-1.

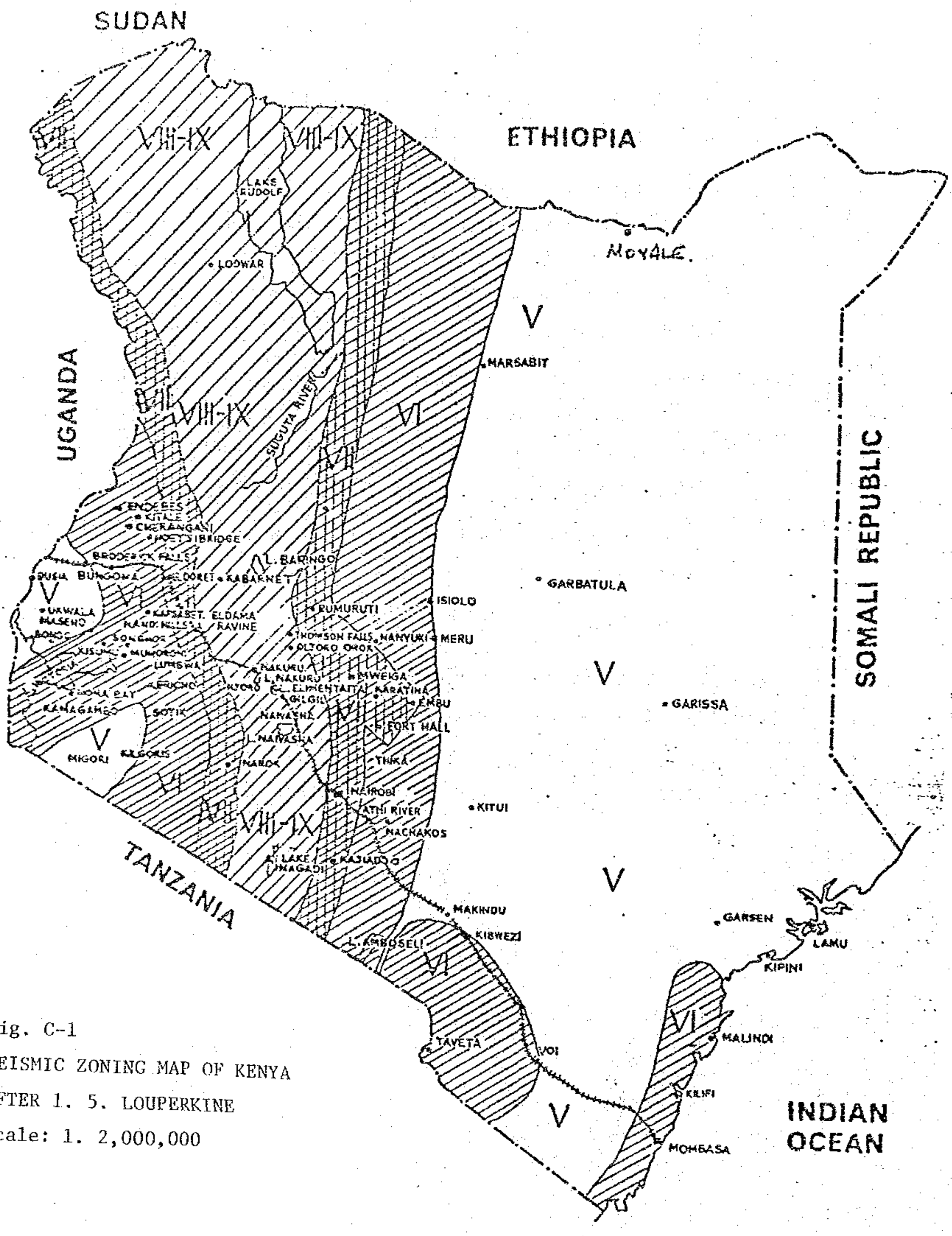


Fig. C-1

SEISMIC ZONING MAP OF KENYA

AFTER 1. 5. LOUPERKINE

Scale: 1. 2,000,000

Table C-1 MODIFIED MERCALLI SCALE

Intensity Scale	Modified Mercalli Scale (Wood and Neumann, 1931)	Seismic Intensity (gal)
I.	Not felt except by a very few under specially favourable circumstances. (Rossi-Forel scale)	0.5-1.0
II.	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.	1.0-2.1
III.	Felt quite noticeable indoors, especially on upper floors at buildings, but many people do not recognize it as an earthquake. Standing motor-cars may rock slightly. Vibration like passing of truck. Duration estimated.	2.1-5.0
IV.	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motor-cars rock noticeably.	5.0-10.0
V.	Felt by nearly everyone, many awakened. Some Dishes, windows, etc., broken; a few instance of craked plaster; unstable objects overturned. Disturbances of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.	10.0-21.0
VI.	Felt by all many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.	20.0-44.0
VII.	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; some chimneys broken. Noticed by persons driving motor-cars.	44.0-94.0
VIII.	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures: Fall of chimneys, factory stacks, colums, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor-cars disturbed.	94.0-202.0
IX.	Damage considerable in specially designed structurers; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked consipicuously. Underground pipes broken.	202.0-432.0

X.	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Considerable landslides from river-banks and steep slopes. Shifted sand mud. Water splashed (slopped) over banks.	more than 432.0
XI.	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines ruptured. Earth slumps and land slips in soft ground. Rails bent greatly.	
XII.	Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown upward into air.	

2) Seismic design

Before proceeding to detailed design recommendations, a table of building usage and types set against earthquake zoning, and giving recommended precautions is set out by "Code of Practice for the Design and Construction of Buildings and other Structures in relation to Earthquakes" (printed by the Kenya Building Centres, Nairobi, 1973).

Those are shown in Table C-2.

Table C-2 TABLE RELATING SEISMIC DESIGN TO TYRES & USAGES OF BUILDINGS

TYPE OF STRUCTURE & USAGE CLASS.		ZONE V		ZONE VI		ZONE VII		ZONE VIII ~ IX	
		SEISMIC DESIGN REQUIRED	LIMITING STOREYS OR HEIGHT.	SEISMIC DESIGN REQUIRED	LIMITING STOREYS OR HEIGHT.	SEISMIC DESIGN REQUIRED	LIMITING STOREYS OR HEIGHT	SEISMIC DESIGN REQUIRED	LIMITING STOREYS OR HEIGHT
R.C., Steel, etc. Framed Structures (Flexible or Rigid)	Class A	No	No limit	No Unless 12 storeys or over	No limit	No Unless 6 storeys or over	No limit	Yes	No limit, but special precautions
	Class B	No	3 storeys for offices, hotels etc. 4 storeys for flats	No	3 storeys for offices, hotels etc. 4 storeys for flats	No	3 storeys for offices, hotels etc. 4 storeys for flats	Yes if 3-4 storeys	3 storeys for offices, hotels etc. 4 storeys for flats
	Class C	No	No limit	No	No limit	Depends on use and importance and level of damage acceptable. At Engineer's discretion.			
	Class D	No	2 storeys	No	2 storeys	No	2 storeys	No	2 storeys
Load Bearing Walls	Class A	No	No limit	Yes	Not more than four storeys	Yes	Not more than three storeys	Yes	Not more than two storeys
	Class B	No	3 storeys for offices, hotels etc. 4 storeys for flats	Yes	3 storeys for offices, hotels etc. 4 storeys for flats.	Yes	3 storeys for offices, hotels etc. 4 storeys for flats	Yes	Not more than 3 storeys in in all cases
	Class C	No	Not over 3 storeys	No	Not over 3 storeys	Load bearing walls for installations not recommended over 2 storeys. At Engineer's discretion.			
	Class D	No	3 storeys	No	3 storeys	Yes	3 storeys	Yes	2 storeys
	Class E	No control of domestic buildings in Rural areas is envisaged, but buildings over 3 storeys should be discouraged, because of likely poor design and construction.							

Note: Where "Seismic Design" is referred to this means:
In case of Framed Buildings - Engineering Computation of effect of forces on frame as recommended in this Code.
" " " Load Bearing - Compliance with particular Recommendations in this Code.

Appendix D *UNIT COST FOR BRIDGE CONSTRUCTION*

P.C MAIN BRIDGE

H = 73.2 M, PHASE-I

	Work Item	Sub-Item	Class	Unit	Unit Cost (K.Shs.)		
					L.C	F.C	Total
Superstructure	Main Girder	Concrete	σck = 350 kg/cm²	CU.M	930	750	1,680
		Form	Steel	SQ.M	68	232	300
		Reinforcement	SD30	Ton	2,387	11,833	14,220
		P.C Rod	SBPR 95/120	Ton	7,386	57,114	64,500
		P.C Cable	SWPR	Ton	12,883	97,117	110,000
	Stayed Cable	P.C Cable	SWPR	Ton	16,150	122,550	138,700
	Erection & Equipment	–	–	L.S	5,532,000	33,432,000	38,964,000
Tower	Tower	Concrete	σck = 350 kg/cm²	CU.M	930	750	1,680
		Form	Steel	SQ.M	80	270	350
		Reinforcement	SD30	Ton	2,387	11,833	14,220
	Erection & Equipment	–	–	L.S	1,338,000	7,862,000	9,200,000
Substructure & Footing	Body & Footing	Concrete	σck = 300 kg/cm²	CU.M	960	690	1,650
			σck = 240 kg/cm²	CU.M	900	650	1,550
		Form	Steel	SQ.M	80	270	350
		Reinforcement	SD30	Ton	2,387	11,833	14,220
	Pile Foundation	Cast-in-Place Pile	R.C.D ϕ3.0m	L.M	13,800	53,900	67,700
	Shoe	Tefron	800x800x150	No	14,000	56,000	70,000
		Roller		Ton	12,377	95,923	108,300
	Expansion Joint		Demag	L.M	37,900	151,700	189,600
Temporary & Other Works				L.S	22,709	128,686	151,395

P.C MAIN BRIDGE

H = 45 M, PHASE-I & II

	Work Item	Sub-Item	Class	Unit	Unit Cost (K.Shs.)		
					L.C	F.C	Total
Superstructure	Main Girder	Concrete	σck = 350 kg/cm²	CU.M	930	750	1,680
		Form	Steel	SQ.M	68	232	300
		Reinforce-ment	SD30	Ton	2,387	11,833	14,220
		P.C Rod	SBPR 95/120	Ton	7,386	57,114	64,500
		P.C Cable	SWPR	Ton	12,883	97,117	110,000
	Stayed Cable	P.C cable	SWPR	Ton	16,150	122,550	138,700
	Erection & Equipment	-	-	L.S	3,322,000	18,824,000	22,146,000
Tower	Tower	Concrete	σck = 350 kg/cm²	CU.M	930	750	1,680
		Form	Steel	SQ.M	80	270	350
		Reinforcement	SD30	Ton	2,387	11,833	14,220
	Erection & Equipment	-	-	L.S	1,008,000	5,714,000	6,722,000
Substructure & Footing	Body & Foot-ing	Concrete	σck = 300 kg/cm²	CU.M	960	690	1,650
			σck = 240 kg/cm²	CU.M	900	650	1,550
		Form	Steel	SQ.M	80	270	350
		Reinforcement	SD30	Ton	2,387	11,833	14,220
	Pile Foundation	Cost-in-Place Pile	R.C.D ϕ3.0m	L.M.	13,800	53,900	67,700
	Shoe	Tefron		No	14,000	56,000	70,000
		Roller		Ton	12,377	95,923	108,300
	Expansion Joint			L.M	37,900	151,700	189,600
	Temporary & Other Works			L.S	16,540,000	93,731,000	110,271,000

STEEL MAIN BRIDGE

H = 73.2M, PHASE-I

	Work Item	Class	Unit	Unit Cost (K.Shs.)		
				L.C	F.C	Total
Superstructure	Main Girder	SS41, SM50Y	Ton	5,310	21,240	26,550
		HTB (F10T)	Ton	6,260	25,040	31,300
	Shoe	Roller	Ton	12,377	95,923	108,300
	Stayed Cable	SWPR	Ton	16,150	122,500	138,700
	Expansion Joint	Demag	L.M	37,900	151,700	189,600
	Erection,Equipment		L.S	5,922,000	38,739,000	44,661,000
Tower	Tower	SS41, SM50Y & SM58	Ton	5,480	21,920	27,400
		HTB (F10T)	Ton	6,260	25,040	31,300
	Erection,Equipment		L.S	1,940,000	12,687,000	14,627,000
Substructure	Concrete	σck = 300 kg/cm^2	CU.M	960	690	1,650
		σck = 240 kg/cm^2	CU.M	900	650	1,550
	Form	Steel	SQ.M	80	270	350
	Reinforcement	SD30	Ton	2,387	11,833	14,220
	Pile Foundation	R.C.D ø 3 m	L.M	13,800	53,900	67,700
Others	Temporary & Other Works		L.S			
Total						

STEEL MAIN BRIDGE

H = 55^M, PHASE-I & II

	Work Item	Class	Unit	Unit Cost (K.Shs.)		
				L.C	F.C	Total
Superstructure	Main Girder	SS41, SM50Y	Ton	6,000	24,000	30,000
		HTB (F10T)	Ton	6,260	25,040	31,300
	Shoe	Roller	Ton	12,377	95,923	108,300
	Stayed Cable	SWPR	Ton	16,150	122,550	138,700
	Expansion Joint	Demag	L.M	37,900	151,700	189,600
	Erection, Equipment		L.S	5,910,000	29,135,000	35,045,000
Tower	Tower	SS41, SM50Y & SM58	Ton	6,080	24,320	30,400
		HTB (F10T)	Ton	6,260	25,040	31,300
	Erection, Equipment		L.S	1,862,000	9,296,000	11,158,000
Substructure	Concrete	σck = 300 kg/cm^2	CU.M	960	690	1,650
		σck = 240 kg/cm^2	CU.M	900	650	1,550
	Form	Steel	SQ.M	80	270	350
	Reinforcement	SD30	Ton	2,387	11,833	14,220
	Pile Foundation	R.C.D ϕ 3 m	L.M	13,800	53,900	67,700
Others	Temporary & Other Works		L.S			
Total						

STEEL MAIN BRIDGE

$H = 45^{M}$, PHASE-I & II

	Work Item	Class	Unit	Unit Cost (K.Shs.)		
				L.C	F.C	Total
Superstructure	Main Girder	SS41, SM50Y	Ton	6,000	24,000	30,000
		HTB (F10T)	Ton	6,260	25,040	31,300
	Shoe	Roller	Ton	12,377	95,923	108,300
	Stayed Cable	SWPR	Ton	16,150	122,550	138,700
	Expansion Joint	Demag	L.M	37,900	151,700	189,600
	Erection, Equipment		L.S	6,639,000	28,406,000	35,045,000
Tower	Tower	SS41, SM50Y & SM58	Ton	6,080	24,320	30,400
		HTB (F10T)	Ton	6,260	25,040	31,300
	Erection, Equipment		L.S	2,107,000	9,051,000	11,158,000
Substructure	Concrete	σck = 300 kg/cm²	CU.M	960	690	1,650
		σck = 240 kg/cm²	CU.M	900	650	1,550
	Form	Steel	SQ.M	80	270	350
	Reinforcement	SD30	Ton	2,387	11,833	14,220
	Pile Foundation	R.C.D ϕ 3 m	L.M	13,800	53,900	67,700
Others	Temporary & Other Works		L.S			
Total						

