arising from merging and diverging of traffic lanes and curving alignment.
- to reduce the thickness of the beams as much as possible.

The most effective way of satisfying requirements 1 and 2 is to use viaducts and to minimize the stretch of embankment and retaining walls. Although this would increase construction cost, viaducts are easier to maintain and manage.

Good visibility improves the traffic performance and is an important function of interchange. This function is also linked to the prevention of traffic accident. Viaduct stretch should be planned to span as long as possible to assure the sight distance. In the case the span could be lengthened, numbers of pier would be lessened. Single column type pier or Y shaped pier is suitable. A round cross section for column is also desirable.

Retaining wall will be applicable only for stretches where the height of wall between the original ground and proposed height is less than 2m, otherwise to employ viaduct.

Concreting cast-in-situ for the superstructure of viaduct is suitable to girder variations in width and resultant undulation of the road surface by transverse and vertical gradient.

To reduce the thickness of girder, prestressed concrete and continuous beam are recommended. For spans of up to 30m, a hollowed slab in reinforced concrete can be used for the super structure and box section girder for spans above 30m as shown in Fig.9.14.

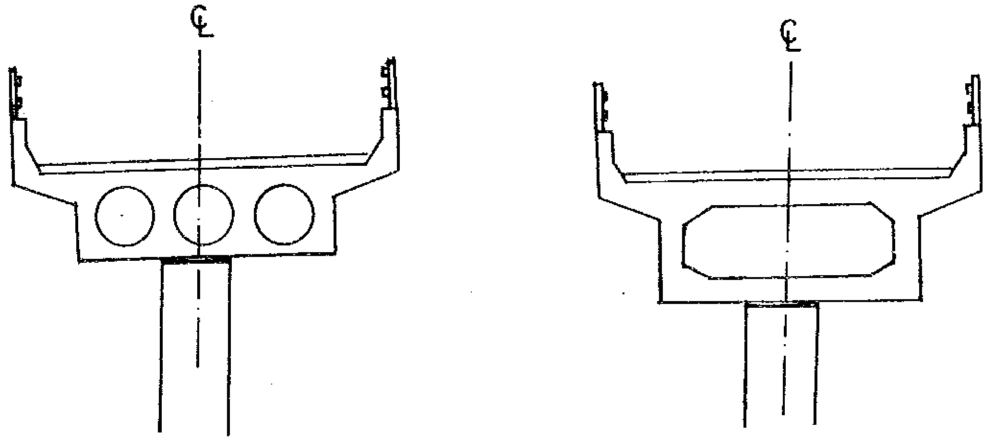


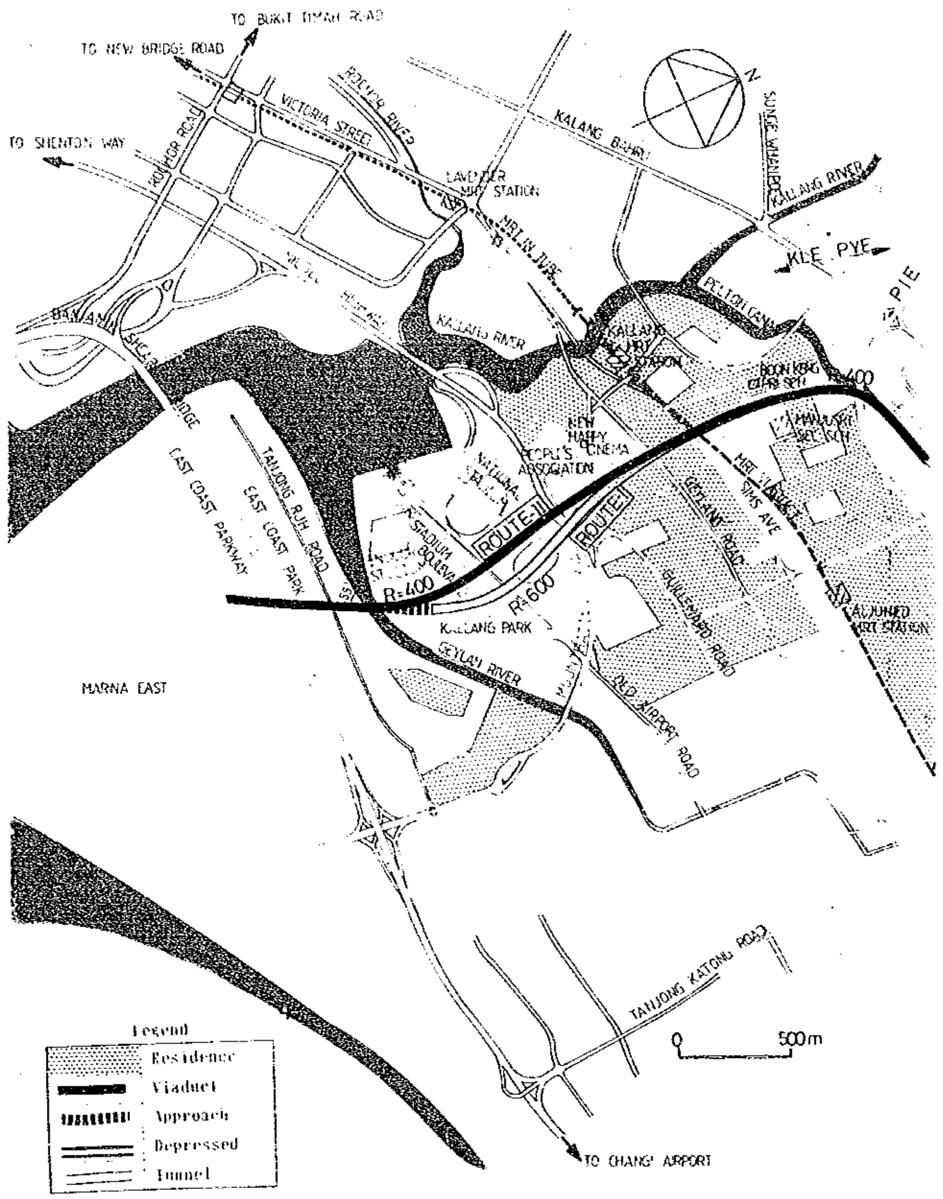

**Fig. 9.14 Superstructure type for interchange viaduct**

### *9.6.3 Structure Planning for the KLE*

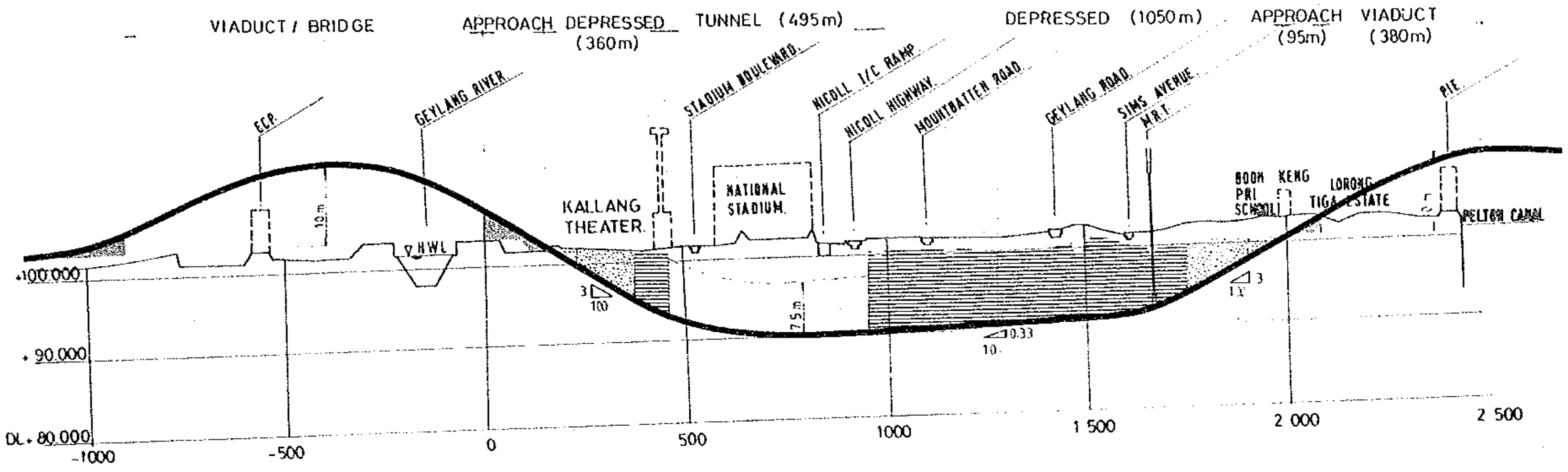
**1) Route-I (Tunnel scheme as seen in Fig. 9.15)**

**a.** The crossing over the ECP requires to span 60m long. Since bridge pier has been not positioned in the median strip of the ECP all along, the bridge is planned to follow the current practice and not to locate pier in the median of the ECP. The bridge will need a three span continuous PC girder of 140m long, which has such characteristics as that the beam depth is thin in the middle of central span, the distance between end joints is long and that the traffic is not affected by the

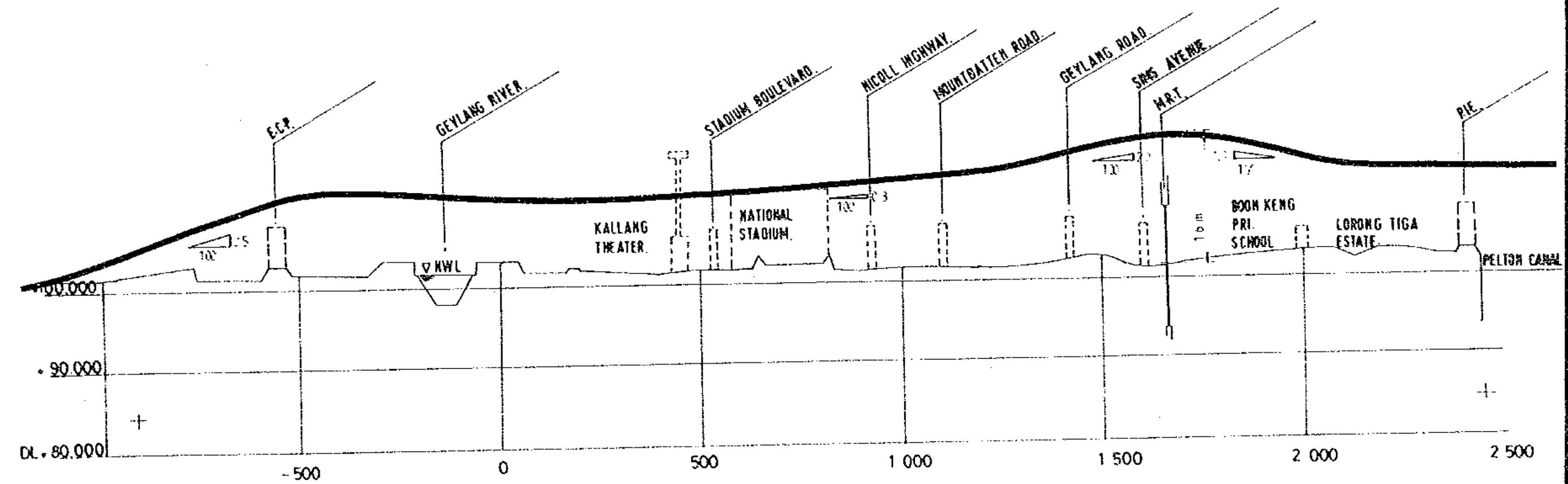
# PLAN




# PROFILE




ROUTE-I

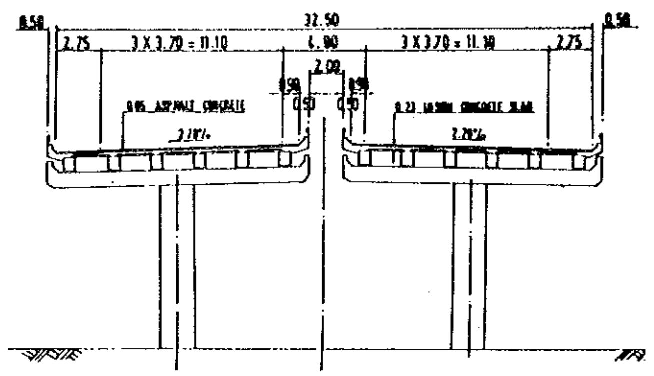



ROUTE-II

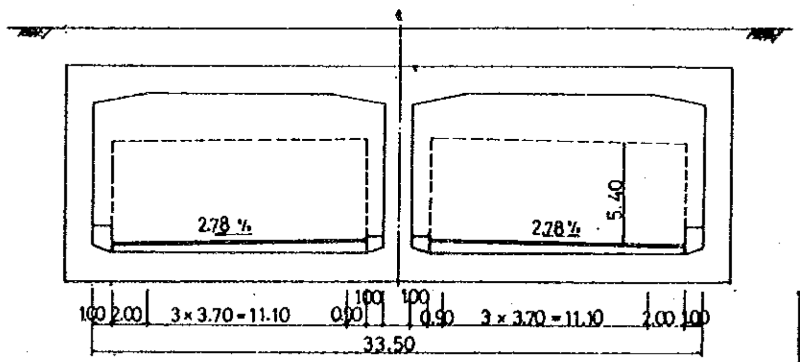
LEGEND:

- EMBANKMENT RETAINING WALL
- TUNNEL
- U SHAPED TROUGH
- SEMI COVERED TROUGH

# CROSS SECTION




VIADUCT SECTION




TUNNEL SECTION

Fig. 9.15 Structure planning for KLE

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

erection work. The cantilever method for erection is recommended.