APPROACH BRIDGE
H = 73.2 M, PHASE-I

Work Item		Sub-Item	Class	Unit	Unit Cost (K.Shs.)		
					L.C	F.C	Total
Superstructure	R.C Hollow	Concrete	σ ck = 240 kg/cm²	CU.M	900	650	1,550
		Form	Steel	SQ.M	80	270	350
		Reinforce-ment	SD 30	Ton	2,387	11,833	14,220
	Post-Tensioned I-Girder	Concrete	σ ck = 350 kg/cm²	CU.M	930	750	1,680
		Form	Steel	SQ.M	75	245	320
		Reinforce-ment	SD 30	Ton	2,387	11,833	14,220
		P.C Cable	SWPR	Ton	12,883	97,117	110,000
	P.C Rigid Frame	Concrete	σ ck = 350 kg/cm²	CU.M	930	750	1,680
		Form	Steel	SQ.M	68	232	300
		Reinfroce-ment	SD 30	Ton	2,387	11,833	14,220
		P.C Rod	SBPR 95/120	Ton	7,386	57,114	64,500
	Erection & Equipment			L.S	11,851,000	67,162,000	79,013,000
Substructure	Body & Foot-ing	Concrete	σ ck = 240 kg/cm²	CU.M	900	650	1,550
		Form	Steel	SQ.M	80	270	350
		Reinforce-ment	SD 30	Ton	2,387	11,833	14,220
	Pile Foundation	Case-in Place Pile	R.C.D ∅3.0	L.M	13,800	53,900	67,700
			∅2.5	L.M	11,800	46,200	58,000
			∅2.0	L.M	9,860	38,540	48,400
	Shoe	B.P		Ton	3,250	13,001	16,251
		Rubber	R65	No	1,400	5,600	7,000
			R45	No	1,160	4,640	5,800
	Expansion Joint	Rubber		L.M	2,840	11,360	14,200
Temporary & Other Works				L.S	20,079	113,778	133,857

APPROACH BRIDGE
H = 73.2 M, PHASE-II

	Work Item	Sub-Item	Class	Unit	Unit Cost (K.Shs.)		
					L.C	F.C	Total
Superstructure	R.C Hollow	Concrete	σck = 240 kg/cm²	CU.M	900	650	1,550
		Form	Steel	SQ.M	80	270	350
		Reinforcement	SD 30	Ton	2,387	11,833	14,220
	Post-Tensioned T-Girder	Concrete	σck = 350 kg/cm²	CU.M	930	750	1,680
		Form	Steel	SQ.M	75	245	320
		Reinforcement	SD 30	Ton	2,387	11,833	14,220
		P.C Cable	SWPR	Ton	12,883	97,117	110,000
	P.C Rigid Frame	Concrete	σck = 350 kg/cm²	CU.M	930	750	1,680
		Form	Steel	SQ.M	68	232	300
		Reinforcement	SD 30	Ton	2,387	11,833	14,220
		P.C Rod	SBPR 95/120	Ton	7,386	57,114	64,500
	Erection & Equipment			L.S	23,517,000	133,261,000	156,778,000
Substructure	Body & Footing	Concrete	σck = 240 kg/cm²	CU.M	900	650	1,550
		Form	Steel	SQ.M	80	270	350
		Reinforcement	SD 30	Ton	2,387	11,833	14,220
	Pile Foundation	Cast-in Place Pile	R.C.D ϕ3.0	L.M	13,800	53,900	67,700
			ϕ2.5	L.M	11,800	46,200	58,000
			ϕ2.0	L.M	9,860	38,540	48,400
	Shoe	B.P.		Ton	3,250	13,001	16,251
		Rubber	R65	No	1,400	5,600	7,000
			R45	No	1,160	4,640	5,800
	Expansion Joint	Rubber		L.M	2,840	11,360	14,200
	Temporary & Other Works			L.S	36,626,000	207,551,000	244,177,000

APPROACH BRIDGE
H = 45^{M}, PHASE-I

	Work Item	Sub-Item	Class	Unit	Unit Cost (K.Shs.) L.C	F.C	Total
Superstructure	R.C Hollow	Concrete	σck = 240 kg/cm^2	CU.M	900	650	1,550
		Form	Steel	SQ.M	80	270	350
		Reinforcement	SD 30	Ton	2,387	11,833	14,220
	Post-Tensioned T-Girder	Concrete	σck = 350 kg/cm^2	CU.M	930	750	1,680
		Form	Steel	SQ.M	75	245	320
		Reinforcement	SD 30	Ton	2,387	11,833	14,220
		P.C Cable	SWPR	Ton	12,883	97,117	110,000
	P.C Rigid Frame	Concrete	σck = 350 kg/cm^2	CU.M	-	-	-
		From	Steel	SQ.M	-	-	-
		Reinforcement	SD 30	Ton	-	-	-
		P.C Rod	SBPR 95/120	Ton	-	-	-
	Erection & Equipment			L.S	1,646,000	9,328,000	10,974,000
Substructure	Body & Footing	Concrete	σck = 240 kg/cm^2	CU.M	900	650	1,550
		Form	Steel	SQ.M	80	270	350
		Reinforcement	SD 30	Ton	2,387	11,833	14,220
	Pile Foundation	Cast-in-Place Pile	R.C.D ø3.0m	L.M	-	-	-
			ø2.5	L.M	-	-	-
			ø2.0	L.M	-	-	-
	Shoe	B.P		Ton	3,250	13,001	16,251
		Rubber	R75	No	1,480	5,920	7,400
			R65	No	1,400	5,600	7,000
			R55	No	1,280	5,120	6,400
			R45	No	1,160	4,640	5,800
	Expansion Joint			L.M	2,840	11,360	14,200
	Temporary & Other Works			L.S	7,425,000	42,074,000	49,499,000

APPROACH BRIDGE
$H = 45^M$, PHASE-II

	Work Item	Sub-Item	Class	Unit	Unit Cost (K.Shs.) L.C	F.C	Total
Superstructure	R.C Hollow	Concrete	σck = 240 kg/cm^2	CU.M	900	650	1,550
		Form	Steel	SQ.M	80	270	350
		Reinforce-ment	SD 30	Ton	2,387	11,833	14,220
	Post-Tensioned T-Girder	Concrete	σck = 350 kg/cm^2	CU.M	930	750	1,680
		Form	Steel	SQ.M	75	245	320
		Reinforce-ment	SD 30	Ton	2,387	11,833	14,220
		P.C Cable	SWPR	Ton	12,883	97,117	110,000
	P.C Rigid Frame	Concrete	σck = 350 kg/cm^2	CU.M	930	750	1,680
		Form	Steel	SQ.M	68	232	1,300
		Reinforce-ment	SD 30	Ton	2,387	11,833	14,220
		P.C Rod	SBPR 95/120	Ton	7,386	57,114	64,500
	Erection & Equipment			L.S	1,925,000	10,907,000	12,832,000
Substructure	Body & Foot-ing	Concrete	σck = 240 kg/cm^2	CU.M	900	650	1,550
		Form	Steel	SQ.M	80	270	350
		Reinforcement	SD 30	Ton	2,387	11,833	14,220
	Pile Foundation	Case-in-Place Pile	R.C.D ϕ3.0m	L.M	13,800	53,900	67,700
			ϕ2.5	L.M	11,800	46,200	58,000
			ϕ2.0	L.M	9,860	38,540	48,000
	Shoe	B.P Rubber		Ton	3,250	13,001	16,251
			R75	No	1,480	5,920	7,400
			R65	No	1,400	5,600	7,000
			R55	No	1,280	5,120	6,400
			R45	No	1,160	4,640	5,800
	Expansion Joint			L.M	2,840	11,360	14,200
	Temporary & Other Works			L.S	13,233,000	74,989,000	88,222,000

Appendix E QUANTITY FOR BRIDGE CONSTRUCTION

P.C MAIN BRIDGE
H = 73.2M, PHASE-I

	Item	Sub-Item	Class	Unit	Quantities Phase-I
Superstructure	Main Girder	Concrete	σck = 350 kg/cm²	CU.M	16,335
		Form	Steel	SQ.M	61,511
		Reinforcement	SD30	Ton	1,960
		P.C Rod	SBPR 95/120	Ton	338
		P.C Cable	SWPR	Ton	218
	Stayed Cable	P.C Cable	SWPR	Ton	1,345
	Erection & Equipment	-	-	L.S	1
Tower	Tower	Concrete	σck = 350 kg/cm²	CU.M	9,168
		Form	Steel	SQ.M	8,220
		Reinforcement	SD30	Ton	642
	Erection & Equipment	-	-	L.S	1
Substructure & Foundation	Body and Footing	Concrete	σck = 300 kg/cm²	CU.M	22,115
		Footing	σck = 240 kg/cm²	CU.M	13,208
		Form	Steel	SQ.M	20,475
		Reinforcement	SD30	Ton	3,578
	Pile Foundation	Cast-in-Place Pile	R.C.D ø 3.0 m	L.M	2,960
	Shoe	Tefron	800 x 800 x 150	No	8
		Roller	16 No	Ton	30
	Expansion Joint	Demag		L.M	48

P.C MAIN BRIDGE

$H = 45^M$, PHASE-I & II

	Item	Sub-Item	Class	Unit	Quantities Phase-I&I
Superstructure	Main Girder	Concrete	$\sigma ck = 350\ kg/cm^2$	CU.M	11,286
		Form	Steel	SQ.M	39,743
		Reinforcement	SD30	Ton	1,354
		P.C Rod	SBPR 95/120	Ton	225
		P.C Cable	SWPR	Ton	151
	Stayed Cable	P.C Cable	SWPR	Ton	966
	Erection & Equipment	-	-	L.S	1
Tower	Tower	Concrete	$\sigma ck = 350\ kg/cm^2$	CU.M	5,558
		Form	Steel	SQ.M	6,380
		Reinforcement	SD30	Ton	389
	Erection & Equipment	-	-	L.S	1
Substructure & Foundation	Body & Footing	Concrete	$\sigma ck = 300\ kg/cm^2$	CU.M	7,508
			$\sigma ck = 240\ kg/cm^2$	CU.M	5,552
		From	Steel	SQ.M	9,846
		Reinforcement	SD30	Ton	1,280
	Pile Foundation	Cast-in-Place Pile	R.C.D ø 3.0 m	L.M	1,920
	Shoe	Tefron	800 x 800 x 150	No	8
		Roller	12NOS	Ton	23.2
	Expansion Joint	Demag		L.M	22

STEEL MAIN BRIDGE
H = 73.2 M

	Work Item	Sub-Item	Class	Unit	Quantity		Remarks
					Phase-I	Phase-II	
Superstructure	Main Girder	Steel Plate & Shape	SS41, SM50Y	Ton	8,221	-	
		HTB	F10T	Ton	393	-	
	Shoe	Roller		Ton	109	-	
	Stayed Cable	P.C Cable	SWPR	Ton	788	-	
	Expansion Joint	Demag		L.M	48	-	
	Erection Equipment			L.S	1	-	
Tower	Tower	Steel Plate & Shape	SS41, SM50Y & SM58	Ton	2,962	-	
		HTB	F10t	Ton	153	-	
	Erection & Equipment			L.S	1	-	
Substructure & Foundation	Body & Hooting	Concrete	δck = 300 kg/cm²	CU.M	17,830	-	
			δck = 240 kg/cm²	CU.M	5,792	-	
		Form	Steel	SQ.M	17,068	-	
		Reinforcement	SD30	Ton	2,577	-	
	Pile Foundation	Cast-in-Place Pile	R.C.D ϕ 3.0m	L.M	1,920	-	

STEEL MAIN BRIDGE
H = 55M, PHASE-I & II

	Work Item	Sub-Item	Class	Unit	Quantity Phase-I	Quantity Phase-II	Remarks
Superstructure	Main Girder	Steel Plate & Shape	SS41, SM50Y	Ton	6,754	6,754	
		HTB	F10T	Ton	300	300	
	Shoe	Roller		Ton	85	85	
	Stayed Cable	P.C Cable	SWPR	Ton	465	465	
	Expansion Joint	Demag		L.M	22	22	
	Erection & Equipment			L.S	1	1	
Tower	Tower	Steel Plate & Shape	SS41, SM50Y & SM58	Ton	2,432	2,432	
		HTB	F10T	Ton	125	125	
	Erection & Equipment			L.S	1	1	
Substructure & Foundation	Body & Footing	Concrete	σck = 300 kg/cm²	CU.M	8,428	8,428	
			σck = 240 kg/cm²	CU.M	4,128	4,128	
		Form	Steel	SQ.M	12,238	12,238	
		Reinforcement	SD30	Ton	1,303	1,303	
	Pile Foundation	Cast-in-Place Pile	R.C.D ϕ 3.0m	L.M	1,440	1,440	

STEEL MAIN BRIDGE
$H = 45^{M}$, PHASE-I & II

	Work Item	Sub-Item	Class	Unit	Quantity		Remarks
					Phase-I	Phase-II	
Superstructure	Main Girder	Steel Plate & Shape	SS41, SM50Y	Ton	6,754	6,754	
		HTB	F10T	Ton	300	300	
	Shoe	Roller		Ton	85	85	
	Stayed Cable	P.C Cable	SWPR	Ton	465	465	
	Expansion Joing	Demag		L.M	22	22	
	Erection & Equipment			L.S	1	1	
Tower	Tower	Steel Plate & Shape	SS41, SM50Y & SM58	Ton	2,432	2,432	
		HTB	F10T	Ton	125	125	
	Erection & Equipment			L.S	1	1	
Substructure & Foundation	Body & Footing	Concrete	$\sigma ck = 300$ kg/cm^2	CU.M	6,792	6,792	
			$\sigma ck = 240$ kg/cm^2	CU.M	4,128	4,128	
		Form	Steel	SQ.M	8,566	8,566	
		Reinforcement	SD30	Ton	1,098	1,098	
	Pile Foundation	Cast-in-Place Pile	R.C.D ϕ3.0m	L.M	1,440	1,440	

APPROACH BRIDGE
H = 73.2 M, PHASE-I&II

	Work Item	Sub-Item	Class	Unit	Quantity Phase-I	Quantity Phase-II	Remarks
Superstructure	R.C Hollow	Concrete	σck = 240 kg/cm^2	CU.M	1,963	9,790	
		Form	Steel	SQ.M	4,446	22,173	
		Reinforce-ment	SD 30	Ton	363	1,811	
	Post-Tention T-Girder	Concrete	σck = 350 kg/cm^2	CU.M	3,415	5,572	
		Form	Steel	SQ.M	19,911	31,969	
		Reinforce-ment	SD 30	Ton	388	653	
		P.C Cable	SWPR	Ton	171	294	
	P.C Rigid Frame	Concrete	σck = 350 kg/cm^2	CU.M	13,397	21,592	
		Form	Steel	SQ.M	41,776	69,720	
		Reinforce-ment	SD 30	Ton	1,600	2,579	
		P.C Rod	SBPR 95/120	Ton	1,123	1,693	
Substructure	Main Body	Concrete	σck = 240 kg/cm^2	CU.M	20,821	41,706	
		Form	Steel	SQ.M	29,298	56,436	
		Reinforce-ment	SD 30	Ton	1,818	3,192	
	Pile Foundation	Cast-in-Place Pile	R.C.D ϕ3.0 m	L.M	910	910	
			ϕ2.5	L.M	560	1,330	
			ϕ2.6	L.M	420	1,140	
	Shoe	B.P		Ton	25.5	28.5	
		Rubber	R65t	No	156	324	
			R45t	No	276	852	
	Expansion Joint	Rubber		L.M	488	1,166	

APPROACH BRIDGE
H = 45^{M}, PHAST-I & II

	Work Item	Sub-Item	Class	Unit	Quantity		Remarks
					Phase-I	Phase-II	
Superstructure	R.C Hollow	Concrete	σck = 240 kg/cm²	CU.M	3,946	5,394	
		Form	Steel	SQ.M	8,938	12,217	
		Reinforce-ment	SD 30	Ton	730	998	
	Post-Tension T-Girder	Concrete	σck = 350 kg/cm²	CU.M	4,962	5,135	
		Form	Steel	SQ.M	28,881	29,297	
		Reinforce-ment	SD 30	Ton	561	606	
		P.C Cable	SWPR	Ton	242	268	
	P.C Rigid Frame	Concrete	σck = 350 kg/cm²	CU.M	-	2,500	
		Form	Stell	SQ.M	-	8,733	
		Reinforce-ment	SD 30	Ton	-	299	
		P.C Rod	SBPR 95/120	Ton	-	168	
Substructure	Main Body	Concrete	σck = 240 kg/cm²	CU.M	10,753	14,111	
		Form	Steel	SQ.M	10,254	15,401	
		Reinforce-ment	SD 30	Ton	749	1,020	
	Pile Foundation	Cast-in-Place Pile	R.C.D ϕ3.0m	L.M	0	280	
			ϕ2.5	L.M	0	0	
			ϕ2.6	L.M	0	140	
	Shoe	B.P		Ton	8.6	2.5	
		Rubber	R75t	No	60	90	
			R65t	No	168	240	
			R55t	No	0	24	
			R45t	No	156	372	
	Expansion Joint	Rubber		L.M	330	605	

Appendix F BRIDGE CONSTRUCTION COST

(1) P.C MAIN BRIDGE CASE (Unit: 1,000 K.Shs.)

Navigation Clearance & Phase		Approach Bridge		Main Bridge		Total Cost	
		L.C	F.C	L.C	F.C	L.C	F.C
73.2^{M}	Phase-I	116,425	465,699	172,275	689,101	288,700	1,163,800
	II	212,373	849,490	-	-	212,373	849,490
	Sub-Total	328,798	1,315,189	172,275	689,101	501,073	2,004,290
	Total	1,643,987		861,376		2,505,363	
55^{M}	Phase-I	55,568	222,276	113,380	453,521	168,949	675,796
	-II	81,658	326,630	113,380	453,521	195,038	780,151
	Sub-Total	137,226	548,906	226,760	907,042	363,987	1,455,947
	Total	686,132		1,133,802		1,819,934	
45^{M}	Phase-I	34,107	136,424	110,271	441,083	144,377	577,508
	-II	55,980	223,922	110,271	441,083	166,251	665,005
	Sub-Total	90,087	360,346	220,542	882,166	310,628	1,242,513
	Total	450,433		1,102,708		1,553,141	

(2) STEEL MAIN BRIDGE CASE (Unit: 1,000 K.Shs.)

Navigation Clearance & Phase		Approach Bridge		Main Bridge		Total Cost	
		L.C.	F.C.	L.C.	F.C.	L.C.	F.C.
73.2m	Phase-I	116,425	465,699	179,252	717,008	295,677	1,182,707
	" II	212,373	849,490	-	-	212,373	849,490
	Sub-Total	328,798	1,315,189	179,252	717,008	508,050	2,032,197
	Total	1,643,987		896,260		2,540,247	
55m	Phase-I	55,568	22,276	138,634	554,536	194,202	776,812
	" II	81,658	326,630	138,634	554,536	220,292	881,166
	Sub-Total	137,226	548,906	277,268	1,109,072	414,494	1,657,978
	Total	686,132		1,386,340		2,072,472	
45m	Phase-I	34,107	136,424	136,909	547,637	171,016	684,061
	" II	55,980	223,922	136,909	547,637	192,889	771,559
	Sub tal	90,087	360,346	273,818	1,095,274	363,905	1,455,620
	Total	450,433		1,369,092		1,819,525	

P.C MAIN BRIDGE

$H = 73.2^M$, PHASE-I

	Work Item	Sub-Item	Class	Unit	Construction Cost (1,000 K.Shs.)		
					L.C	F.C	Total
Superstructure	Main Girder	Concrete	σck = 350 kg/cm^2		15,192	12,251	27,443
		Form	Steel		4,182	14,271	18,453
		Reinforce-ment	SD30		4,678	23,193	27,871
		P.C. Rod	SBPR 95/120		2,496	19,305	21,801
		P.C Cable	SWPR		2,808	21,172	23,980
	Stayed Cable	P.C Cable	SWPR		21,722	164,830	186,552
	Erection & Equipment				5,532	33,432	38,964
Tower	Tower	Concrete	σck = 350 kg/cm^2		8,526	6,876	15,402
		Form	Steel		658	2,219	2,877
		Reinforce-ment	SD30		1,532	7,597	9,129
	Erection & Equipment				1,338	7,862	9,200
Substructure	Substructure	Concrete	σck = 300 kg/cm^2		21,231	15,259	36,490
			σck = 240 kg/cm^2		11,887	8,585	20,472
		From	Steel		1,638	5,528	7,166
		Reinforce-ment	SD30		8,541	42,338	50,879
	Foundation	Cast-in-place Pile	R.C.D ϕ3.0m		40,848	159,544	200,392
Other	Shoe	Tefron	800x800x150		112	448	560
		Roller			371	2,878	3,249
	Expansion Joint	Demag			1,819	7,282	9,101
	Temporary & Other Works				22,709	128,686	151,395
	Total				172,275	689,101	861,376

P.C MAIN BRIDGE
H = 55 , PHASE-I & II

Work Item		Sub-Item	Class	Unit	Construction Cost (1,000 K.Shs.)		
					L.C	F.C	Total
Superstructure	Main Girder	Concrete	σck = 350 kg/cm²		10,495	8,465	18,960
		Form	Steel		2,703	9,220	11,923
		Reinforce-ment	SD30		3,232	16,022	19,254
		P.C Rod	SBPR 95/120		1,662	12,851	14,513
		P.C Cable	SWPR		1,945	14,665	16,610
		Stayed Cable	SWPR		15,601	118,383	133,984
	Erection & Equipment				3,368	20,351	23,719
Tower	Tower	Concrete	σck = 350 kg/cm²		5,168	4,169	9,337
		From	Steel		510	1,723	2,233
		Reinforce-ment	SD30		929	4,603	5,532
	Erection & Equipment				1,050	6,150	7,200
Substructure	Substructure	Concrete	σck = 300 kg/cm²		9,700	6,972	16,672
			σck = 240 kg/cm²		4,997	3,609	8,606
		Form	Steel		1,120	3,778	4,898
		Reinforce-ment	SD30		3,836	19,016	22,852
	Foundation	Cast-in-place Pile	R.C.D ϕ3.0m		26,496	103,488	129,984
Other	Shoe	Tefron	800x800x150		112	448	560
		Roller			287	2,226	2,513
	Expansion Joint	Demag			834	3,337	4,171
	Temporary & Other Works				17,007	96,373	113,380
Total					113,380	453,521	566,901

N = 45", PHASE-I & II

	Work Item	Sub-Item	Class	Unit	Construction Cost (1,000 K.Shs.) L.C	F.C	Total
Superstructure	Main Girder	Concrete	σck = 350 kg/cm^2		10,495	8,465	18,960
		Form	Steel		2,703	9,220	11,923
		Reinforce-ment	SD30		3,232	16,022	19,254
		P.C Rod	SBPR 95/120		1,662	12,851	14,513
		P.C Cable	SWPR		1,945	14,665	16,610
		Stayed Cable	SWPR		15,601	118,383	133,984
	Erection & Equipment				3,322	18,824	22,146
Tower	Tower	Concrete	σck = 350 kg/cm^2		5,169	4,168	9,337
		Form	Steel		510	1,723	2,233
		Reinforcement	SD30		928	4,603	5,531
	Erection & Equipment				1,008	5,714	6,722
Substructure	Substructure	Concrete	σck = 350 kg/cm^2		7,207	5,181	12,388
			σck = 240 kg/cm^2		4,997	3,609	8,606
		Form	Steel		788	2,658	3,446
		Reinforce-ment	SD30		3,055	15,147	18,202
	Foundation	Cast-in-place Pile	R.C.D ϕ3.0m		26,496	103,488	129,984
Other	Shoe	Tefron	800x800x150		112	448	560
		Roller			287	2,226	2,513
	Expansion Joint	Demag			834	3,337	4,171
	Temporary & Other Works				16,540	93,731	110,271
Total					110,271	441,083	551,354

STEEL MAIN BRIDGE
H = 73.2^{M}, PHASE-I

Work Item		Sub-Item	Class	Unit	Construction Cost (1,000 K.Shs.)		
					L.C	F.C	Total
Superstructure	Main Girder	Steel	SS41, SM50Y		43,654	174,614	218,268
		HTB	FIOT		2,460	9,841	12,301
	Shoe	Roller			1,349	10,456	11,805
	Stayed Cable	P.C Cable	SWPR		12,726	96,570	109,296
	Expansion Joint	Demag			1,819	7,282	9,101
					5,922	38,739	44,661
Tower	Tower	Steel Plate & Shape	SS41, SM50Y & SM58		16,232	64,927	81,159
		HTB	FIOT		958	3,831	4,789
	Erection & Equipment				1,940	12,687	14,627
Substructure	Body & Footing	Concrete	$\sigma ck = 300 \; kg/cm^2$		17,117	12,303	29,420
			$\sigma ck = 240 \; kg/cm^2$		5,213	3,765	8,978
		Form	Steel		1,365	4,609	5,974
		Reinforcement	SD30		6,151	30,494	36,645
	Foundation	Cast-in-place Pile	R.C.D ϕ3m		26,496	103,488	129,984
Other	Temporary & Other Works				35,850	143,402	179,252
Total					179,252	717,008	896,260

STEEL MAIN BRIDGE
H = 55^{M}, PHASE-I & II

	Work Item	Sub-Item	Class	Unit	Construction Cost (1,000 K.Shs.) L.C	F.C	Total
Superstructure	Main Girder	Steel	SS41, SM50Y		40,524	162,096	202,620
		HTB	FIOT		1,878	7,512	9,390
	Shoe	Roller			1,052	8,154	9,206
	Stayed Cable	P.C Cable	SWPR		7,510	56,986	64,496
	Expansion Joint	Demag			834	3,337	4,171
	Erection Equipment				5,910	29,135	35,045
Tower	Tower	Steel Plate & Shape	SS41, SM50Y & SM58		14,787	59,146	73,933
		HTB	FIOT		783	3,130	3,913
	Erection & Equipment				1,862	9,296	11,158
Substructure	Body & Footing	Concrete	σck = 300 kg/cm^2		8,091	5,815	13,906
			σck = 240 kg/cm^2		3,715	2,683	6,398
		Form	Steel		979	3,304	4,283
		Reinforcement	SD30		3,110	15,419	18,529
	Foundation	Cast-in-place Pile	R.C.D ϕ3.0m		19,872	77,616	97,488
Other	Temporary & Other Works				27,727	110,907	138,634
Total					138,634	554,536	693,170

STEEL MAIN BRIDGE
$H = 45^M$, PHASE-I & II

	Work Item	Sub-Item	Class	Unit	Construction Cost (1,000 K.Shs.)		
					L.C	F.C	Total
Superstructure	Main Girder	Steel	SS41, SM50Y		40,524	162,096	202,620
		HTB	FIOT		1,878	7,512	9,390
	Shoe	Roller			1,052	8,154	9,206
	Stayed Cable	P.C Cable	SWPR		7,510	56,986	64,496
	expansion Joint	Demag			834	3,337	4,171
	Erection Equipment				6,639	28,406	35,045
Tower	Tower	Steel	SS41, SM50Y & SM58		14,787	59,146	73,933
		HTB	FIOT		783	3,130	3,913
	Erection & Equipment				2,107	9,051	11,158
Substructure	Body & Footing	Concrete	$\sigma ck = 300$ kg/cm^2		6,520	4,687	11,207
			$\sigma ck = 240$ kg/cm^2		3,715	2,683	6,398
		Form	Steel		685	2,313	2,998
		Reinforce-ment	SD30		2,621	12,993	15,614
	Foundation	Cast-in-place Pile	R.C.D ø3.0m		19,872	77,616	97,488
Other	Temporary & Other Works				27,382	109,527	136,909
Total					136,909	547,637	684,546

APPROACH BRIDGE
H = 73.2^M, PHASE-I

Work Item		Sub-Item	Class	Unit	Construction Cost (1,000 K.Shs.)		
					L.C	F.C	Total
Superstructure	R.C Hollow	Concrete	σck = 240 kg/cm²		1,767	1,276	3,043
		Form	Steel		356	1,200	1,556
		Reinforce-ment	SD30		867	4,295	5,162
	Post-Tensioned T-Girder	Concrete	σck = 350 kg/cm²		3,176	2,561	5,737
		Form	Steel		1,494	4,878	6,372
		Reinforce-ment	SD30		926	4,591	5,517
		P.C Cable	SWPR		2,203	16,607	18,810
	P.C Rigid Frame	Concrete	σck = 350 kg/cm²		12,459	10,048	22,507
		Form	Steel		2,841	9,692	12,533
		Reinforce-ment	SD30		3,819	18,933	22,752
		P.C Rod	SBPR 95/120		8,295	64,139	72,434
	Erection & Equipment				11,851	67,162	79,013
Substructure	Substructure	Concrete	σck = 240 kg/cm²		18,739	13,534	32,273
		Form	Steel		2,344	7,910	10,254
		Reinforce-ment	SD30		4,340	21,512	25,852
	Foundation	Cast-in-place Pile	R.C.D ϕ3.0m		12,558	49,049	61,607
			ϕ2.5		6,608	25,872	32,480
			ϕ2.0		4,141	16,187	20,328
Other	Shoe	B.P			82	332	414
		Rubber	R65		218	874	1,092
			R45		320	1,281	1,601
	Expnasion Joint	Rubber			1,386	5,544	6,930
	Temporary & Other Works				20,079	113,778	133,857
Total					116,425	465,699	582,124

APPROACH BRIDGE
H = 73.2^{M}, PHASE-II -

	Work Item	Sub-Item	Class	Unit	Construction Cost (1,000 K.Shs.)		
					L.C	F.C	Total
Superstructure	R.C Hollow	Concrete	σck = 240 kg/cm²		8,811	6,364	15,175
		Form	Steel		1,774	5,987	7,761
		Reinforce-ment	SD30		4,323	21,429	25,752
	Post-Tensioned T-Girder	Concrete	σck = 350 kg/cm²		5,182	4,179	9,361
		From	Steel		2,398	7,832	10,230
		Reinforce-ment	SD30		1,559	7,727	9,286
		P.C Cable	SWPR		3,788	28,552	32,340
	P.C Rigid Frame	Concrete	σck = 350 kg/cm²		20,081	16,194	36,275
		Form	Steel		4,741	16,175	20,916
		Reinforce-ment	SD30		6,156	30,517	36,673
		P.C Rod	SBPR 95/120		12,505	96,694	109,199
	Erection & Equipment				156,778		156,778
Substructure	Substructure	Concrete	σck = 240 kg/cm²		37,535	27,109	64,644
		Form	Steel		4,515	15,238	19,753
		Reinforce-ment	SD30		7,619	37,771	45,390
	Foundation	Cast-in-place Pile	R.C.D ϕ3.0m		12,558	49,049	61,607
			ϕ2.5		15,694	61,446	77,190
			ϕ2.0		11,240	43,936	55,176
Other	Shoe	B.P			93	370	463
		Rubber	R65t		454	1,814	2,268
			R45t		989	3,953	4,942
	Expansion Joint	Rollers			3,311	13,246	16,557
	Temporary & Other Works						244,177
	Total				212,373	849,490	1,061,863