The substructure is planned as column type pier supported by footing. The site subsoil is formed by marine clay sediment 20m to 50m thick. The foundation will be piles driven to the Old Alluvium. Rating from the weight and size of the structure and the saline environment of the reclaimed land, the popular H steel piles are not acceptable. PC piles or steel casing concrete piles, which were used in the construction of the Paya Lebar Flyover and the Benjamin Sheares Bridge respectively, would be suitable.

b. As the stretch passing through the East Coast Park and Tanjong Rhu Road is connected to the bridge over the Geylang River, an elevated structure will be applied. The size of the crossing span is small and possible to select spans freely. Economy can be assured by standard viaduct type of PC precast girder of 30m long span. The proposed rise of viaduct is between 8m to 9m. A two column type pier will be recommended based on aesthetical consideration. PC square pile will be used as foundation, rating from the weight and size of the structure.

c. The KLE crosses the Geylang River at an angle of 45 degrees. As the skew spanning over the waterway is 90m, a bridge length of 170m is required. As the KLE descends northward at the gradient of 3% from the southern crest, the rise of the bridge at the right sided revetments in the north is limited to 4m. For this type of bridge, it is necessary to select a continuous beam type where the girder end on the side span is thin or the through bridge type with stiffened or stayed girder by steel. A concrete bridge is decided based on the current practice in Singapore. A three span continuous beam is recommended with bridge piers built on both sides of the river to avoid disturbance to the river flow. In order not to occupy the waterway during construction, erection will be carried out by the cantilever method. Occupation of the waterway will be limited to the revetments at the bridge pier and a construction platform. Construction work on the bridge pier will be divided into 2 phases to retain waterway in case flood occurred. Steel casing concrete pile is suitable for foundation rating from the size and weight of the structure. Comparison of the bridge type is shown in Appendix 9.9.

d. After descending at the gradient of 3% over the Geylang River, the KLE enters Kallang Park. An embankment with retaining wall will be used on the approach end of the Geylang River Bridge. After this, depressed stretch will follow 300m long. As this area is reclaimed land, settlement will occur if a new embankment is loaded. L-shaped retaining wall supported by piled foundation will be needed. A trough structure is recommended to cope with settlement for the depressed stretch. In the deeper depressed stretch, a semi-covered trough structure with cantilever slab at the ground level projected above the carriageway will serve an effective space for streets. Semi-covered trough is applicable for the depressed stretch 150m long extending to a tunnel entrance.

e. The stretch beginning from the middle of Kallang Park is made a tunnel 495m long until the south of the Nicoll Highway. As the cut and cover method can be used for construction of the tunnel, a rectangle cross section is the most effective and economic. Since the top slab of 35m span loaded by 2m thick soil covering and vehicle can not be made of reinforced concrete, the tunnel cross section with 6 lanes is separated by diaphragm wall into 2 cells. The cut and cover method will be used in principle.

f. The KLE stretch after going out of tunnel is planned as the depressed trough structure from the south of the Nicoll Highway, passing under the Mountbatten Road, Geylang Road to the Sims Avenue. It also passes under the MRT viaduct in the depressed trough and goes up to the ground level at the flat grass area to the east of Boon Keng Primary School. During the underground work below the crossing road under operation, a detour shall be provided. Temporary decks would be used to provide traffic service only if there were no available land in the vicinity. A detour route can be secured for all areas alongside except for Geylang Road.

A depressed trough with cantilever slab on top will be used for the stretch of about 800m from Nicoll Highway to Sims Avenue in order to provide effective space at the ground level. An overbridge will be used for crossing over the KLE trough to join this cantilever slabs.

At the crossing under MRT viaduct, there is no space to build a trough wall for depressed stretch due to the column of the MRT viaduct closer to the KLE carriageway. Recommendable method is to combine the wall to the column by supporting the wall with pile foundation as shown in Appendix 9.10.

g. An embankment retaining wall is planned for the stretch 95m long from the east of Boon Keng Primary School traveling northward to connect to the viaduct at the gradient of 3%. As the ground around the site is rather soft, the height of the retaining wall is designed to be lower than 2m.

h. The stretch at the north end of the KLE takes winding course over the PIE in the radius of 400m by viaduct to connect the PYE. Where it crosses over the PIE and over the Pelton Canal by bridge, the ramps for access to the PIE is also located here, although the elevated structure of viaduct appears complicated. The following structural problems need solutions;

- Location of the pier.
- Multi-layer structure of the pier.
- Simplification of the structure of the pier.

A standard viaduct type by crane erection will be used for the viaduct stretch in the straight alignment on both main route and ramp. A standard viaduct type is also applicable for the main route even on a curving stretch. As it is impossible to occupy a space for crane at night on the PIE, the launching method by erection girder will be used for spans to exceed 40m over the PIE and next span over Pelton Canal. The adjacent span which is included in the PYE will be constructed simultaneously.

As the KLE main route is crossed by rampway viaduct, a two column pier type which enables easy adjustment to the arrangement of the columns will be recommendable. PC continuous box girder by erection method will be used. In order to simplify the up-jumbling elevated structures and make them look neat, the piers for the main route viaduct and ramp viaduct should as far as possible be combined so as to reduce the number of columns required. The same consideration should be made for the span planning. Columns for piers should be positioned in a row to make the appearance look neat.

**2) Route-II (Viaduct Scheme as seen in Fig. 9.14 and 9.15)**

a. The difference of the Route-II from the Route-I is that it does not go underground after crossing over the Geylang River. It runs instead in grade separation by viaduct for more than 2km until the Pelton Canal. Except for the long span crossing, a standard viaduct type with span length of 30m is applicable. As there are expected undulations on the bearing strata and to minimize the noise at the location near town, cast in situ concrete piling is recommended. A two column type with a simple appearance will be used.(refer to Fig 9.16). Comparison of the pier type is shown in Appendix 9.11.

b. The erection work can be carried out by stopping traffic service for the night work at crossings where there are very little traffic at night. A detour route at night will be ensured in the case of the Nicoll Highway. As the span length is longer than that of standard viaduct, girder length can be adjusted by widening the width of the cross head pier.

c. At the crossing over the Mountbatten Road, standard viaduct type is not applicable because the span over this crossing requires 50m long. A three span continuous PC box beam with side span length of 35m will be used. Erection work will be completed by cantilever method where traffic at the crossing would not be affected.

d. The crossing over the MRT viaduct requires a careful erection work. An incremental launching method will be recommended. Protection covering over the MRT shall be furnished during erection work.

**3) Planning for bridge construction of the Geylang River Bridge**

**(1) Appreciation of bridge site**

According to the 1985 Master Plan, both banks of Geylang River will be used as industrial estates. However, the stretch from Geylang River to Marina Bay is a favorite location for water sports by young people. Besides, Kallang Park where state activities are frequently held, is about 250m north of bridge. The interchange with the ECP is about 300m south.

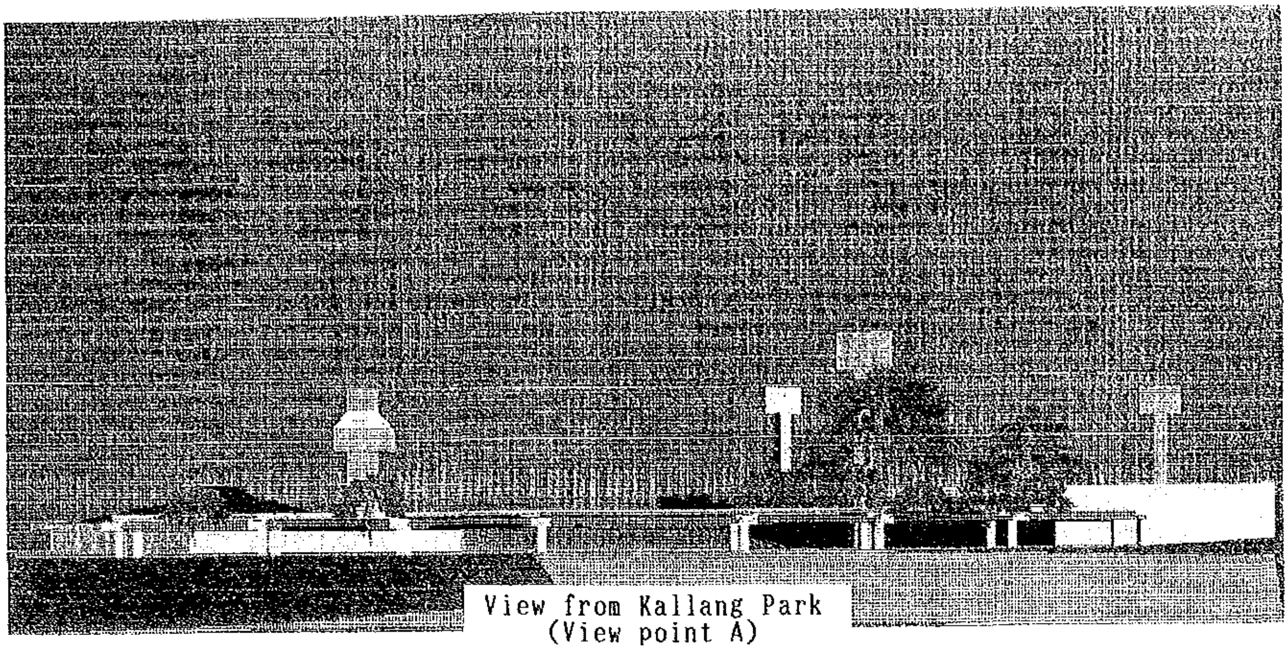
The bridge will be built near the mouth of Geylang River. Although the width of Geylang River is not constant, it is about 105m. As it is near the sea, the depth is affected by tides and the deepest record is 3m. The flow is very slow.

**(2) Basic conditions**

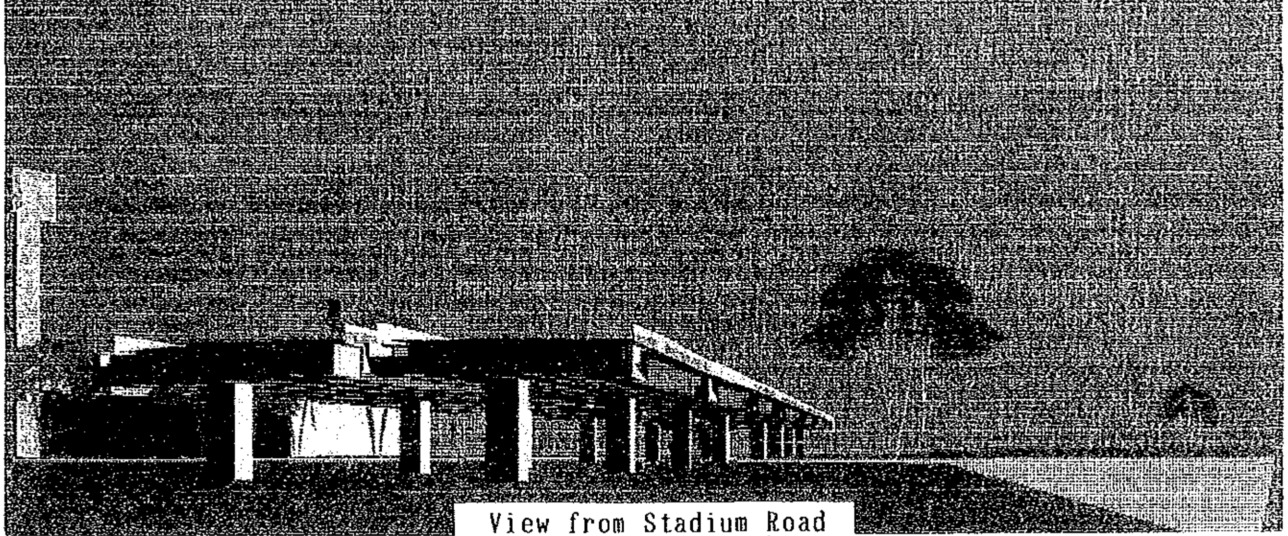
(a) Structural type

Concrete as main material shall be used for the superstructure. A concrete structure is definitely more economical than a steel structure. Besides, as the bridge site is near the sea, paint work on a steel bridge would be deteriorated due to sea breeze and it would be difficult to maintain. Concrete structure is used.