APPROACH BRIDGE
H = 55M, PHASE-I

	Work Item	Sub-Item	Class	Unit	Construction Cost (1,000 K.Shs.) L.C	F.C	Total
Superstructure	R.C Hollow	Concrete	σck = 240 kg/cm²		2,728	1,970	4,698
		Form	Steel		549	1,853	2,402
		Reinforcement	SD30		1,339	6,638	7,977
	Post Tensioned T-Girder	Concrete	σck = 350 kg/cm²		3,393	2,736	6,129
		Form	Steel		1,587	5,184	6,771
		Reinforcement	SD30		1,005	4,982	5,987
		P.C Cable	SWPR		2,358	17,772	20,130
	P.C Rigid Frame	Concrete	σck = 350 kg/cm²		4,195	3,383	7,578
		Form	Steel		1,038	3,542	4,580
		Reinforcement	SD30		1,287	6,378	7,665
		P.C Rod	SBPR 95/120		2,393	18,505	20,898
	Erection & Equipment				4,040	22,899	26,939
Substructure	Substructure	Concrete	σck = 240 kg/cm²		10,389	7,504	17,893
		Form	Steel		1,088	3,671	4,759
		Reinforcement	SD30		2,767	13,714	16,481
	Foundation	Cast-in-place Pile	R.C.D ϕ3.0m		0	0	0
			ϕ2.5		3,304	12,936	16,240
			ϕ2.0		4,141	16,187	20,328
Other	Shoe	B.P			51	203	254
		Rubber	R75		0	0	0
			R65		269	1,075	1,344
			R55		0	0	0
			R45		223	891	1,114
	Expansion Joint	Rubber			1,124	4,499	5,623
	Temporary & Other Works				10,808	61,246	72,054
Total					55,568	222,276	277,844

APPROACH BRIDGE
H = 55^M, PHASE-II

	Work Item	Sub-Item	Class	Unit	Construction Cost (1,000 K.Shs.) L.C	F.C	Total
Superstructure	R.C Hollow	Concrete	σck = 240 kg/cm²		4,557	3,291	7,848
		Form	Steel		9 17	3,096	4,013
		Reinforcement	SD30		2,237	11,087	13,324
	Post-Tensioned T-Girder	Concrete	σck = 350 kg/cm²		4,361	3,518	7,879
		Form	Steel		2,000	6,535	8,535
		Reinforcement	SD30		1,344	6,662	8,006
		P.C Cable	SWPR		3,169	23,891	27,060
	P.C Rigid Frame	Concrete	σck = 350 kg/cm²		5,610	4,524	10,134
		Form	Steel		1,405	4,793	6,198
		Reinforcement	SD30		1,718	8,520	10,238
		P.C Rod	SBPR 95/120		3,125	24,159	27,284
	Erection & Equipment				3,922	22,228	26,150
Substructure	Substructure	Concrete	σck = 240 kg/cm²		18,719	13,518	32,237
		Form	Steel		1,943	6,554	8,496
		Reinforcement	SD30		3,750	18,590	22,340
	Foundation	Cast-in-place Pile	R.C.D ϕ3.0m		0	0	0
			ϕ2.5		2,478	9,702	12,180
			ϕ2.0		8,282	32,374	40,656
Other	Shoe	B.P			31	125	156
		Rubber	R75		89	355	444
			R65		420	1,680	2,100
			R55		31	123	154
			R45		557	2,227	2,784
	Expansion Joint				2,125	8,497	10,622
	Temporary & Other Works				17,917	101,533	119,450
Total					81,658	326,630	408,288

APPROACH BRIDGE
H = 45^{M}, PHASE-I

	Work Item	Sub-Item	Class	Unit	Construction Cost (1,000 K.Shs.) L.C	F.C	Total
Superstructure	R.C Hollow	Concrete	σck = 240 kg/cm²		3,551	2,565	6,116
		Form	Steel		715	2,413	3,128
		Reinforcement	SD30		1,743	8,638	10,381
	Post-Tensioned T-Girder	Concrete	σck = 350 kg/cm²		4,614	3,722	8,336
		Form	Steel		2,166	7,076	9,242
		Reinforcement	SD30		1,339	6,638	7,977
		P.C Cable	SWPR		3,118	23,502	26,620
	P.C Rigid Frame	Concrete	σck = 350 kg/cm²		0	0	0
		Form	Steel		0	0	0
		Reinforcement	SD30		0	0	0
		P.C. Rod	SBPR 95/120		0	0	0
	Erection & Equipment						10,974
Substructure	Substructure	Concrete	σck = 240 kg/cm²		9,678	6,989	16,667
		Form	Steel		820	2,769	3,589
		Reinforcement	SD30		1,788	8,863	10,651
Other	Shoe	B.P			28	112	140
		Rubber	R75		89	355	444
			R65		235	941	1,176
			R55		0	0	0
			R45		181	724	905
	Expansion Joint	Rubber			937	3,749	4,686
	Temporary & Other Works				7,425	42,074	49,499
Total					34,107	136,424	170,531

APPROACH BRIDGE
H = 45^M, PHASE-II

	Work Item	Sub-Item	Class	Unit	Construction Cost (1,000 K.Shs.) L.C	F.C	Total
Superstructure	R.C Hollow	Concrete	σck = 240 kg/cm²		4,855	3,506	8,361
		Form	Steel		977	3,299	4,276
		Reinforcement	SD30		2,383	11,809	14,192
	Post-Tensioned T-Girder	Concrete	σck = 350 kg/cm²		4,776	3,851	8,627
		Form	Steel		2,197	7,178	9,375
		Reinforcement	SD30		1,446	7,171	8,617
		P.C Cable	SWPR		3,453	26,027	29,480
	P.C Rigid Frame	Concrete	σck = 350 kg/cm²		2,325	1,875	4,200
		Form	Steel		594	2,026	2,620
		Reinforcement	SD30		714	3,538	4,252
		P.C Rod	SBPR 95/120		1,241	9,595	10,836
	Erection & Equipment						12,832
Substructure	Substructure	Concrete	σck = 240 kg/cm²		12,700	9,172	21,872
		Form	Steel		1,232	4,158	5,390
		Reinforcement	SD30		2,434	12,070	14,504
	Foundation	Cast-in-place Pile	R.C.D ϕ3.0m		3,864	15,092	18,956
			ϕ2.5		0	0	0
			ϕ2.0		1,360	5,396	6,756
Other	Shoe	B.P			8	33	41
		Rubber	R75		133	533	666
			R65		336	1,344	1,680
			R55		31	123	154
			R45		432	1,726	2,158
	Expansion Joint	Rubber			1,718	6,873	8,591
	Temporary & Other Works				13,233	74,989	88,222
Total					55,980	223,922	279,902

Appendix G CONSTRUCTION COST FOR ADDITIONAL FERRY TERMINAL

1. General

Existing Likoni ferry terminal should be expanded according to the ferry traffic demand forecast given in Chapter 5. The construction cost is estimated for the base case (without project) of economic evaluation

New berth is planned at the eastern side of existing Mbaraki berth and at the western side of Likoni berth considering existing facilities and slope length of access roads.

2. Cost Estimation

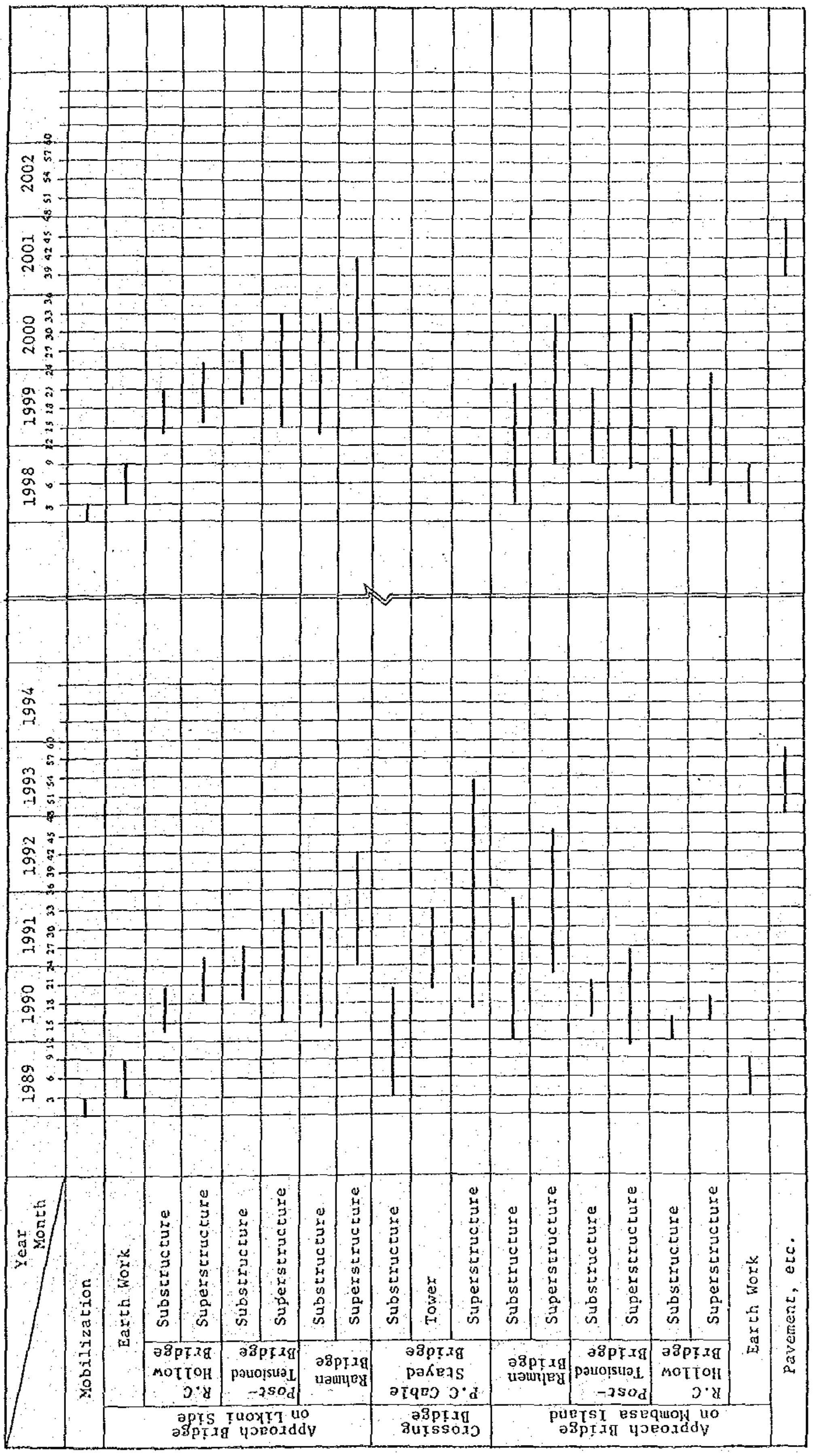
Quantities for work items are calculated using 1:5,000 topographic maps. The unit costs estimated in Chapter 8 are used for the cost estimation. The construction cost is estimated in Table G-1.

Table G-1 CONSTRUCTION COST FOR ADDITIONAL FERRY BERTH

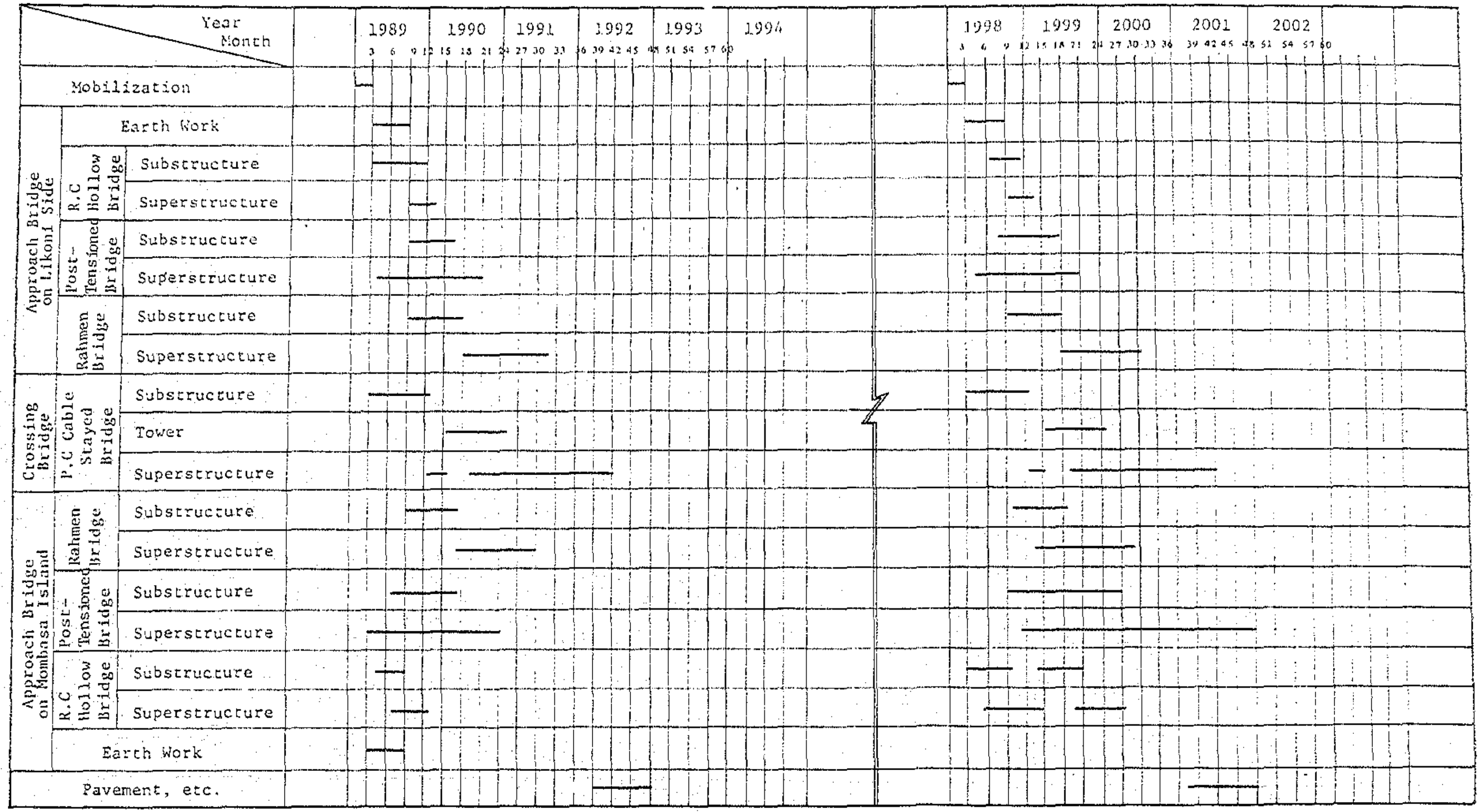
Work Item	Unit	Unit Cost (Shs.)	Quantity	Cost (x 1,000 Shs.)
Excavation & Disposal	M^3	66	16,800	1,108.8
Apron Work	M^3	1,500	1,600	2,400.0
Concrete Pavement	M^2	300	4,200	1,260.0
Asphalt Pavement				
Subgrade preparation	M^2	25	3,010	75.3
Sub-base	M^3	240	567	136.1
Base	M^3	475	452	214.7
Asphalt pave. t=50	Ton	680	346	235.3
Asphalt pave. t=30	Ton	410	95	39.0
Guardrail	M	400	540	216.0
Tollgate	No	30,000	2	60.0
Lighting Post	No	16,000	25	400.0
Concrete Curb	M	58	490	28.4
Concrete Curb & Gutter	M	100	490	49.0
Catch Basin	No	2,300	5	11.5
Pipe ø 400	M	585	490	286.7
Others (Land Aquisition, Contingency)	L.S	-	-	1,079.2
Total				7,600.0

Appendix H CONSTRUCTION SCHEDULE

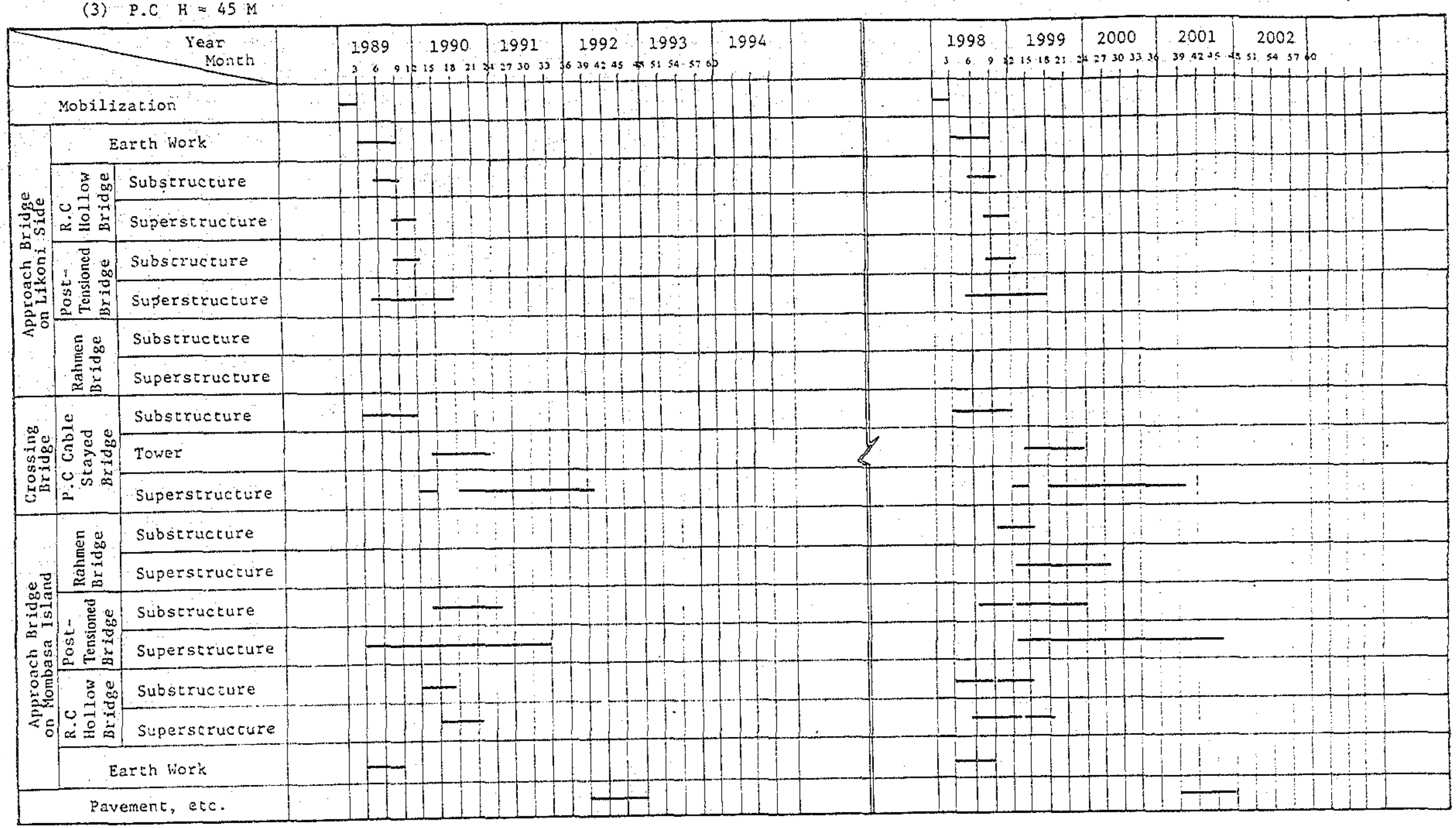
(1) P.C H = 73.2 M



(2) P.C H = 55 M


Year
Month
1989
1990
1991
1992
1993
1994
1998
1999
2000
2001
2002
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60
Mobilization
Approach Bridge on Likoni Side
Earth Work
R.C Hollow Bridge
Substructure
Superstructure
Post-Tensioned Bridge
Substructure
Superstructure
Rahmen Bridge
Substructure
Superstructure
Crossing Bridge
P.C Cable Stayed Bridge
Substructure
Tower
Superstructure
Approach Bridge on Mombasa Island
Rahmen Bridge
Substructure
Superstructure
Post-Tensioned Bridge
Substructure
Superstructure
R.C Hollow Bridge
Substructure
Superstructure
Earth Work
Pavement, etc.

(3) P.C H = 45 M



Year
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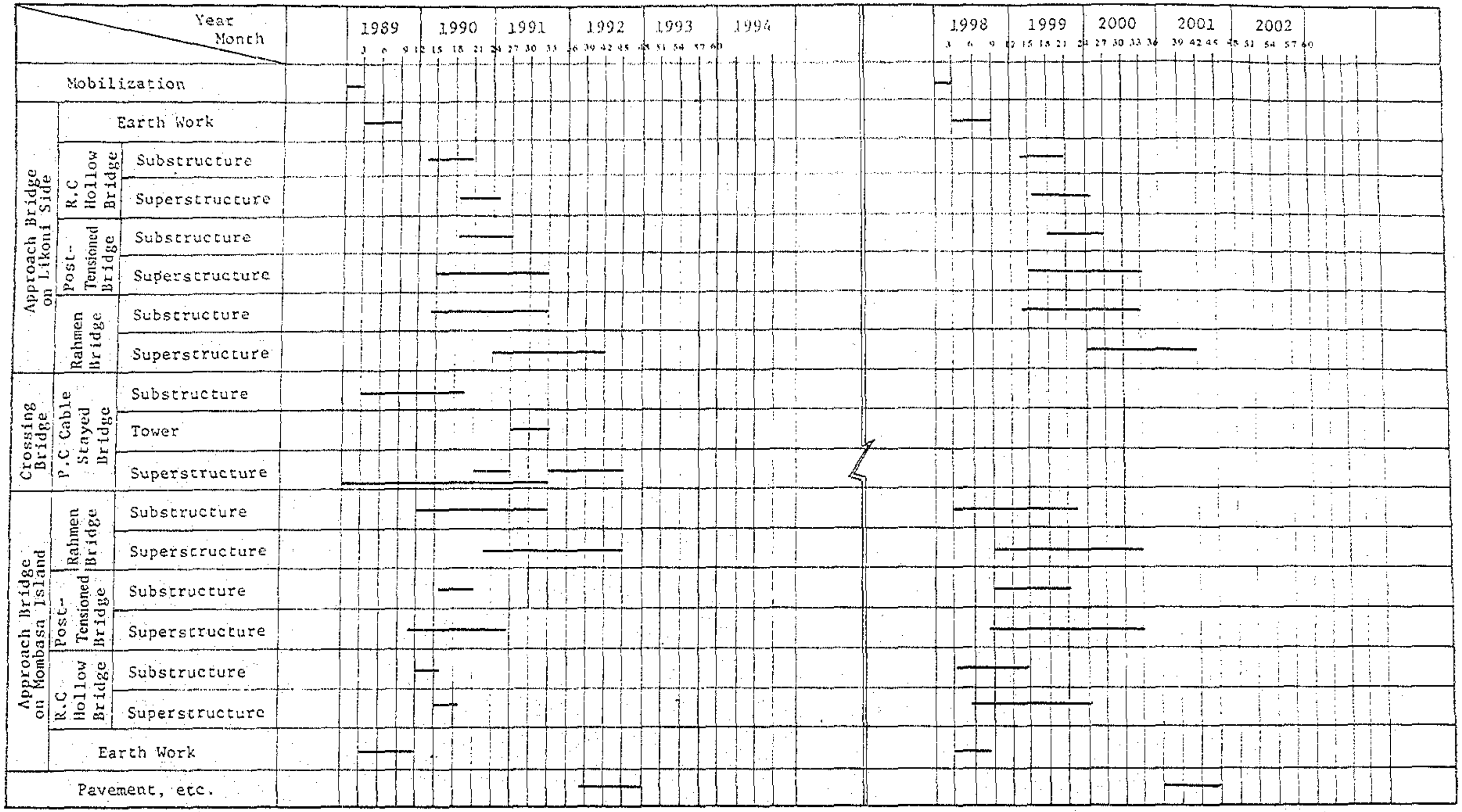
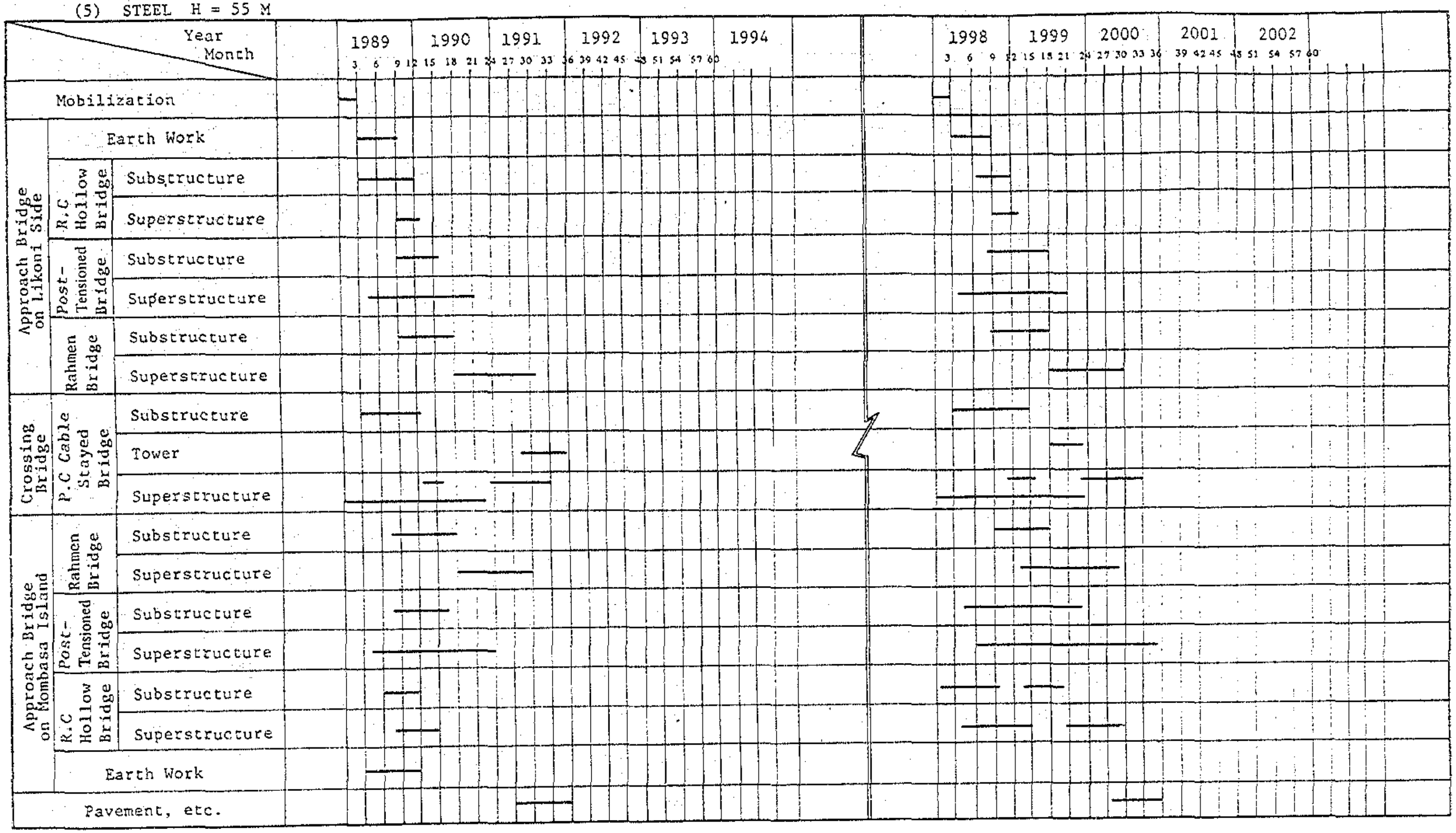
2002
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60
Mobilization
Approach Bridge on Likoni Side
Earth Work
R.C Hollow Bridge
Substructure
Superstructure
Post-Tensioned Bridge
Substructure
Superstructure
Rahmen Bridge
Substructure
Superstructure
Crossing Bridge
P.C Cable Stayed Bridge
Substructure
Tower
Superstructure
Approach Bridge on Mombasa Island
Rahmen Bridge
Substructure
Superstructure
Post-Tensioned Bridge
Substructure
Superstructure
R.C Hollow Bridge
Substructure
Superstructure
Earth Work
Pavement, etc.