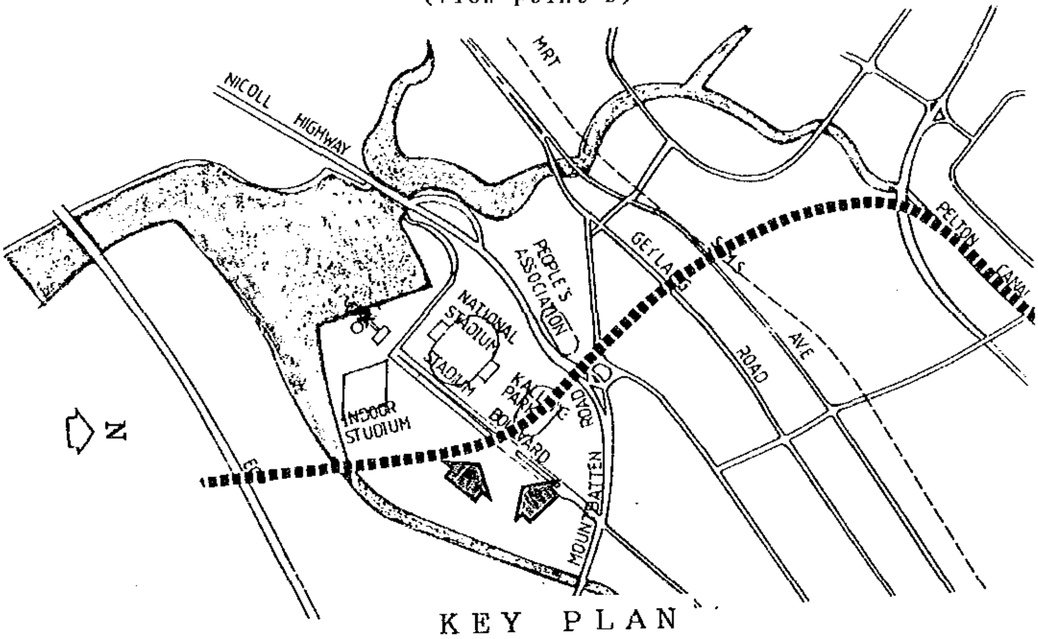
Aesthetically, the bridge could be designed as a land mark creating an impressive scenery though it is not advisable to construct something tall such as a wire stayed bridge since there are no tall structure



View from Kallang Park
(View point A)



View from Stadium Road
(View point B)




KEY PLAN

Fig. 9.16 Rendering view of Kallang Park Viaduct

nearby.

The following 3 proposals were conceived for studying the bridge.

- A 2 span continuous PC box girder; This will cross Geylang River in 2 spans
- A 3 span continuous PC box girder; This will cross Geylang River in 3 spans
- A simple PC Composite girder; This will cross Geylang River by 30m spans.

When a PC box girder is used for the superstructure, a wall type pier shall be constructed in the direction of the river flow, whilst a 2 column round piers shall be used when the superstructure is a PC Composite girder.

b) Alignment

The alignment of ECP interchange affected the bridge alignment and some widening for ramp was added to expressway. The vertical gradient of Route I (tunnel scheme) was 3% and that of Route II(viaduct scheme) was 0.3%, both down toward Kallang Park. Geylang River is skewed at an angle of 50 degrees. The effect of alignment on landscape will be that the widening for ramp would affect the whole width of the bridge and that the space below would be very small and dark when the gradient was very steep as in the case of Route I.

c) Economic analysis

The construction costs for 3 proposals were as follows:

- Two span continuous PC box girder; S$ 8,415,000(S$56,100/m) 1.06
- Three span continuous PC box girder; S$10,065,000(S$67,100/m) 1.27
- Simple PC Composite girder; S$ 7,920,000(S$52,800/m) 1.00

**(3) Landscape plan**

Plans for the landscape of the whole structure was carried out with the following consideration:

a) Harmony in the surrounding environment.

Taking into consideration that Geylang River is a suitable spot for water sports and at nearby Kallang Park, it was recommended to create a scenic impression to harmonize the surrounding environment.

b) Bridge span planning

Balance will be achieved by adjusting the ratio of the central span to side span.

c) Continuity

- Continuity of beam height, and continuity with the standard viaduct are to be ensured.
- Continuity of the girder cross section ; Difference between the cross section of the box girder and I beam, or a difference in

the cantilever length of the slab would destroy the beauty of the bridge.
- Project a sense of rhythm
- A smooth face girder for side view is beautiful.

d) Slender appearance

- The shape of the girder cross section; Using a reverse trapezoid shape for the box girder and lengthening the cantilever of the slab will give an emphasized slender appearance.
- Relationship between the span length (L) and the height of superstructure (h); A high (h/L) value will give an impression that the structure is heavy and thick and small value for a slenderness. A slender shape is desirable in this case.
- Relationship between the span (L) and the height below the bridge (H); A suitable (H/L) value should be ensured.
- Relationship between the height below the beam (H) and the thickness of the superstructure (h); Any sense of oppression will be removed keeping the (h/H) value low.

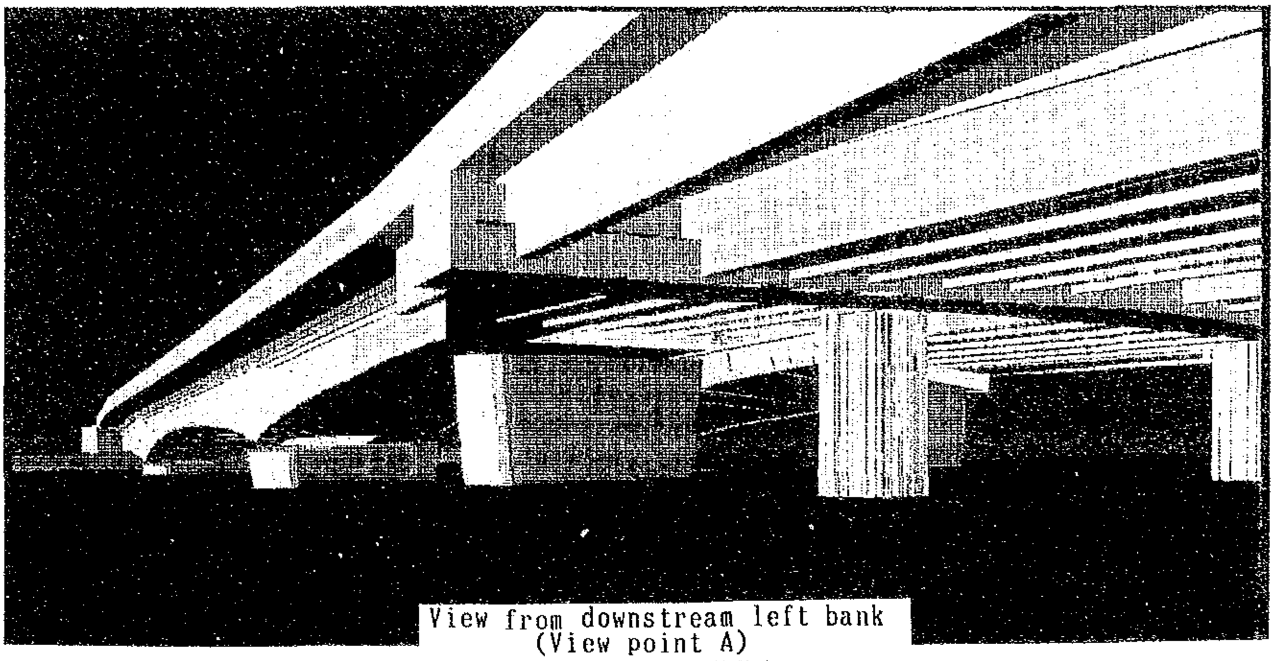
**(4) Conclusion**

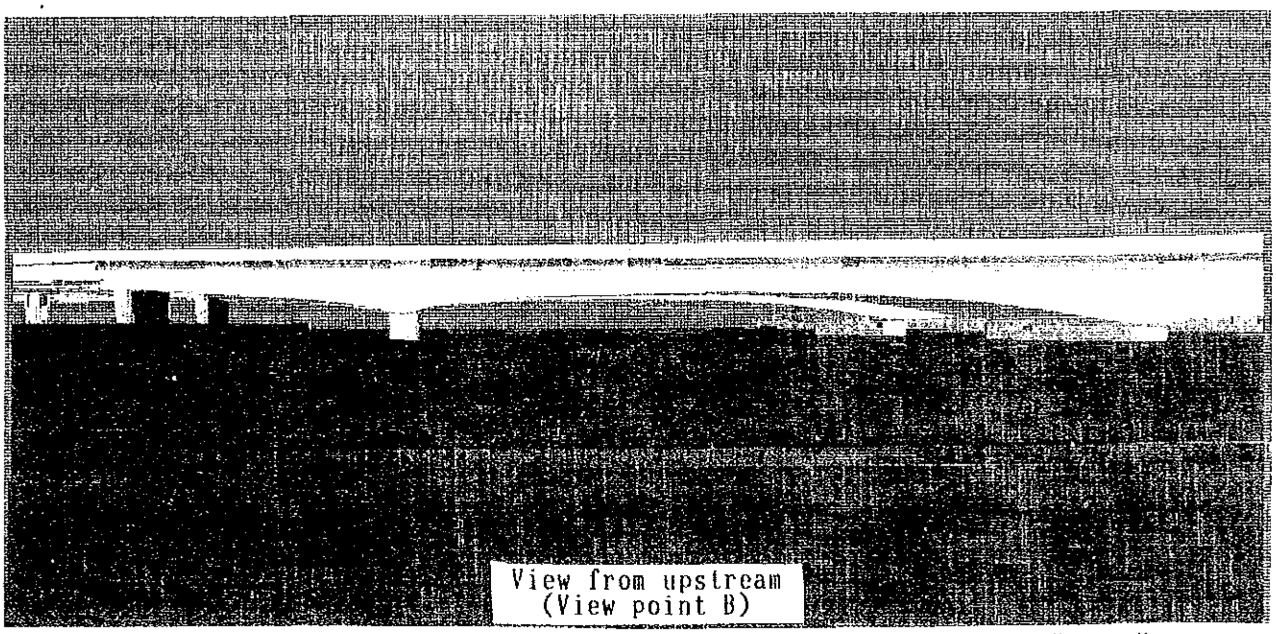
Based on the evaluation result included in Appendix 9.9, a three span continuous girder is the best out of the 3 proposals. This is shown in Table 9.19 and Fig. 9.17.

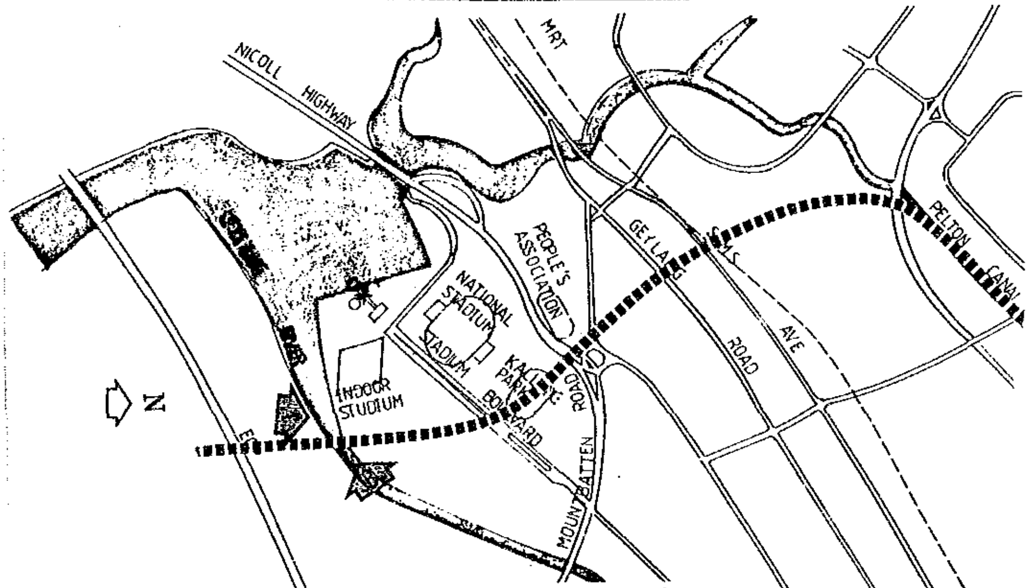
**Table 9.19 Landscape elevation for the Geylang River Bridge**

| Evaluation Items | Two span continuous box girder | Three span continuous box girder | Simple PC Composite girder |
|---|---|---|---|
| Harmony in environ<br>1.Harmony & creation of scenery | △ | ◎ | △ |
| Span Planning<br>1.Ratio of Central/Side span | ○ | ◎ | ○ |
| Continuity<br>1.girders height & adjacent | △ | ○ | ◎ |
| 2.Continuity in Structure | △ | △ | ◎ |
| 3.Rythmicallness | ○ | ◎ | △ |
| 4.Side face of girder | ◎ | ◎ | △ |
| Slenderness<br>1.Shape of girder | ○ | ○ | △ |
| 2.Thickness of girder & span | △ | ◎ | ○ |
| 3.Bridge height and span | △ | ○ | ◎ |
| 4.Superstructure thickness | △ | ○ | ◎ |

Note; ◎ :Favorable ○ :Acceptable △ :Problematic


View from downstream left bank
(View point A)


View from upstream
(View point B)




KEY PLAN

Fig. 9.17 Rendering view of Geylang River Bridge

### 9.6.4 Structure Planning for the PYE

**1) Route-I (Air Base Scheme as seen in Fig.9.18 )**

**a.** After crossing over the PIE by viaduct, the PYE goes along the Pelton Canal and intersects with Paya Lebar road by flyover. As there is no limitation on the span division for the flyover that passes along Pelton Canal, a standard viaduct type will be used. Girders can be erected by crane. A three column pier type will be used to minimize obstruction to the waterway (refer to Fig.9.19 and Appendix 9.12). As the marine clay covers this area, a deep foundation will be required. Cast in situ concrete pile will be necessary.