(4) STEEL H = 73.2 M



(5) STEEL H = 55 M



Year
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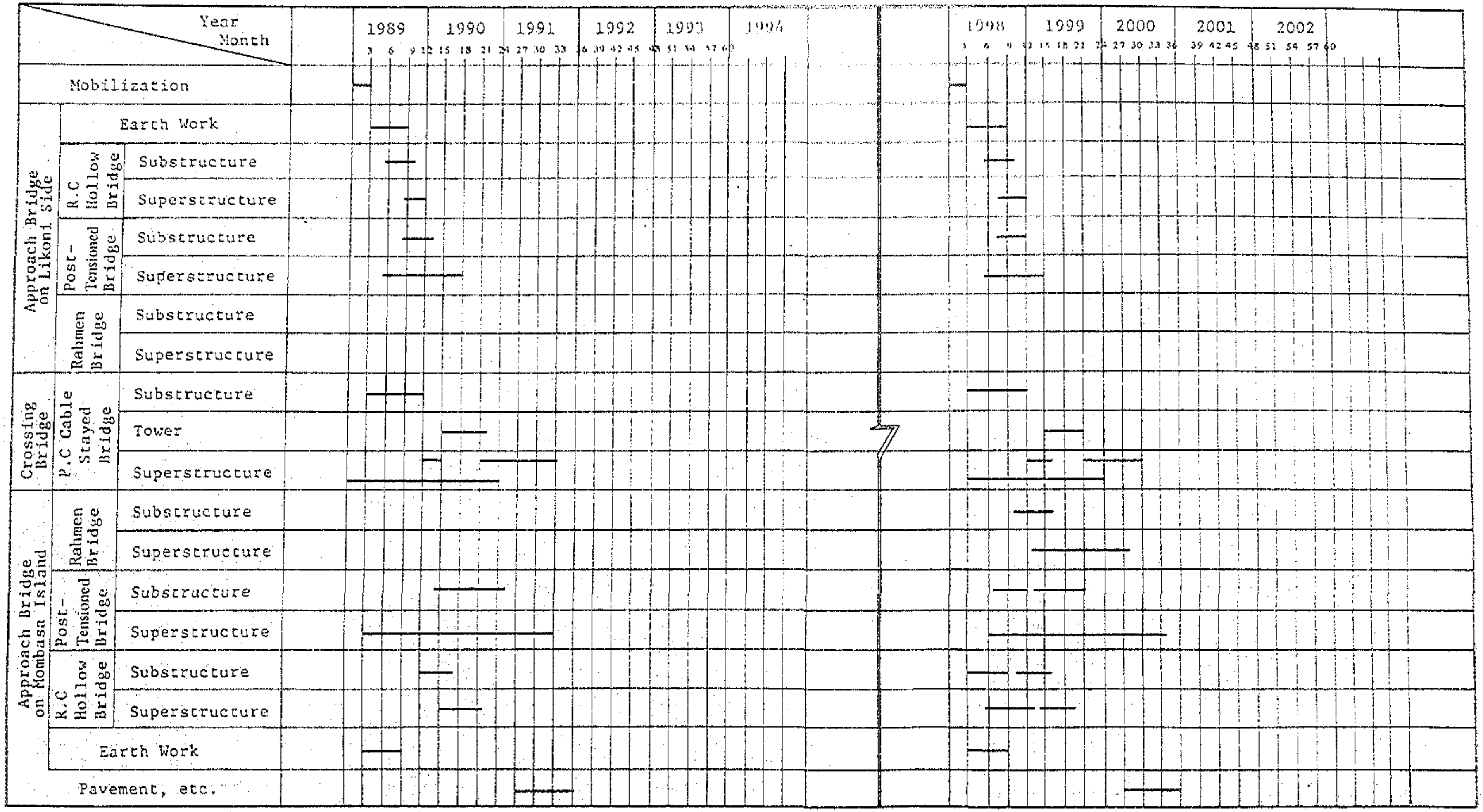
2000
2001
2002
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60
Mobilization
Approach Bridge on Likoni Side
Earth Work
R.C Hollow Bridge
Substructure
Superstructure
Post-Tensioned Bridge
Substructure
Superstructure
Rahmen Bridge
Substructure
Superstructure
Crossing Bridge
P.C Cable Stayed Bridge
Substructure
Tower
Superstructure
Approach Bridge on Mombasa Island
Rahmen Bridge
Substructure
Superstructure
Post-Tensioned Bridge
Substructure
Superstructure
R.C Hollow Bridge
Substructure
Superstructure
Earth Work
Pavement, etc.

(6) STEEL H = 45 M



Year
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2002
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60
Mobilization
Approach Bridge on Likoni Side
Earth Work
R.C Hollow Bridge
Substructure
Superstructure
Post-Tensioned Bridge
Substructure
Superstructure
Rahmen Bridge
Substructure
Superstructure
Crossing Bridge
P.C Cable Stayed Bridge
Substructure
Tower
Superstructure
Approach Bridge on Mombasa Island
Rahmen Bridge
Substructure
Superstructure
Post-Tensioned Bridge
Substructure
Superstructure
R.C Hollow Bridge
Substructure
Superstructure
Earth Work
Pavement, etc.

APPENDIX I ADDITIONAL STUDY FOR IMMERSED TUBE TUNNEL (T_2)

1. General

The major objectives of this appendix are to check the cost of the immersed tube tunnel (T2-Route) estimated in the Phase-I study and to review the concept by using the same planning conditions as that of the bridge scheme.

The cost (4-lanes and 2-lanes), pedestrian passage, etc are associated in this review. The conventional tunnel (T_2-Route) was removed from the alternatives due to disadvantages of cost, constructability (soil conditions), traffic service to the island, etc as described in paragraph 6.3.3 of Chapter 6.

2. Review of Immersed Tube Tunnel (T_2)

1) Planning conditions

(1) Alignment

In general, an immersed tube tunnel should be placed in the area where the channel depth is less than 40m, and the tidal current velocity is less than 1.0 ∿ 1.5 m/sec based on construction considerations.

The immersed tube tunnel should be located in a straight line or flat curvature. A minimum radius of curvature of 400m is applied for the approach tunnel alignment.

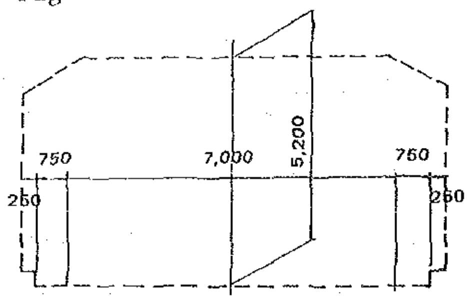
Tunnel gradient is an important design factor as it relates to the traffic safety and construction efficiency as described in 6.3.3.of chapter 6 and Progress Report-I.

In this review a limited length of 6% gradient is also applied for the tunnel entrance section based on the "Road Design Manual", Part-I, Geometric Design of Rural Roads, MOTC. The case of a 3% gradient was studied in Progress Report-I.

(2) Roadway and Pedestrian Clearance

The vertical clearance of the roadway adopted in the Phase I study was 4.7m above the road surface. This must be increased to 5.2m to conform to the criteria established for the bridge scheme. The lateral clearance is the same width as that of the Phase-I Report as shown in Fig. I-1. The footpath is the same as 2.0x2.5m (width and vertical clearance) as that of bridge scheme and should be separated from the carriageway.

Fig. I-1 ROADWAY CLEARANCE



(3) Future Traffic Demand

In Phase-I the ventilation was based on 20,000 PCU in 2,010. This must be revised in accordance with the traffic forecast described in Chapter 5.

(4) Soils Condition

The soils condition of the immersed tube tunnel (T_2) can be assumed from the borehole data obtained from the survey in this study and past surveys as described in Chapter 7.

The data can be summarized as follows:-

- On land area the coral layer exists with a thickness of 10∿15m from the ground surface.
- Under the seabed there is a soft soil layer with the thickness of 2∿3m, and beneath this layer generally the dense sand with coral fragments can be found with an N-value of 15∿70 down to 30m below the seabed.

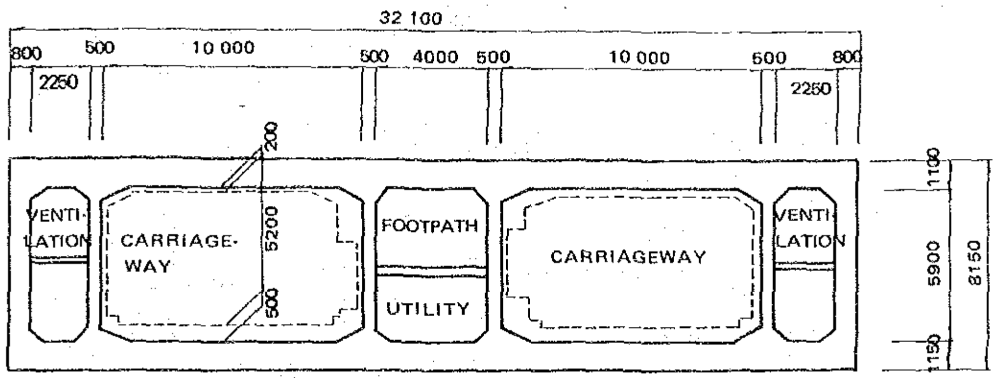
(5) Navigation Requirements

KPA requested that the navigable width was to be 1,100 feet (335m) and the depth 45 feet (13.72m) from the lowest low water level.

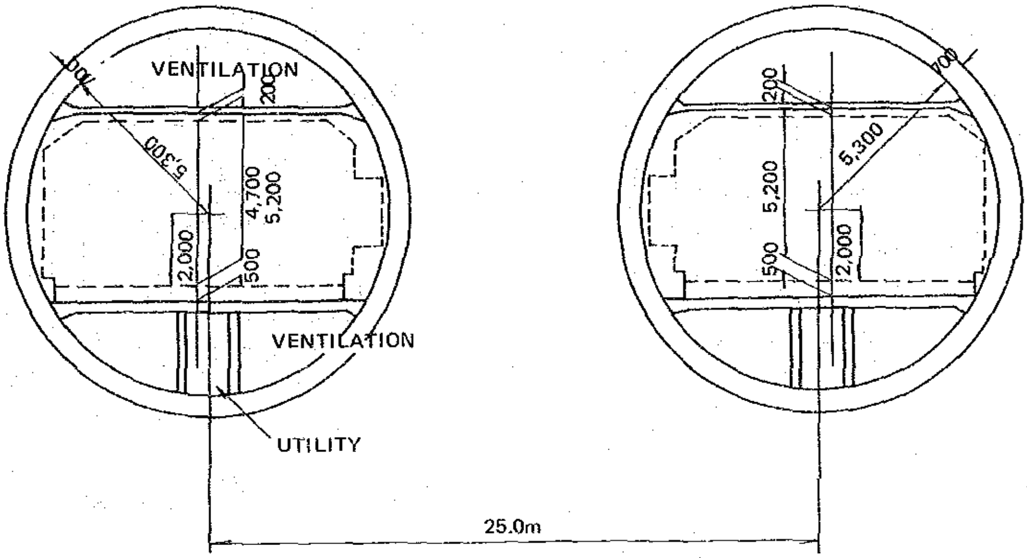
(6) Required Tunnel Cross Section

The tunnel cross section comprises the space of the carriageway, inspection corridor, ventilation duct and footpath. Floatation for towing is another design consideration for immersed tube elements. The designed cross sections are shown in Fig. I-2.

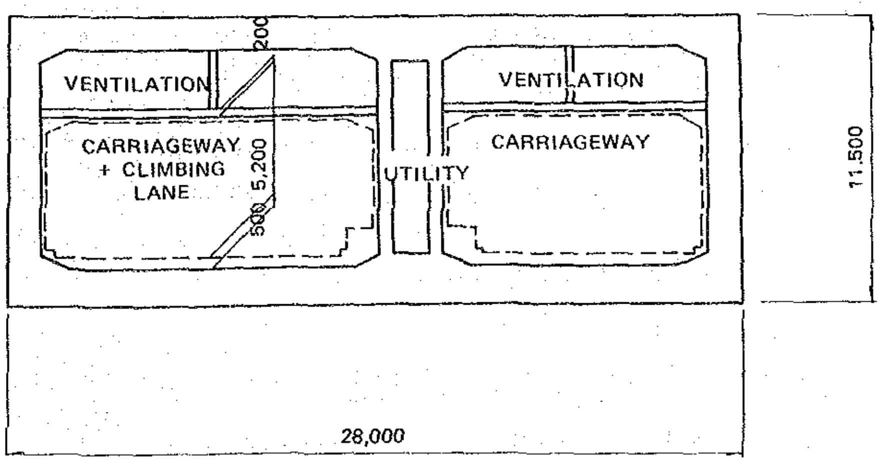
Fig. I-2 TUNNEL CROSS SECTION
SINGLE STAGE CONSTRUCTION
IMMERSED TUBE SECTION



SHIELD SECTION

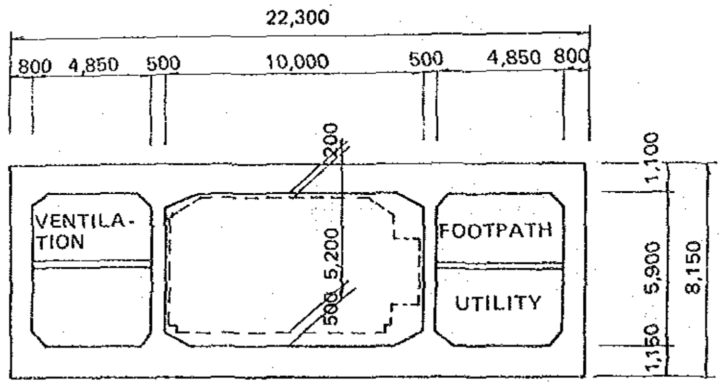


CUT and COVER SECTION

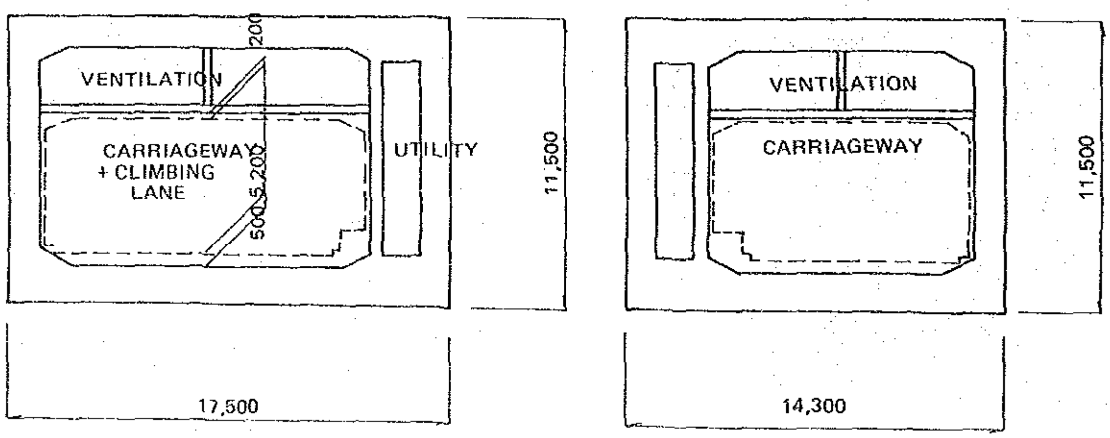


STAGED CONSTRUCTION

IMMERSED TUBE SECTION



CUT and COVER SECTION



(7) Earth Cover

The earth cover above the immersed tube tunnel is determined according to the potential damage caused by a ship's anchor.

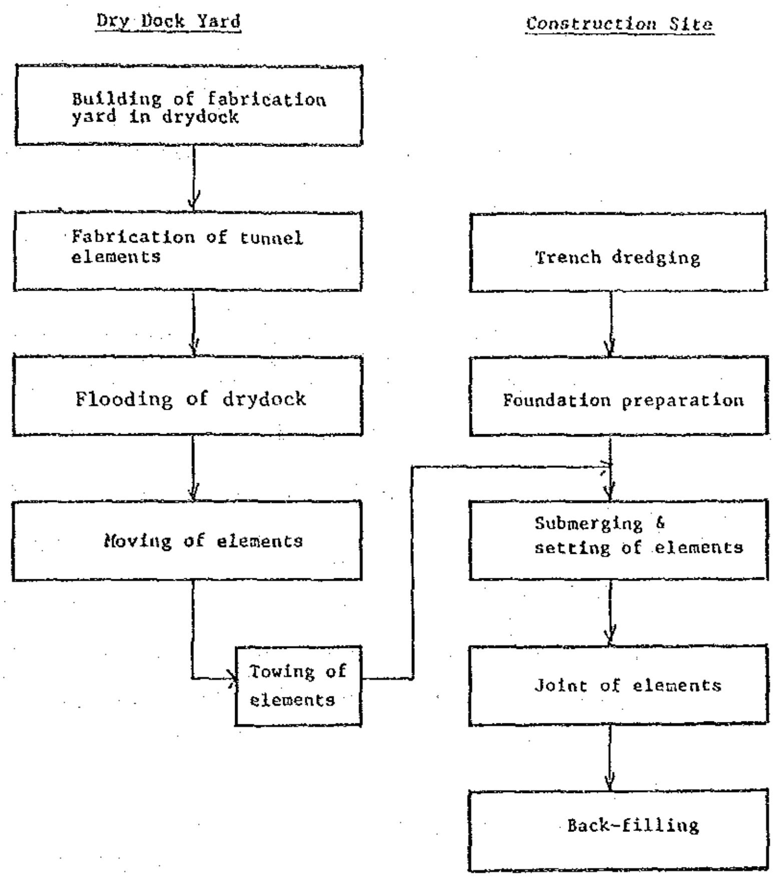
Observing the sizes of the anchors of the world largest ships a 2m cover is the minimum requirement to avoid damage to the tunnel.

2) Construction Aspects

(1) *Work Flow Chart*

The work for the immersed tube tunnel is largely divided into two; on shore and off shore work as shown in Fig. I-3.

Fig. I-3 WORK FLOW CHART



(2) Tunnel Element

The element lengths of the immersed tube are decided by the width of the navigation passage and the difficulty in shifting the channel. The longest element lengths manufactured were 120 - 130m. In general, the construction of an immersed tube tunnel should be divided into least number of elements. This contributes to cost reduction and a shorter construction period.

Considering the channel width and the depth and the channel navigation, a width of 200m can be maintained for one-way operation of 20,000 ton ships. This can be considered to be the minimum width under the current port operations. In this study, the element length of the immersed tube is therefore proposed to be 120m.

(3) Dock Yard

The construction cost and period of the immersed tube tunnel are dominated by the location and scale of drydock. The drydock must have a rigging yard with enough space for element fabrication.

It is desireable to use an existing drydock located close to the construction site. After investigation of the port area, it is not possible to use Mbaraki Repairing Dock, because the depth (6m) is not enough to float the fabricated element. Therefore a new dock must be constructed in Mueza Creek.

(4) Trench Dredging

The dredging cost is normally very small in the total construction cost. However, where water is deep as in this project, costs of trench excavation including both shores will be a large sum.

The trench slope varies with the nature of soil and is decided to be 1 : 2 because of the existing soft soil condition. A bucket dredger is used for the dredging work.

A soil dump site should be near the construction site. The site is proposed to be the same location as was used for the dredging project by the U.S.A. in January 1983.

(5) Element Towing, Submerging, Setting and Joining

The elements manufactured in the drydock are towed by tug boats to the site.

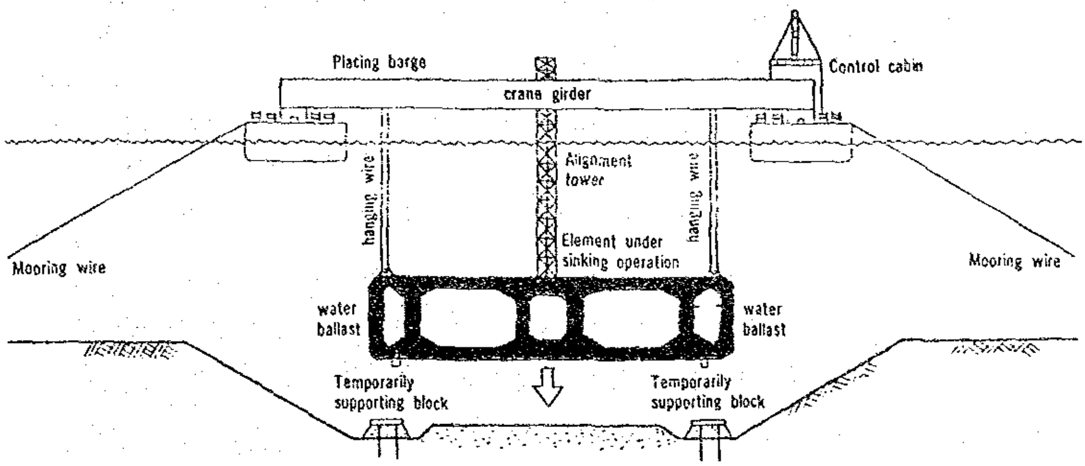
The sinking and setting work is the most important amongst the various works of the submerged tunnel construction.

The element is usually made so as to float with a small free-board of 10 to 40 cm. and then towed to the site. At the worksite the ballast for sinking is added to the element.

For joining the elements, it is desirable to adopt the water pressure joining method using rubber gaskets.

For the selection of a work ship, some examples used in the past have been a placing barge, heavy lift ship, fixed scaffolding and self elevating platform (SEP) work ship. Among these with a current velocity of 2 - 3 Knots, the SEP work ship has most merits in the reliability of construction, short construction period and the least obstruction to ship operations in the channel as shown in Fig. I-4.

Fig. I-4 ELEMENT SETTING AND SINKING



To form a flat-finished ground surface after dredging, gravel laying and mortar filling is used between the element and the bottom of the trench.

3) Construction of Approach Tunnel

The on-shore tunnel section (from the vertical shaft of the immersed tube tunnel to the ground surface) is constructed by two methods: shield and open cut and cover sections.

The open-cut and cover method is applied for the section where the depth is less than 25m. For a depth of more than 25m the shield method is usually used for economic and technical reasons.

The shield methed is the most suitable method under the soil conditions (silty sand and dense sand) and ground water. The safety and practical depth of shield method is determined within the range of 1.0∿1.5 times of shield diameter to avoid upheaval of the existing ground.

The depth of the tunnel is also controled by the existence of the hard coral as a lower limit and the need to be lower than an upper limit which is governed by the need to weight balance the air pressuse in the shield.

The excavation of the open-cut and cover section adjacent to the shield section is also another important aspect to determine the extent of the shield section.

Under these conditions the change-over between shield and open-cut and cover section is determined as the depth of 25m below the ground.

The gradient of shield section is generally less than 2%, but 3% is the limit of shield construction.

The shield section is separately constructed for twin and parallel 2 - lane tunnel. The minimum distance of 2 D (twice of shield diameter) should be maintained for the safety excavation.

The cut and cover section is used between the shield section and at-grade section. This section is planned by considening the up lift by water and the existing developed situation on the ground.

The location of the tunnel portal is decided as being at a depth of 10m below ground giving economic and structural advantages.

From this description, each tunnel section is determined as shown in Fig. I-2.

4) Tunnel Alignment and Access Study

(1) Tunnel Location

The construction of the immersed tube tunnel is limited by the water depth. I_2 route,selected in phase-I study is confirmed as the shallowest location amongst the alternative routes in the harbour.

It will connect Lunga Lunga Road on the Likoni side and Nyerere Ave. or Archbishop Makarios Road on the island side.

(2) Regional Development Effects

In the Likoni area the tunnel route must be evaluated from the development effect of the region.

Refering to the past study, two strategic development areas in the south Mainland were proposed; Dongo Kundu area (including Mtongwe) and coastal belt along the Indian Ocean.

Comparing with the bridge route there are no significant differing development effects to these areas because the distance from the Dongo Kundu area to both routes is around 6 km and the route is almost down the middle of the coastal belt.

(3) Road Access

In Likoni area the tunnel road uses the existing right-of-way of Lunga Lunga Road. The existing road section must therefore be relocated at the access and portal of the cut and cover section.

On the island the access should be planned from the traffic distribution and the future extension towards the trunk road. An approach distance of 1.2 km is needed from the edge of Mbaraki berth to the at-grade section.

For access to Nyerere Ave. this reaches beyond the intersection of Nyerere Ave. and Dedan Kimathi Road., and causes the same problem of traffic distribution as the bridge case of 73.2m clearance. Therefore the tunnel access should be aligned towards Mbaraki Road.

The traffic connection by simple interchanges with Tangana Road and Moi Ave. is another subject of the tunnel alignment. In the plan the access alignment is to have sufficient distance to Tangana Road so as to provide a fly-over on Tangana Road in the future.

From this access plan, the extension towards the future trunk road can be assured as the same level as that of the bridge alternatives.

Fig. I-5 shows the tunnel plan and profile as the result of the study.

5) Footpath Plan

(1) Pedestrian Service

A total of 36,925 persons per day are served by the Likoni Ferry based on the traffic survey conducted in April, 1983. Only 7,641 persons are pedestrians without any vehicle mode. In future a maximum 570 persons per one direction is estimated to walk in the tunnel as described in Progress Report-I.

A pedestrian footpath is provided only for the immersed tube tunnel section and space should be separate from the carriageway. At the ventilation shaft elevators serve pedestrians to and from the ground level.

(2) Some Problems

The tunnel, even with a length of less than 1,000m, is unsafe for pedestrians. It is a long and dark tube even when provided with lighting, and no refuge space can be provided for incidents.

In the case of crime, it is quite difficult to organize rescue and

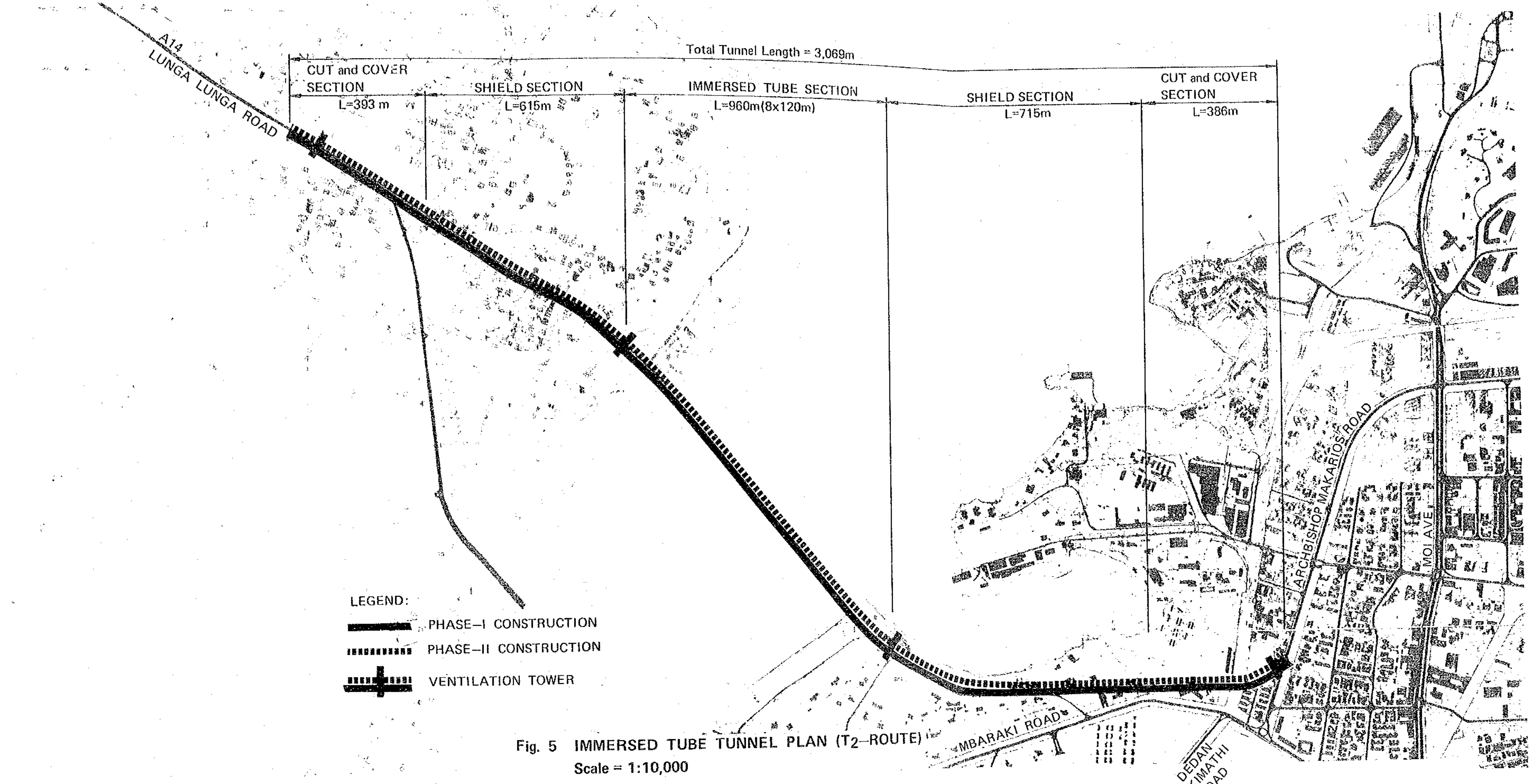
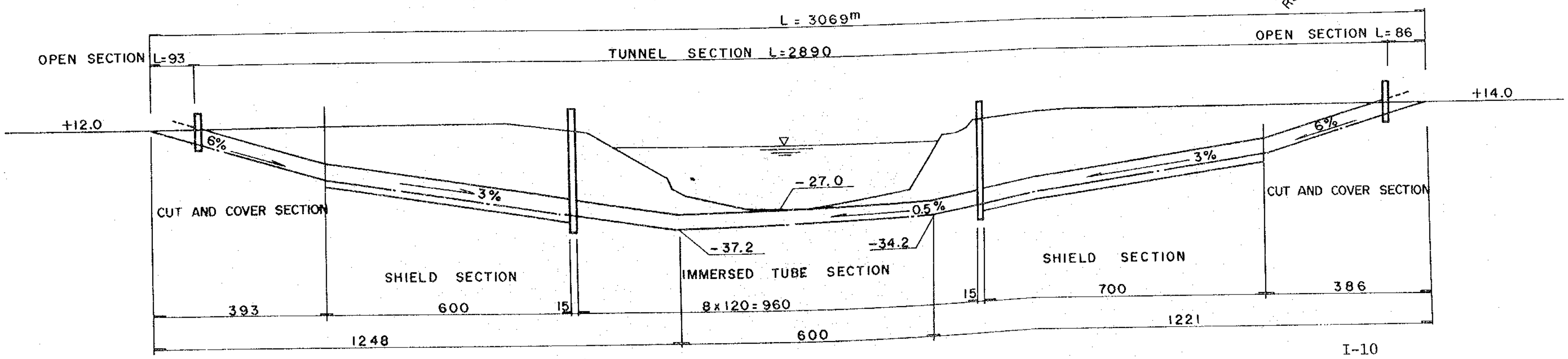


Fig. 5 IMMERSED TUBE TUNNEL PLAN (T_2-ROUTE)
Scale = 1:10,000



will take time. Garbage and raw sewage are other problems for tunnel footpaths and this is difficult to clean.

To minimize these risks police patrols and elevator operators are indispensable.

6) Anciliary Facilities

(1) General

A tunnel is a sensitive structure and requires care in its routine operation since it is an enclosed space unlike an ordinary road. Special considerations must be given to traffic safety and comfort. To ensure routine operations many kinds of anciliary facilities such as the ventilation system, lighting, disaster prevention facilities, drainage system and so forth, must be provided.

These facilities are designed by using detailed data relating to the traffic volume and fixed conditions such as the length, cross-section and gradient of the tunnel.

(2) Ventilation System

A ventilation system is provided in the tunnel to dilute carbor-monoxide and smoke discharged by vehicles.

The criteria establishes dilution levels so as not to injure the health of the tunnel user (CO concentration of less than 150 PPM based on PIARC recommendation) and for transparency of smoke (40∿ 50% fransparency per 100m distance).