The span that passes over Aljunied Road and Paya Lebar Road is required to be 40m long. This span can be achieved by using a precast beam with the widened cross head.

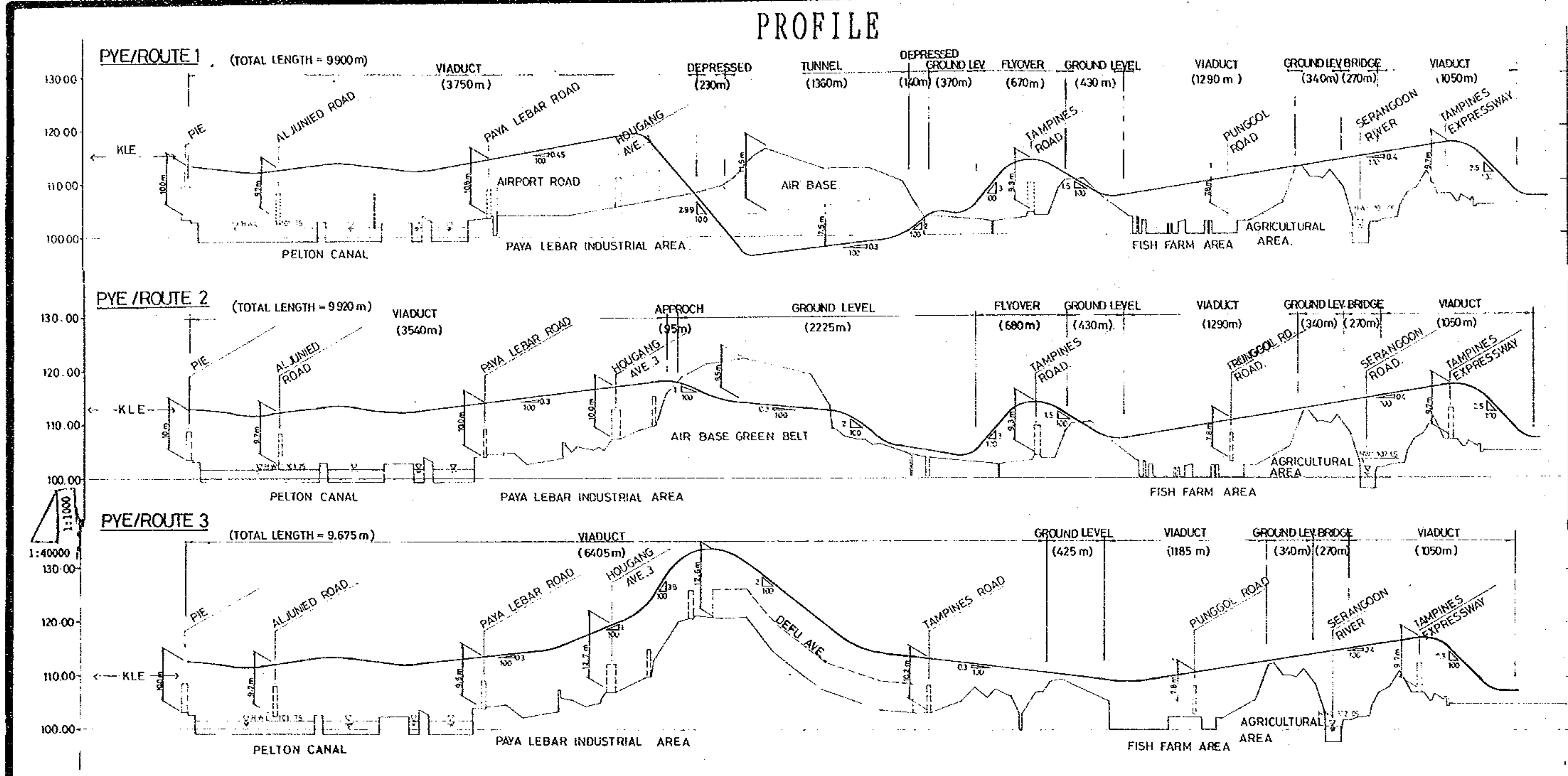
**b.** After crossing over Paya Lebar Road, the PYE enters Airport Road on a viaduct and passes through the Hougang Avenue 3 gradually to descends. Standard viaduct type can be used for the stretch that passes along Airport Road. As the piers can be positioned on the median, a Y shape pier type is suitable. As the ground in this region is around the boundary of the Kallang Formation and the Old Alluvium, it is better to recommend piled foundation.

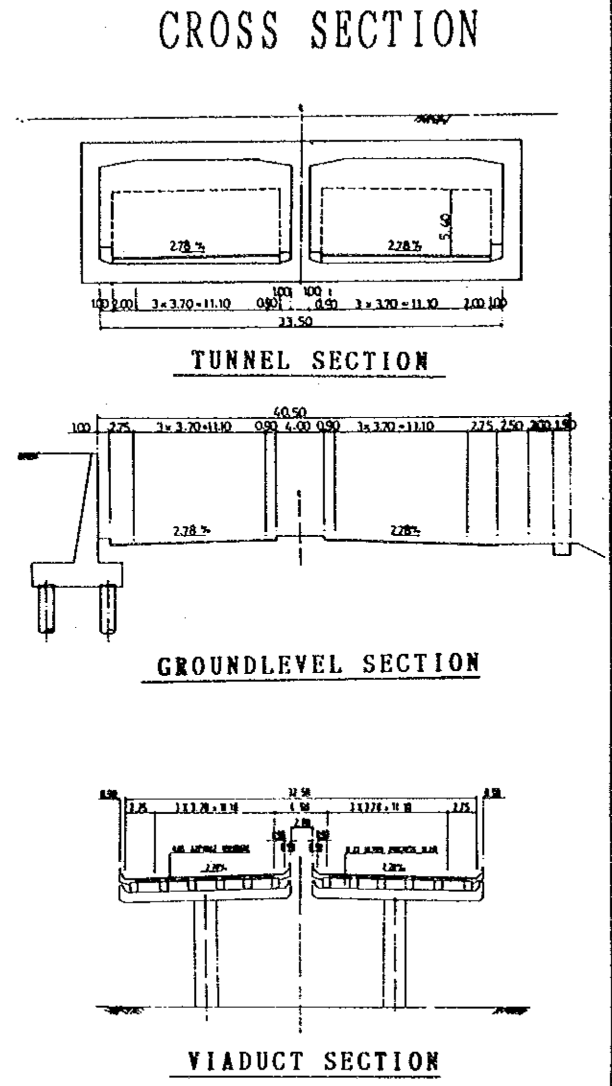
**c.** After passing over Hougang Avenue 3, the PYE slopes down gradually as it enters the tunnel under the Air Base. The entrance to this tunnel is located at in the middle of Airport Road, it will be necessary to shift the lanes of Airport Road to outside. The ramp connected to the Airport Road branches out from the center lane and divert outward before the abutment of the viaduct. The semi-covered trough paralleled with the tunnels of this ramp and the main route at this location. (refer to Appendix 9.13) In order to prevent the differential displacement, piled foundation will be needed.

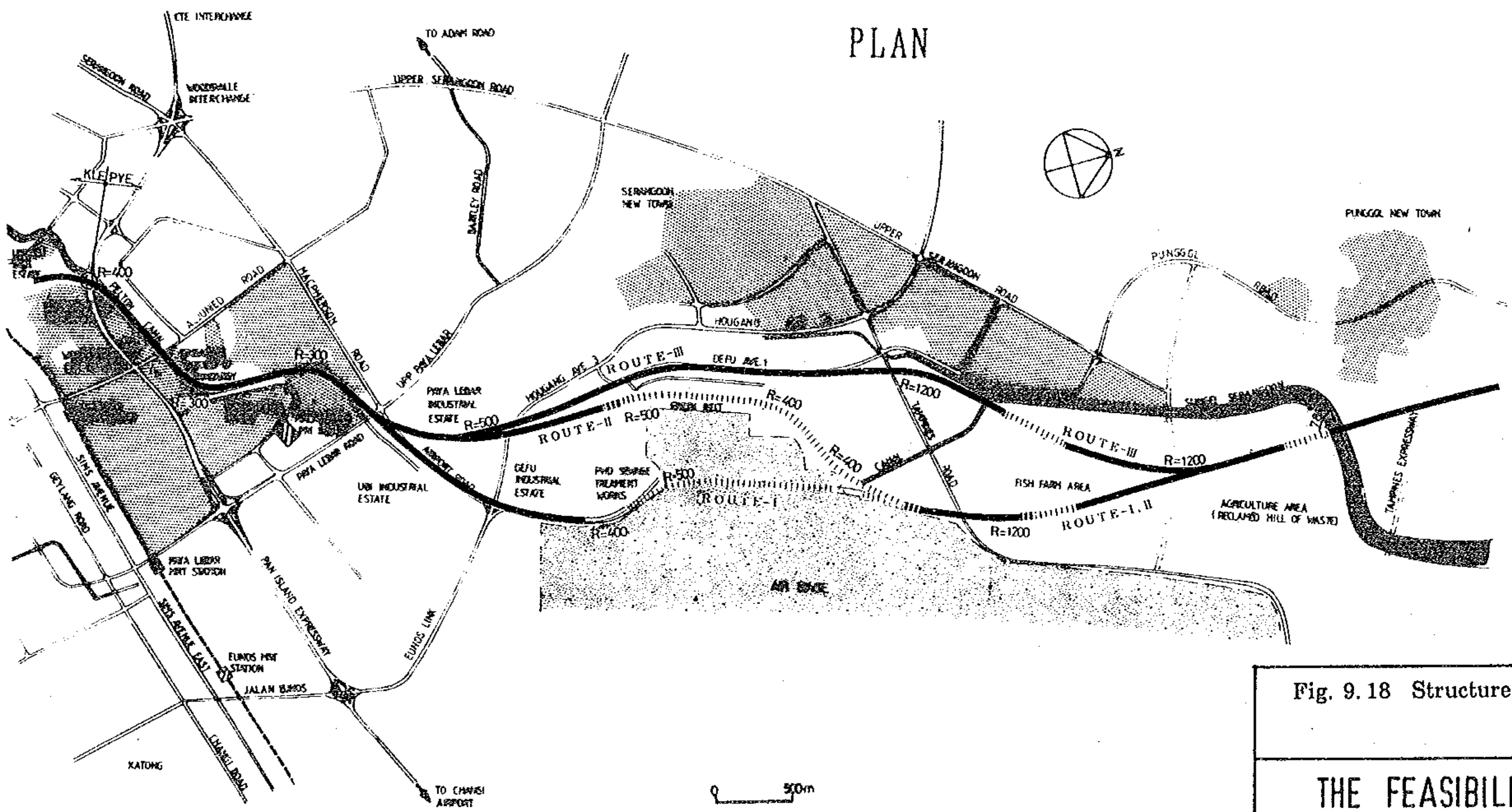
**d.** The PYE passes through under the Air Base via tunnel together with ramps at Airport Road. The extension of the tunnel will be 1.35km. Vertical clearance of the tunnel is to be provided an additional 1.8m above the vehicle clearance of 5.4m in order to enable the placing of traffic signs at the ceiling of the tunnel. Including the pavement thickness of 42cm and the 20cm for pavement overlay in future, the total height inside tunnel requires 8m. Ventilation fans will be placed in the space allowed for traffic signs. In order to up grade the tunnel safety, emergency exits are desirable to be positioned in the middle of the tunnel. The exits will link with the pavement of the Airport Road. As ventilation system is of longitudinal flow, the diaphragm wall in the middle cannot be replaced by columns.

**e.** After crossing under the Air Base through the tunnel, the PYE joins the industrial estate in the north via 150m depressed trough. After cutting across the industrial estate via ground level expressway 400m long, the PYE rises at the gradient of 3% and enters the flyover above Tampines Road after climbing the approach about 100m.

**f.** Standard viaduct type is applicable to the approach of the flyover over Tampines Road. A three span continuous PC box girder bridge will be used for the flyover. A diamond type interchange proposed for the Tampines Road IC, necessitates a good visibility in order to overlap



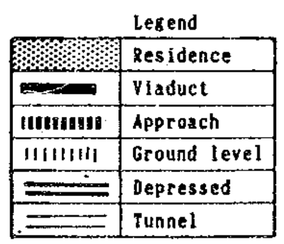




Fig. 9.18 Structure planning for PYE

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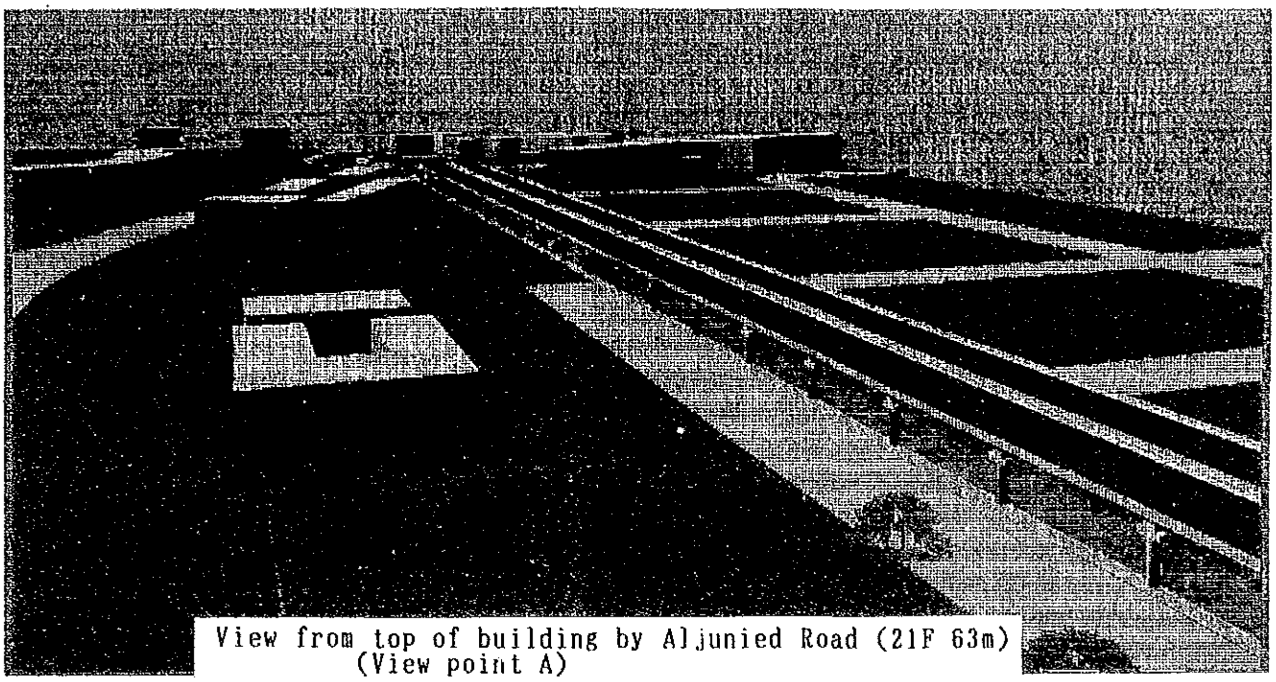
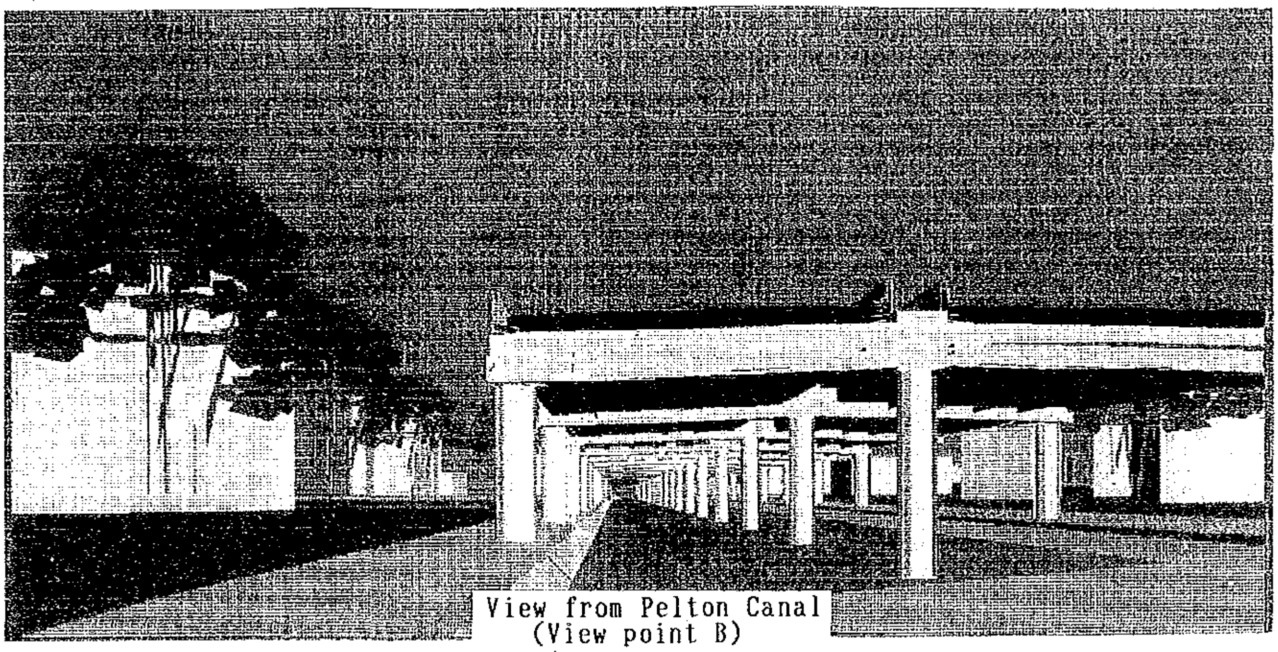
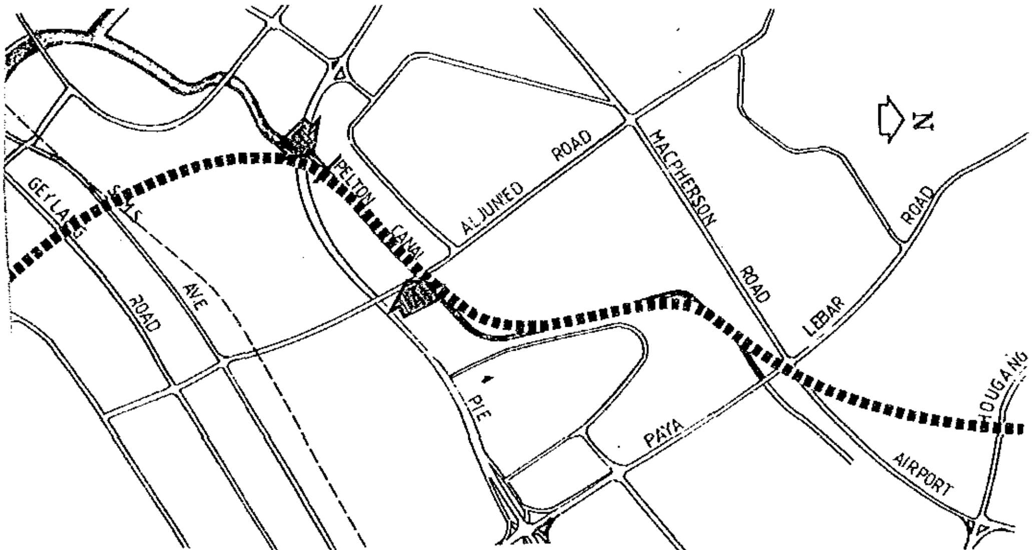


View from top of building by Aljunied Road (21F 63m)
(View point A)



View from Pelton Canal
(View point B)




KEY PLAN

Fig. 9.19 Rendering view of Pelton Canal Viaduct

traffic at the intersection below the flyover by signal. The main span requires about 70m long to avoid placing the pier on the median or verge services on the roadside. The length of the flyover is about 160m. As the soil condition is expected a firm Old Alluvium, piles of about 10m will be used. There is no need to diverge the Tampines Road traffic during construction.

g. After Tampines Road, the stretch from the fishing farm area to the area just before the approach to Serangoon River crossing will be of viaduct stretch. There is a low ground stretching about 1.1km from the fishing farm area. The swamp at the old waterway of Serangoon River is still remained. The right bank of the crossing point of Serangoon River was reclaimed using waste and elevated at the height of 110m.

h. The reclaimed terrace on the right bank of the Serangoon River slants towards the waterway. The height decreases by about 8m at horizontal distance 70m away. The width of the Serangoon River is 120m and waterway width is 110m. A three span continuous PC box girder supported by 2 piers placed in the waterway will be recommendable based on the following three reasons, especially emphasizing the esthetic view of the bridge across the serangoon River.

- Two span girder bridge is difficult to ensure the waterway during the rainy season while pier work is being carried out in the middle of the water flow.
- A standard viaduct type with 4 piers within the waterway will obstruct seriously the waterway.
- A three span continuous girder bridge will enable the construction of two piers in the alternate manner as to ensure the required waterway.

As the terrain stretching to both banks forms a trough shape with the river at its bottom, it will be necessary to proportion the bridge to a mounting elevation. The bridge must span about 100m long. The caisson foundation is recommended for the Serangoon River Bridge. For the approach, standard viaduct type is applicable.

i. After crossing the Serangoon River, the 500m stretch until the Tampines Expressway will be of grade separation due to connecting to the Tampines IC with elevated ramps. Standard viaduct type will be applicable. The pile foundation will be desirable as the ground is not firm.

**2) Route-II (By the Air Base Scheme)**

a. After crossing the PIE and passing through Pelton Canal via viaduct, the PYE will take the same course and structure as Route-II until crossing to Paya Lebar Road.

b. The PYE on viaduct crosses over Paya Lebar Road at the south of the intersection to Airport Road and cuts diagonally across Airport Road. It travels northward in grade separation for about 800m and travels diagonally across Hougang Avenue 3. After this crossing, the PYE takes route along the eastern side of Hougang Avenue 3 and parallel to it for about 400m and hits the western side of the SBS bus depot to enter the green belt beside the Air Base.

c. At the location to the west of the SBS bus depot, the abutment of viaduct will be positioned. An embankment retaining wall will be used for the stretch of about 100m running north from the back of this abutment. As the ground from this region ahead to the north is favorably firm with diluvial strata at shallow depth, an inverted T shaped retaining wall will be suitable. As it enters the bus depot, the proposed profile decreases at the gradient of 1%. On the terrace terrain of the bus depot and the industrial estate to the north of the Air Base, a depressed stretch by earth work will be used. The elevation of PYE is designed to be the same as that of the Air Base. As for the stretch between the SBS bus depot and the industrial estate, a retaining wall at cut and embankment will be required.

The stretch of the PYE 900m in length curving in S shape in the green belt alongside the Air Base is planned at the ground level where the ground seems to meet the required CBR value of subgrade.

d. The Route-II Alternative of the PYE after passing alongside the Air Base, is connected to the flyover above the Tampines Road by taking the same course as the Route-I.