The ventilation ducts (each for exhaust and in-take) are estimated as $7m^2$ for immersed tube section and $15m^2$ for approach tunnel section. A total 4 ventilation towers are necessary at the ends of immersed tube section and tunnel portals.

(3) Lighting System

The luminance adopted for ordinary automobile tunnels in Japan is 2.3cd/m sq., while the luminance for Urban tunnels is about 8cd/m sq.,

The standard grade of 5cd/m sq., (65 lux at every light on the carriageway) under PIARC (Permanent International Association of Road Congress) recommendation should be adopted for the tunnel.

The entrance section of the tunnel should be illuminated at a higher level of 58 to 35cd/m sq., for some 200m section at the tunnel entrance to alleviate the illuminance difference between the inside and outside of the tunnel, thereby ensuring traffic safety.

With regard to the selection of the type of lamp, fluorescent lamps are used to relieve the yellow of the sodium lamps, which are used as well. The latter provides better visibility and is more economical.

(4) Signals and Signs

Signals are installed at the entrances and the inside of the tunnel to control traffic and to stop vehicles immediately should an accident occur in the tunnel. In addition, various warning signs are installed for traffic control.

(5) Fire Fighting and Alarm Systems

An automatic alarm system, which detects fires, is connected to the control room. Fire hydrants and fire extinguishers are included in the tunnel alarm system.

(6) Sump Drainage System

A sump drainage system is required at four or five sump pits in the tunnel and discharges incoming rainwater, water seepage and wash water.

(7) Power Distribution System

Power distribution system is necessary to make effective use of the tunnel facilities such as ventilation, lighting, drainage system, etc.

The system comprises substations, emergency generators and no-break systems.

(8) Television System

A closed circuit television system is installed at the tunnel entrances and in the tunnel. In order to monitor the flow of the traffic the interval between cameras in the tunnel is around 200m.

(9) Emergency Telephone System

Emergency telephones are installed at some 200m intervals in the tunnel to enable drivers to make emergancy calls when an accident or trouble occurs in the tunnel.

(10) Loudspeaker System

A loudspeaker system is provided to pass messages to drivers and for announcements when an incident occurs in the tunnel.

(11) Elevator

For the pedestrian crossing, elevators are installed at the ventilation shaft. A total of 10 elevators are provided including 2 spares of both ends of the immersed tube tunnel.

(12) Control System

The foregoing facilities and the traffic flow are monitered and controlled effectively through unilateral or mutual communication by the centralized supervisory and operation control system in the control room.

7) Environmental Problems

Total four ventilation shafts are required at the tunnel portal and adjacent to the harbour channel. Concentrated exhaust gases from the ventilation towers will be spread over the area. This is an effect which cannot be ignored upon the resort and residential areas. Especially the towers at the tunnel portal which strongly affect the surrounding residential area.

During and after construction of the on-shore tunnel sections, settlement at ground level will occur due to soil looseness and cavitation caused by the tunnel excavation. This is another problem which accompanies tunnel construction.

3. Cost Estimation and Construction Schedule

1) Review of Cost

Several projects are under construction or at the planning stage in the South-East Asia (Singapore, Hongkong, Taiwan, etc.) and Japan. Those estimates were reviewed and compared with the project.

The cost of immersed tube tunnel is made based on the data and estimate carried out in this and the other projects.

Preliminary design is made as shown in Fig. I-5 and quantities for every work items are calucatated.

2) Comparison of tunnel gradient

For the tunnel entrance section the tunnel gradients of 3%, 4.3% and 6% are compared for their cost based on "Road Design Manual, Part-I, Geometric Design fo Rural Roads" MOTC.

The flatter gradients of 3% and 4.3% do not need a climbing lane, but the 6% gradient needs a climbing lane.

As a result 6% is the cheapest among them and adopted for the preliminary design as shown in Table I-1.

Table I-1 COMPARISON OF TUNNEL GRADIENT

	i = 3%	i = 4.3%	i = 6%
Length (m)	1,556	1,086	779
Number of Lanes	4 - Lanes	4 - Lanes	4 - Lanes + Climbing Lane
Construction Cost (M.Shs)	732	510	399

Note. Single Stage Construction.

3) Project Cost

The land acquisition and compensation cost are estimated based on the same data used in this project. The operation and maintenance cost are estimated basd on the actual operation of tunnel facilities as described before.

Those costs estimated are summarized in Table I-2.

Table I-2 OUTLINE OF TUNNEL SECTIONS AND CONSTRUCTION COST

	Single Stage	Stage Construction		
	Construction	Phase-I	Phase-II	Total
1. Lengths (m)	3,069	3,069	3,069	3,069
Immersed Tube Tunnel	960	960	960	960
Shield Tunnel	1,330	1,330	1,330	1,330
Cut and Cover Tunnel	779	779	779	779
2. Construction Cost (M.Shs)				
Immersed Tube Tunnel	1,495	1,047	1,047	2,094
Shield Tunnel	975	488	488	975
Cut and Cover Tunnel	399	274	257	531
Ventilation Tower	135	80	67	147
Facilities	575	363	296	659
Sub Total	3,579	2,252	2,155	4,406
3. Land Acquisition Cost (M.Shs)	57	57	0	57
4. Total Cost (M.Shs)	3,636	2,309	2,155	4,463
5. Operation and Maintenance Costs (M.Shs)	16	10.5	5.5	16

The project cost is estimated in Table I-3 based on the Table I-4.

Table I-3 PROJECT COST CONSTRUCTED IN SINGLE STAGE CONSTRUCTION

(Unit: 1,000 K.Shs.)

	L.C	F.C	Total
1) Construction Cost	715,800	2,863,200	3,579,000
2) Engineering Fee, 10%	71,580	286,320	357,900
3) Land Acquisition & Compensations	57,000	-	57,000
4) Sub-Total	844,380	3,149,520	3,993,900
5) Contingency, 10%	84,438	314,952	399,390
6) Total	928,818	3,464,472	4,393,290

Table I-4 PROJECT COST IN STAGED CONSTRUCTION

(Unit: 1,000 K.Shs.)

	Phase-I			Phase-II		
	L.C	F.C	Total	L.C	F.C	Total
Construction Cost	450,400	1,801,600	2,252,000	431,000	1,724,000	2,155,000
Engineering Fee, 10%	45,040	180,160	225,200	43,100	172,400	215,500
Land Acquisition	57,000	-	57,000	-	-	-
Sub-Total	552,440	1,981,760	2,534,200	474,100	1,896,400	2,370,500
Contingency, 10%	55,244	198,176	253,420	47,410	189,640	237,050
Total	607,684	2,179,936	2,787,620	521,510	2,086,040	2,607,550

The project cost by staged construction is estimated to be around 23% higher than that constructed in a single stage.

4) Construction Schedule

The implementation schedule is also planned for two cases, construction in single phase and by staged construction as shown in Fig. I-6 and I-7.

The construction period is estimated as five and half years for both cases, but a further five years is needed for Phase II as shown in Fig. I-8 and I-9.

The immersed tube tunnel is evaluated in chapter 10 using these costs and implementation schedule.

Fig. I-6 IMPLEMENTATION SCHEDULE BY SINGLE PHASE CONSTRUCTION

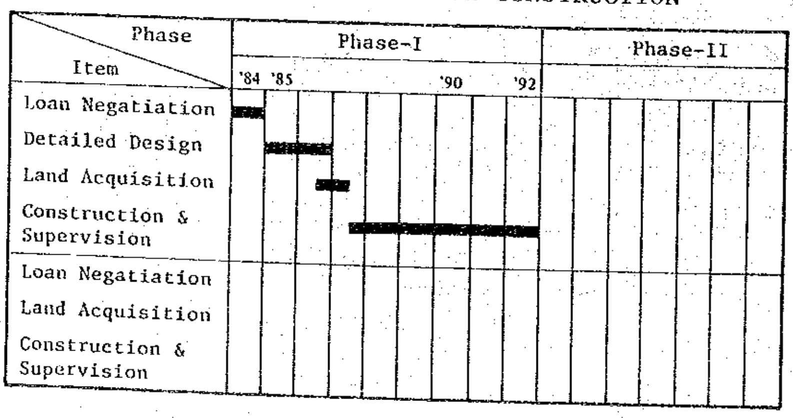


Fig. I-7 IMPLEMENTATION SCHEDULE BY STAGED CONSTRUCTION

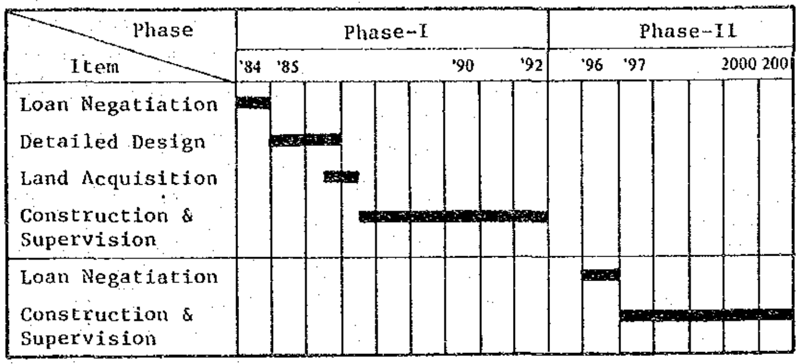


Fig. I-8 CONSTRUCTION SCHEDULE BY SINGLE STAGE CONSTRUCTION

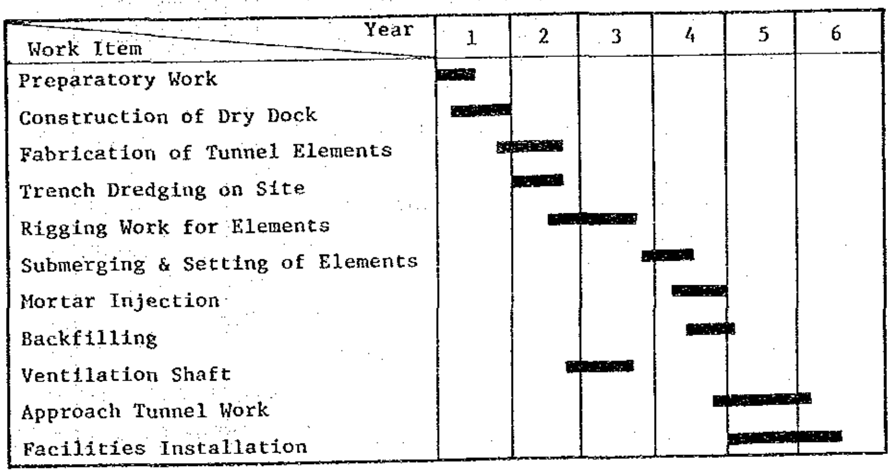
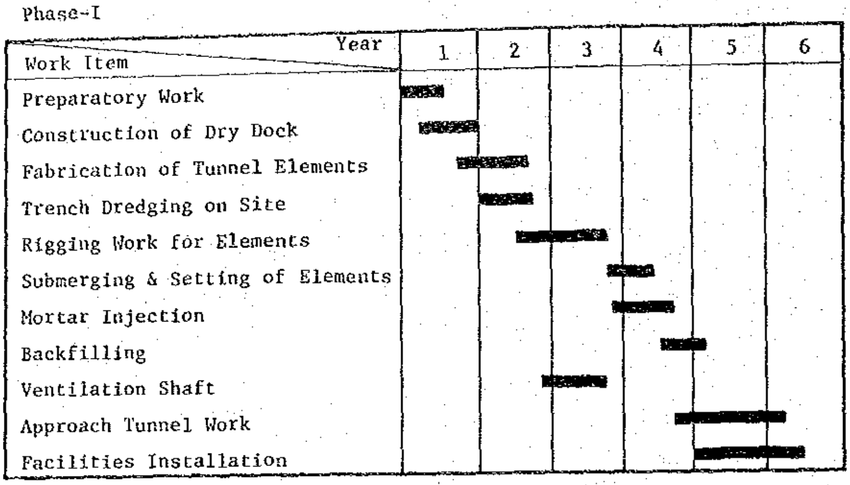
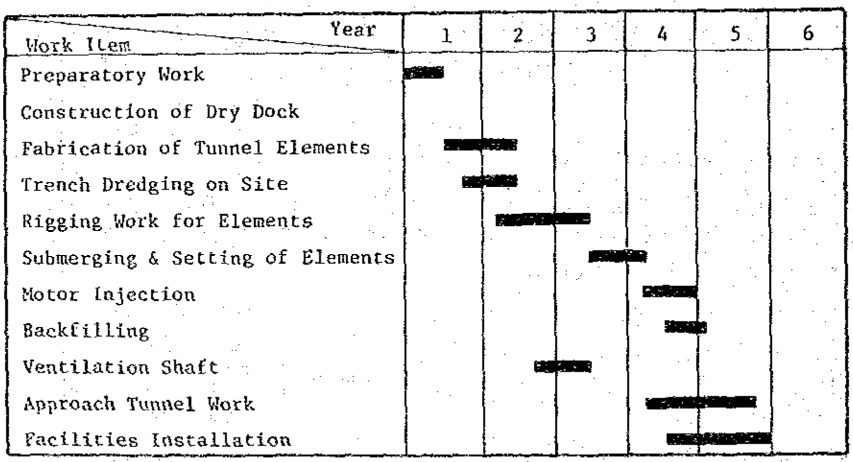


Fig. I-9 CONSTRUCTION SCHEDULE BY STAGED CONSTRUCTION

Phase-I



Phase-II



4. Hong Kong Cross Horbour Tunnel

1) Planning and Construction Conditions

(1) Tunnel Length

- Immersed tube tunnel : 1,604m
  (Average element length : 15 x 106.9m/unit)
- Cut & cover tunnel : 253.6m
- Louver section : 300m

  Total Length : 2,157.6m

(2) Number of lanes

- 2 dual lanes except the cut & cover and louver section, which has a climbing lane.
- Carriageway (dual) lane width : 6.7m
- Traffic headroom : 4.88m

(3) Gradient : 0.435~6.25%

(4) Channel Requirment

- Depth : -12.2m P.D
- Channel width : 400m

(5) Tide

- Max. current : 3 Knots (Approx. 1.5m/sec)
- Variation : Spring, Approx. 2.5m

(6) Traffic Volume

- Traffic capacity : 80,000 veh./day
- Pedestrian : Not considered but transported by existing ferry

(7) Sub-soil conditions

Marine deposit (Soft silt and fine sand) partially clay and boulders.

(8) Dock yard on site with fabricating yard of elements.

(9) Dredging & Dumping Site

Dredged for the maximum depth of 28m using Lima 2,400 B (Cap. 2.6∿4.5m^3) and dumping 10∿15km off-shore from the site.

(10) Sinking : Two storied twin screed/lay barge

(11) Mound : 60cm thickness of crushed stone

(12) Back Filling

Sand for the sides of element and crushed stone (20∿50kg/stone) on the top with thickness of 2m.

2) Construction Cost Estimation

The tunnel was opened in Oct. 1972, and the construction cost was estimated using an escalation rate. This however is difficult due to the oil crisis which occured in-between, therefore the estimate is made using the conditions described above and current prices of material involved as shown below:

Item	Construction Cost (Million Shs.)
Immersed Tube Section	2,190
Cut & Cover Section (including Louver section)	437
Ventilation Tower & Facilities	568
Total	3,195

The land acquisition/compensation cost, engineering/supervision fee and contingency are not included in the above estimate.

The major differences between Likoni Tunnel (T_2) and H.K Cross Harbour Tunnel are the length and cross section of the tunnel.