**3) Route-III (Defu Avenue Viaduct Scheme)**

a. The stretch that runs along Pelton Canal in grade separation until crossing Paya Lebar Road is the same as the Route-I and II. The Route-III deviates from the other route alternatives after crossing Airport Road. After hitting the north west corner of the SBS bus depot, it will enter the Hougang Avenue 3 and merge to the Defu Avenue 1 on viaduct.

b. The SBS bus depot will be flied over by viaduct to climb the slope of 3.8%, where the land acquisition will not be necessary. The elevation of the viaduct will be designed at 12m to 15m height. A single column Y shaped pier will be used. Standard viaduct type by crane erection method is suitable. As the subsoil condition is good with diluvial strata at the shallow depth, caisson foundation will be applicable.

c. After running for 500m on the terrace of 120m in height starting from the SBS bus depot, it will descend into the median of Defu Avenue 1 at the gradient of 2%. A two or three column pier will be used for the viaduct. The stretch parallel to Defu Avenue 1 extending 1.5km long, will use standard viaduct with span lengths of 30m, 35m and 40m. Since the subsoil condition is good, viaduct supported by shallow foundation will be used. Y shaped pier is recommended based on the study. (refer to Appendix 9.14)

d. The Route-III leaves Defu Avenue 1 just before the crossing to Tampines Road. It continues to run across Tampines Road by viaduct. After crossing Tampines Road, it runs along Serangoon River at the east side and enters the grass on the right bank of Serangoon River. The grass area extends along the right bank eastward along Serangoon River and continues to the river mouth. As this is likely to service as agricultural pilot farms, viaduct expressway is recommended.

e. The stretch to the north of Punggol Road interchange is the same course as the Route-I and II.

**4) Planning for the Serangoon River Bridge**

**(1) Appreciation of bridge site**

According to the 1985 Master Plan, both banks of Serangoon River will be used as agricultural areas. Besides, new towns to inhabit 500,000 residents are planned at four locations to the west of Serangoon River. The Serangoon River is 120m wide. Revetments on both banks are under repair work and completed nearby at the location of the bridge crossing. The ground level on the right bank has been raised to about 110m by reclaiming waste, while on the left bank is nearly 103m.

(2) Basic conditions

a) Structural type

Concrete as main material shall be used for the superstructure. A concrete structure is definitely more economical than a steel structure. Besides, as the bridge site is near the sea, the same situation as the Geylang River Bridge is pointed out in maintenance difficulty. Concrete structure is used.

Aesthetically, a simple structure is preferable in order to fit in with the surrounding environment.
The following 3 proposals were conceived for studying the bridge.

- A 2 span continuous PC box girder; This will cross Serangoon River in 2 spans
- A 3 span continuous PC box girder; This will cross Serangoon River in 3 spans
- A simple PC Composite girder; This will cross Serangoon River by 30m spans.

When a PC box girder is used for the superstructure, a wall type pier shall be constructed in the direction of the river flow, whilst a 2 column round piers shall be used when the superstructure is a PC composite girder.

b) Alignment

Although the horizontal alignment of the PYE main route is straight, the ramp connection of TPE IC affects the bridge to taper the width. Proposed profile climbs at the gradient of 0.5% towards the TPE IC. The difference of elevation between the bridge and the high water level is about 13m. The angle of intersection to the Serangoon River is 77 degrees.

c) Economic analysis

The construction costs for 3 proposals were as follows:

- Two span continuous PC box girder in total 180m long ;
  S$10,944,000 (S$60,800/m) 1.06

- Three span continuous PC box girder in total 140m ;
  S$ 9,371,000 (S$66,900/m) 1.29

- Simple PC Composite girder in total 140m ;
  S$ 7,749,000 (S$51,700/m) 1.00

**(3) Landscape plan**

Plans for the landscape of the whole structure was carried out with the same consideration as Geylang bridge. (refer to page 9-51)

**(4) Conclusion**

Based on the evaluation result included in Appendix 9.15, a three span continuous girder is the best out of the 3 proposals. This is shown in Table 9.20.

**Table 9.20 Landscape Elevation for the Serangoon River Bridge**

| Evaluation Items | Two span continuous box girder | Three span continuous box girder | Simple PC Composite girder |
|---|---|---|---|
| Harmony in environ<br>1.Harmony & creation of scenery | ○ | ◎ | △ |
| Span Planning<br>1.Ratio of Central/Side span | ○ | ◎ | ○ |
| Continuity<br>1.girders height & adjacent | △ | ○ | ◎ |
| 2.Continuity in Structure | △ | △ | ◎ |
| 3.Rythmicallness | ○ | ◎ | △ |
| 4.Side face of girder | ◎ | ◎ | △ |
| Slenderness<br>1.Shape of girder | ○ | ○ | △ |
| 2.Thickness of girder & span | ○ | ◎ | ○ |
| 3.Bridge height and span | △ | ○ | ◎ |
| 4.Superstructure thickness | △ | ○ | ◎ |

Note; ◎:Favorable ○:Acceptable △:Problematic

## 9.7 Planning of Pavement Structure

### 9.7.1 Selection of Pavement Type

The principal difference between asphalt concrete pavement and cement concrete pavement is originated from physical characteristics of their materials. Asphalt pavement is composed of viscous material to deform viscoelastic to the continuous and repetitive loading of vehicle. The pavement deformation is transmitted more elastically through the subbase to the subgrade at the lowest layer. The subgrade reacts the loading by consolidation set. The subbase and subgrade are rather viscostically deformed. During the time of sparse traffic, these layers are left to recover the original horizon. Asphaltic pavement is characterized in such behavior as recovering concurrently at whole layers.

Cement concrete pavement deforms elastically to the vehicle loading only by concrete slab while subbase and subgrade otherwise deforms. Discrepancy of deformation between concrete slab and other soil layers takes place with the result that the concrete slab would be suspended and solely exposed to the vehicle impact and fatigue.
According to the Nihon Doro Kodan (Japan Highway Public Corporation), the characteristics of both pavement type are summarized as in Appendix 9.16).

With reference to the characteristic of both pavements and consideration of Singapore practice, asphaltic pavement will be less defective because of the less heavy vehicle. Cement concrete pavement tends to shorten the durability because of harsh weather action. The asphaltic pavement is recommendable.

### 9.7.2 Design Concept

Design standard for pavement structure in Singapore is based on the BS and AASHTO provisions. However the fundamental concept is deemed based on the AASHO (previous one of AASHTO) which declared that the evaluated running performance had been reversely proportional to the accumulated vehicle loading.

PWD provides the specification of standard design for asphalt pavement which includes three types of pavement structure correspondent to highway grade. The standard design of pavement structure applied in the expressway is shown in Fig.9.20. Structure number is 33cm. Total thickness is 72cm. According to the design manual of Nihon Doro Kodan, the applied pavement is rated to carry the accumulated vehicle loading of 140 million turns under the axle weight of 22500pounds. On the condition that the traffic volume be 20000vehicle/day/lane and the heavy vehicle percentage be 1.5%, the life time of the Singapore given pavement is estimated at 14years. The standard type of pavement of PWD is deemed sufficient.

## 9.8 Construction Schedule

The stages of works were scheduled based on Preliminary design. It is important to plan in a most suitable construction schedule to be smoothly, safely and efficiently implemented.

The construction schedule will be affected greatly by the geographic condition and society environment condition. Also it will be affected by the country construction plan and expressway construction cost and government instruction.

Here it is a standard estimate of the required construction period. Implementation Schedule will be taken up in Chapter 13. The estimation condition is as follows:

- The standard work procedure in accordance with the capacity of ordinary construction machinery was determined.

- Some past similar construction projects were referred.

- The construction sections of each expressway were divided by the working contents, work scale, the developing situation on each roadside and construction plans in the Republic of Singapore. (refer to Appendix 9.17)

Each construction section was divided by maximum three years for one construction period of each expressway which were calculated on above terms. Depending on conditions each calculated expressway period of each sector is stated months as in Table 9.21.

**Table 9.21 Construction period**

Unit; month

| | PIE | KLE | | PYE | | |
|---|---|---|---|---|---|---|
| | | Route- I | Route- II | Route- I | Route- II | Route- III |
| 1st Section | 30 | 36 | 36 | 36 | 36 | 36 |
| 2nd Section | 24 | 36 | 24 | 30 | 30 | 30 |
| 3rd Section | 24 | 30 | 30 | 36 | 24 | 36 |
| 4th Section | - | - | - | 36 | 36 | 36 |

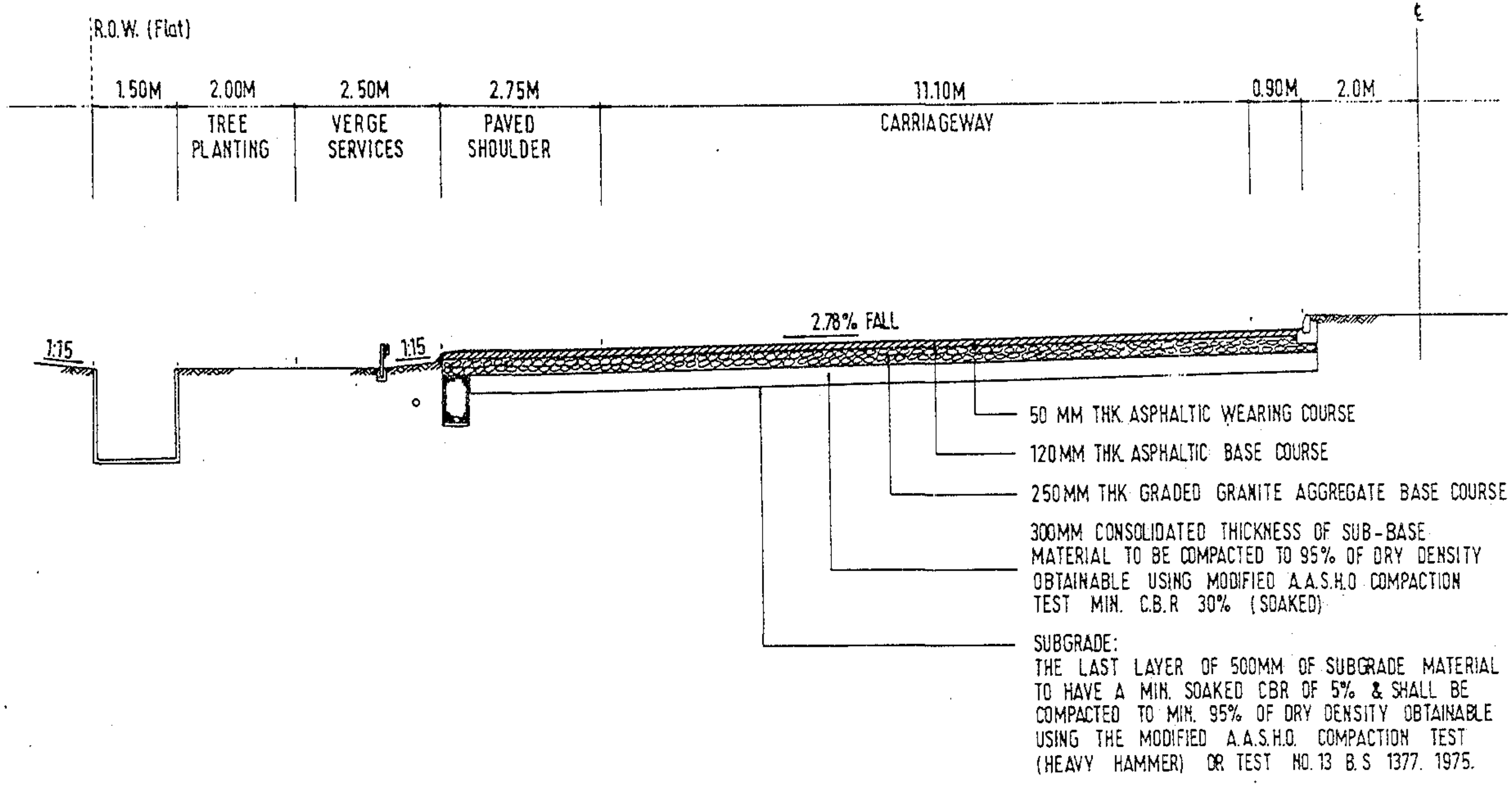



Fig. 9.20 Standard pavement cross section for Expressway

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

# CHAPTER 10

# COST ESTIMATES

# CHAPTER 10 COST ESTIMATES

## 10.1 Contents of Cost Estimation

Based on the preliminary design of various alternative, the quantities and the construction cost has been estimated. The land acquisition, and compensation is also roughly estimated. For comparison of the alternatives, maintenance cost which is used as an indicator for evaluation and decision obtained is estimated.

The estimate items are selected by the preliminary design precision and decided after discussions with the PWD. Unit price is based on the data supplied by the PWD with the consideration of similar construction in Singapore. The ratios of preliminary charge and mobilization, direct construction cost, land acquisition, compensation and contingency are given by the PWD. The area of land acquisition is estimated from a 1:2000 scale map by planimeter.

As to the maintenance cost, various alternatives after study are divided into above-ground and underground and the rest is estimated.

Details are described in the following paragraph.

## 10.2 Estimation of Quantity and Construction Cost

The construction items are shown in Table 10.2. The estimates conditions are as described below.

- Unit price was calculated in September, 1990 by the PWD.
- Construction cost is calculated in local currency.
- Contract Preliminary and Mobilization costs are made up of 10% of the total construction cost.
- Contingency allowance is made up of 10% of the total construction, land acquisition and compensation cost.
- The tunnel facility cost is estimated from the reference of a Japanese example. Exchange rate is ¥75 to S$1.00.

Estimated construction cost is shown in Table 10.1.

**Table 10.1 Construction cost**

Unit: million S$

| Items | PIE | KLE | | PYE | | |
|---|---|---|---|---|---|---|
| | | Route I | Route II | Route I | Route II | Route III |
| Direct Construction Cost | 76.7 | 251.3 | 220.3 | 508.4 | 325.5 | 370.7 |
| Contingency (10%) | 7.7 | 25.1 | 22.0 | 50.8 | 32.6 | 37.1 |
| Total | 84.4 | 276.4 | 242.3 | 559.2 | 358.1 | 407.8 |
| Total/Length Thou.S$/m | 10.2 | 80.5 | 71.3 | 56.5 | 36.1 | 42.1 |

Table 10.2 Items for cost estimation

| | Work Items | Unit | Unit price (s$) | Remarks |
|---|---|---|---|---|
| Direction Construction Cost | 1. Demolition of earthworks | | | |
| | Site clearance | $m^2$ | 0.5 | |
| | Breaking up of concrete | $m^3$ | 51 | |
| | 2. Roadworks | $m^2$ | 33 | subgrade, pave, etc. |
| | 3. Kerbs and Guardrail | m | 73 | |
| | 4. Drainage | m | 333 | |
| | 5. Pedestrain | $m^2$ | 20 | frontage road |
| | 6. Wall | m | 4,560 | RC 3m～6m |
| | 7. Bus shelters and Bay | No. | 22,500 | incl. bus bay |
| | 8. Trees and Turfs | $m^2$ | | |
| | Tree planting | m | 110 | |
| | Turf planting | | | |
| | 9. Traffic | | | |
| | Lane marking & traf. sigh | lane-m | 1,260 | |
| | Street lighting | m | 173 | |
| | 10. Flyover structure | lane-m | 4,220 | crossing condition |
| | 11. River bridge structure | lane-m | 5,130 | |
| | 12. Tunnel structure | lane-m | 17,200 | |
| | 13. Box culvert | lane-m | 17,200 | |
| | 14. Pedestrain overhead bridge | $m^2$ | 2,770 | |
| | Sub-total | | | ① |
| Preminaly Charge/Mobi. | Sub-total | | | ② = ①×10% |
| Land Acquisition and Compensation | | $m^2$ | | |
| | Sub-total | | | ③ |
| Contingency | Sub-total | | | ④=(①+②+③)×10% |
| Total | | | | ①+②+③+④ |

## 10.3 Land Acquisition and Compensation

Land for road construction is as the following category:

- Private land
- State land
- Lease land

For the survey of land category and area, reduced land use map of scales from 1:500 to 1:2000 were used. Land acquisition and compensation for road construction are shown in Table 10.3.

## 10.4 Maintenance Cost

Maintenance cost comprises costs for maintenance management, repair works, furnishing of service facilities, and disaster prevention or damage restoration after the completion of expressway construction. Maintenance works usually involves the managing authority so as to keep up the constant managing system. Therefore, the scale of the required maintenance works may arise as one of the evaluation items. Maintenance works are classified into the following three items,

Table 10.3 Land acquisition & compensation cost

| Items | | KLE | | | | PYE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Route I | | Route II | | Route I | | Route II | | Route III | |
| | | Area | No | Area | No | Area | No | Area | No | Area | No |
| Area & Number | Private | 21.7 | 42 | 15.4 | 43 | 12.9 | 5 | 12.4 | 3 | 12.2 | 2 |
| | Lease | 32.8 | 16 | 31.7 | 15 | 55.6 | 18 | 101.8 | 17 | 40.9 | 7 |
| | Total | 54.5 | 58 | 47.1 | 58 | 68.5 | 23 | 114.2 | 20 | 53.1 | 9 |
| Cost S$m | | 33.1 | | 28.8 | | 7.9 | | 17.2 | | 7.3 | |
| Cost/Length S$/m | | 9,650 | | 8,470 | | 800 | | 1,730 | | 750 | |

Note: Unit ; Area:thousand $m^2$, No:Number
The cost was not accounted for PIE

- **Routine works** to cover fuel, light, and water expenses for operation, cleaning, care for planting, is assigned to the expenditure code for maintenance and control.

- **Periodical works** to cover pavement repair and overlay, structural inspection and repair for accessories, replacing and mending of tunnel facilities, and installation of sound insulation barrier, is assigned to the expenditure code for repair.

- **Occasional works** to cover restoration for slope failure and crash accident, is assigned to the expenditure code for disaster prevention.

Maintenance and repair cost varies depending upon the type of road structure such 3 types as ground level roads including concrete bridge; steel bridge; and tunnel.

Maintenance cost for concrete bridge in general equals that of ground level roads. Maintenance cost for tunnel stretch requires about 8 times that of ground level roads. In Singapore the CTE is under construction for 2.4km long tunnel. Maintenance management of tunnel would be the first experience. There is no data on maintenance. Maintenance cost estimation in the Study has been done by referring to the cases in Japan.

According to their record, maintenance cost has reached to such proportions of the initial construction cost as 2% for ground level roads and concrete bridges and 3% for tunnels in terms of annual expenditure. Accumulated expenditure for 30 years is estimated to reach to the proportions of the initial construction cost such as 20% for ground level roads and concrete bridges and 34% for tunnels in terms of equivalent present worth sum considering of 10% discount ratio. Since the Japanese cases inherit damages due to eventfully climatic and terrain condition, maintenance cost in Singapore for ground level roads and concrete bridges will be less than that of Japan.

The PWD has introduced the record of maintenance expenditure of 1989/1990 as S$10200 per km per annum. Provided that the average construction cost of roads for these 10 years is assumed at S$1.87million per km in 2 lane dual carriageway quoted from the case of construction of Mandai Avenue from Sembawang RD to Mandai RD, maintenance cost ratio can be estimated at 0.5% to the initial construction cost. Proportions of maintenance cost and repair cost are determined from the experience. Table 10.4 shows the result so far estimated.

**Table 10.4 Annual maintenance cost ratios to construction cost**

| | Maintenance | Repair | Disaster | Total |
|---|---|---|---|---|
| Above ground | 0.3% | 0.2% | 0% | 0.5% |
| Under ground | 2.0% | 1.0% | 0% | 3.0% |

Maintenance and repair cost is evaluated by the term of annual average expenditure as summarized in Table 10.5.

**Table 10.5 Yearly meintenance cost**

| Route Name | PIE | KLE | | | | PYE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Route I | | Route II | | Route I | | Route II | | Route III | |
| | S$m | km | S$m | km | S$m | km | S$m | km | S$m | km | S$m |
| Above ground | 0.38 | 0.83 | 0.83 | 19.5 | 1.10 | 20.3 | 1.63 | 22.1 | 1.63 | 21.4 | 1.85 |
| Under ground | 0.0 | 2.53 | 2.53 | 0.0 | 0.0 | 2.1 | 5.46 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total | 0.38 | 3.38 | 3.38 | 19.5 | 1.10 | 22.4 | 7.09 | 22.1 | 1.63 | 21.4 | 1.85 |
| MC/CC % | 0.5 | | 1.3 | | 0.5 | | 1.4 | | 0.5 | | 0.5 |

Note: MC;Maintenance cost, CC:Construction cost
"km" indicates total length of roads including ramps

# CHAPTER 11

# ECONOMIC ANALYSIS

# CHAPTER 11 ECONOMIC ANALYSIS

## 11.1 Concept of Analysis

### 11.1.1 General

The main purpose of economic analysis was to evaluate the effects of the expressway projects on the usage of economic resources, and also to determine if the projects were feasible and viable.

The analysis was conducted by comparing the social benefits expected to be generated by the improvement of the road network with the additional investment costs which society would have to incur to implement and maintain the projects.

The project cost consists of land acquisition/compensation cost, construction cost and maintenance cost. The project cost is converted into the economic costs excluding transfer elements such as taxes and duties.

The economic benefits realized from the implementation of the projects were estimated as the savings in the traveling costs of vehicle users. The travel costs were quantified through improved traffic movement on the road network including proposed expressways. The travel costs were divided into Vehicle Operating Costs (VOC) and passenger's Value of Time (VOT) on the road traffic.

Other economic effects, such as reduction in traffic accidents, environment effects and development impacts usually were not subject of accurate economic measurement. Therefore, these would not be included in such quantified benefits.

Figure 11.1 shows the framework and procedure of the economic analysis.

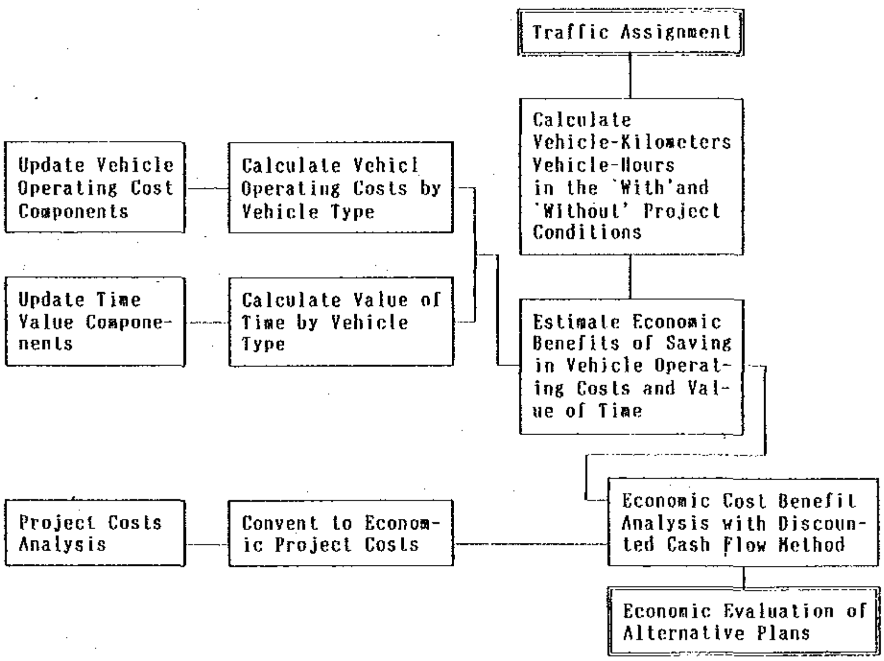



**Fig. 11.1 Framework of economic evaluation**

### 11.1.2 Alternatives

The alternative plans for economic analysis were composed of six(6) cases ranging from the improvement of the PIE in 1995 to the construction of the PYE in 2010.

For the PIE, there was no other than alternative plans as was an improvement project. The KLE project has the alternative of either tunnel or viaduct. The difference was only in the project costs for the economic analysis. The PYE had three alternative routes. These routes were evaluated by comparing their cost and benefit.

The comparative study of the alternatives was carried out between "with" and "without" project situations setting in Table 11.1.

**Table 11.1 Alternative plans for economic analysis**

| Expressway | Case No: | Base Year | Project Evaluated (With project) | Without Project situation |
|---|---|---|---|---|
| Pan Island Expressway(PIE) | 1 | 1995 | PIE(Widening) (Improvement) | Do Nothing (Present) |
| Kallang Expressway (KLE) | 2-1 | 1995 | KLE(Tunnel) | Completion of PIE |
| | 2-2 | 1995 | KLE(Viaduct) | Completion of PIE |
| Paya Lebar Expressway (PYE) | 3-1 | 2010 | PYE(Route I) | Completion of PIE and KLE |
| | 3-2 | 2010 | PYE(Route II) | Completion of PIE and KLE |
| | 3-3 | 2010 | PYE(Route III) | Completion of PIE and KLE |

### 11.1.3 Methodology of Evaluating Alternatives

The conventional method of economic evaluation was used in this report. The different alternatives were compared on the basis of the following three indicators of economic performance.

- Net Present Value (NPV)
- Economic Internal Rate of Return (EIRR)
- Cost Benefit Ratio (B/C or CBR)

The NPV and CBR were estimated assuming an annual discount rate of 4%, 8% and 12%.

## 11.2 Project Costs

### 11.2.1 Investment Cost

The category of initial investment costs for the implementation of expressway projects consisted of the land acquisition/compensation costs and construction costs. The design and investigation costs and the other administrative costs were not included in the investment cost. As major engineering and administrative works of road projects were directly conducted by PWD together with other projects, these costs were not clear at the moment.

The PIE project did not include the land acquisition/compensation costs because the land for this improved project would be available. It had been estimated that the land acquisition/compensation activities would be completed in the two years before the construction works starts.

For the purpose of economic analysis, all project costs were considered at 1990 constant prices and converted into economic costs excluding taxes and duties which were only transfer elements and not usage of economic resources.

According to the taxation system in Singapore, the direct taxes such as company tax, personal income tax, property tax and stamp duty were levied. However, there was no indirect tax such as capital gains tax, general sales tax, value added tax etc. Also there are import duties on a limited range of items in Singapore. However, most of the items have a rate of customs duties less than 5%. Only petroleum products and motor vehicles have a high percentage rate of duties.

Therefore, the taxes and duties were assumed as 5% of the financial investment costs in this report. There is no adjustment for the land acquisition/compensation costs.

Table 11.2 shows the economic and financial investment costs for each project case.

**Table 11.2 Economic and financial investment cost**

Unit:S$'000 at 1990 price

| Express-way | Project Case | | Land Acquis/ Compensation | Construction | Total |
|---|---|---|---|---|---|
| PIE | Case 1 (Widening) | Financial | 0 | 92,810 | 92,810 |
| | | Economic | 0 | 88,170 | 88,170 |
| KLE | Case2-1 (Tunnel) | Financial | 33,150 | 304,070 | 337,220 |
| | | Economic | 33,150 | 288,868 | 322,018 |
| | Case2-2 (Viaduct) | Financial | 28,796 | 266,560 | 295,356 |
| | | Economic | 28,796 | 253,232 | 282,028 |
| PYE | Case3-1 (Route-I) | Financial | 7,895 | 615,160 | 623,055 |
| | | Economic | 7,895 | 584,404 | 592,299 |
| | Case3-2 (Route-II) | Financial | 17,253 | 393,860 | 411,113 |
| | | Economic | 17,253 | 374,169 | 391,422 |
| | Case3-3 (Route-III) | Financial | 7,272 | 448,560 | 455,832 |
| | | Economic | 7,272 | 426,134 | 433,406 |

1) No land acquisition/compensation cost is required

### 11.2.2 Maintenance Costs

Annual maintenance cost of the expressway projects had been estimated in Table 10.4. On this table the small improvement works were also assumed to be added from five years after completion of the construction. The costs excluding taxes and duties were also used in the economic analysis.

## 11.3 Vehicle Operating Costs

### 11.3.1 General

More were limited studies on Vehicle Operating Costs(VOC) conducted in Singapore. The recent study of VOC were developed in Land Transport Study (LTS) prepared by Wilber Smith and Associates in November 1986. The LTS developed original VOC values on the basis of the data supplied by the ROV, although the values were calculated on many rough estimates.

Since no other reliable data base was found in Singapore, the VOC values in this report were estimated based on the LTS study. Some of the basic data were updated as necessary.

For this reason, the results were not necessarily accurate on the VOC of individual vehicle type or classes. However, it should be noted that the economic evaluation for expressway projects did not require the absolute level of the VOC. The evaluation is concerned with aggregate savings of VOC, resulting from the projects.

The expressway projects would be completed at the year 1995 and 2010. By that time, the vehicle fleet and traffic policies in Singapore would have extensively changed as we would forecast into certainty on such policy directions. The estimates would be adequate for the economic analysis at this moment.

### 11.3.2 Annual Vehicle Operating Costs

Vehicle operating costs (VOC) of the representative vehicle types were estimated on 19 vehicle categories used in the statistics of vehicle registration by ROV. The unit prices and performance characteristics of representative vehicle types are shown in Appendix 11.1.

The summary of annual economic VOC excluding taxes and duties were shown in Table 11.3. They were obtained by applying these unit prices to the depreciation and interest rates, life of vehicle, fuel consumption rates and annual kilometers. The maintenance and annual costs were estimated based on the LTS data. All prices were shown in economic prices excluding taxes and duties.

There were some changes in prices of VOC components since November 1986 because fuel prices and wage of crews had been increased.

### 11.3.3 Vehicle Operating Cost by Traffic Classes

The 19 vehicle categories were amalgamated into the six traffic classes.

Table 11.3 Annual vehicle operating cost unit : S$

| CATEGORY | ANNUAL CAPITAL COST | FUEL COSTS | MAINTE-NANCE | INSUR-ANCE | CREW | TOTAL | WEIGH-TING |
|---|---|---|---|---|---|---|---|
| CARS: | | | | | | | |
| 0-1000CC | 1751 | 764 | 1955 | 403 | 0 | 4873 | 41.6 |
| 1001-1600CC | 2514 | 1018 | 2395 | 578 | 0 | 6505 | 179.2 |
| 1601-2000CC | 3577 | 1222 | 3163 | 617 | 0 | 8579 | 39.3 |
| 2001-3000CC | 10247 | 1629 | 3833 | 1767 | 0 | 17476 | 10.2 |
| 3000CC- | 19653 | 1746 | 4600 | 3388 | 0 | 29387 | 1.3 |
| ALL CARS | 2923 | 1035 | 2503 | 613 | 0 | 7077 | 271.6 |
| MOTOCYCLES: | 462 | 249 | 496 | 109 | 0 | 1315 | - |
| TAXIS | 4218 | 5866 | 6253 | 780 | 23520 | 40637 | - |
| LIGHT GV'S | 1694 | 1266 | 1725 | 508 | 5824 | 11017 | - |
| MEDIUM/HEAVY GV'S: | | | | | | | |
| 3-5TONS | 1752 | 1662 | 2875 | 600 | 11648 | 18537 | 17.6 |
| 5-10TONS | 2103 | 2462 | 3220 | 720 | 14560 | 23065 | 13.7 |
| 10-15TONS | 4673 | 3693 | 3680 | 1200 | 17472 | 30719 | 2.5 |
| 15-20TONS | 5841 | 4924 | 4025 | 1250 | 20384 | 36425 | 2.7 |
| 20-30TONS | 7010 | 6331 | 4370 | 1500 | 23296 | 42507 | 3.8 |
| 30TONS- | 7010 | 7387 | 4025 | 1500 | 26208 | 46129 | 2.5 |
| ALL M/H GV'S | 3067 | 2992 | 3305 | 847 | 15356 | 25566 | 42.8 |
| BUSES: | | | | | | | |
| SCHOOOL | 4858 | 4749 | 4025 | 1720 | 26208 | 41560 | 1.4 |
| PRIVATE | 5317 | 1801 | 4600 | 970 | 11648 | 24336 | 1.0 |
| HIRE | 4858 | 2078 | 4600 | 1720 | 14560 | 27816 | 0.8 |
| EXCURSION | 7033 | 11080 | 4600 | 4240 | 29120 | 56073 | 1.5 |
| OMNIBUS | 16056 | 11080 | 6000 | 484 | 18928 | 52548 | 4.6 |
| ALL BUSES | 10797 | 8355 | 5206 | 1434 | 20509 | 46301 | 9.3 |

Source: Estimates by Study Team

Cars, Goods Vehicles and Buses were weighted according to their populations and annual kilometers. For example, heavy weighting was given to omnibuses because of their large annual kilometers.

The average annual costs per kilometer for the six traffic classes were shown in Table 11.4.

Table 11.4 Vehicle operating costs by class of traffic

| CLASS OF TRAFFIC | COST (S$/KM) | | | | | | ANNUAL KM(km) | AVERAGE SPEED (km/h) |
|---|---|---|---|---|---|---|---|---|
| | CAPITAL | FUEL | MAINT. | INSURANCE | CREW | TOTAL | | |
| CAR | 0.1462 | 0.0518 | 0.1252 | 0.0307 | N.A. | 0.3538 | 20,000 | 37 |
| M/CYCLE | 0.0385 | 0.0207 | 0.0413 | 0.0090 | N.A. | 0.1096 | 12,000 | 37 |
| TAXI | 0.0469 | 0.0652 | 0.0695 | 0.0087 | 0.2613 | 0.4515 | 90,000 | 40 |
| LIGHT GV | 0.0652 | 0.0487 | 0.0663 | 0.0195 | 0.2240 | 0.4237 | 26,000 | 35 |
| MED/HVY GV | 0.0854 | 0.0833 | 0.0921 | 0.0236 | 0.4277 | 0.7122 | 35,900 | 33 |
| BUS | 0.2121 | 0.1641 | 0.1023 | 0.0282 | 0.4029 | 0.9097 | 50,900 | 24 |

Source: Estimates by Study Team

### 11.3.4 Vehicle Operating Costs by Vehicle Speed

The VOC would vary by vehicle travel speed, especially at low speed. As no recent survey on this relationship had been done in Singapore, the estimates were based on the speed-cost relationship prepared by the LTS.

Table 11.5 shows the economic costs at different speeds for six traffic classes.

**Table 11.5 Vehicle operating cost(S$/km)**

| TRAVEL SPEED (KM/H) | CARS | M/CYCLE | TAXIS | LIGHT GV | MEDIUM/ HEAVY GV | BUSES |
|---|---|---|---|---|---|---|
| 5 | 1.2718 | 0.3224 | 2.3696 | 1.3308 | 2.2852 | 2.9045 |
| 10 | 0.7411 | 0.1994 | 1.2735 | 0.8016 | 1.3582 | 1.6446 |
| 15 | 0.5642 | 0.1584 | 0.9082 | 0.6253 | 1.0493 | 1.2247 |
| 20 | 0.4757 | 0.1379 | 0.7255 | 0.5371 | 0.8948 | 1.0147 |
| 25 | 0.4227 | 0.1256 | 0.6159 | 0.4842 | 0.8021 | 0.8887 |
| 30 | 0.3873 | 0.1174 | 0.5428 | 0.4489 | 0.7403 | 0.8047 |
| 35 | 0.3620 | 0.1115 | 0.4906 | 0.4237 | 0.6961 | 0.7447 |
| 40 | 0.3430 | 0.1071 | 0.4515 | 0.4048 | 0.6630 | 0.6997 |
| 45 | 0.3283 | 0.1037 | 0.4211 | 0.3901 | 0.6373 | 0.6647 |
| 50 | 0.3165 | 0.1010 | 0.3867 | 0.3783 | 0.6167 | 0.6367 |
| 55 | 0.3069 | 0.0987 | 0.3768 | 0.3687 | 0.5998 | 0.6138 |
| 60 | 0.2988 | 0.0969 | 0.3602 | 0.3607 | 0.5858 | 0.5947 |
| 65 | 0.2920 | 0.0953 | 0.3461 | 0.3539 | 0.5739 | N.A. |
| 70 | 0.2862 | 0.0939 | 0.3341 | 0.3481 | 0.5637 | N.A. |
| 75 | 0.2811 | 0.0928 | 0.3236 | 0.3431 | 0.5549 | N.A. |
| 80 | 0.2767 | 0.0917 | 0.3145 | 0.3387 | 0.5472 | N.A. |
| 85 | 0.2728 | 0.0918 | 0.3064 | 0.3348 | 0.5404 | N.A. |

Source: Estimates by Study Team

## 11.4 Value of Travel Time

### 11.4.1 General

Time spent for travelling was generally considered useless on the economic activities. If some of the travelling time could be saved, they would be used for more productive activities. The value of time savings was evaluated as the opportunity costs of using the time in such alternative activities.

The opportunity costs of travel time would be largely different between those in working time and non-working time. The savings of working time were usually valued at the average earning rate of travellers, while those of non-working time were valued much lower.

The value of travel time for vehicle passengers was estimated by using xthe data such as household income, workers in household, working hours and car ownership related with other economic indicators. The data were mainly obtained from the Household Expenditure Survey conducted in 1987/88. The time values for public transport does not include those of MRT. No influence of MRT was considered to the time value for public transport for the purpose of this study.

### 11.4.2 Value of Working Time

Table 11.6 shows data about the distribution of household income and car ownership in 1987.

**Table 11.6 Household income and car ownership (1987)**

| HOUSEHOLD INCOME($/mth) | % OF H/HOLDS | % OF CAR OWNING H/HOLD | AVERAGE H/HOLD SIZE | NO.OF WORKER IN H/HOLDS |
|---|---|---|---|---|
| - 499 | 3.8 | 2.3 | 3.00 | 1.34 |
| 500- 999 | 20.8 | 9.0 | 3.80 | 1.43 |
| 1000-1499 | 21.4 | 15.6 | 4.22 | 1.87 |
| 1500-1999 | 16.0 | 23.4 | 4.53 | 2.32 |
| 2000-2999 | 17.3 | 38.7 | 4.80 | 2.65 |
| 3000-3999 | 8.7 | 53.1 | 5.11 | 2.87 |
| 4000-4999 | 4.8 | 70.4 | 4.86 | 2.71 |
| 5000+ | 7.2 | 84.6 | 5.04 | 2.61 |
| TOTAL/AVG | 100.0 | 29.8 | 4.40 | 2.14 |

Source: REPORT ON THE HOUSEHOLD EXPENDITURE SURVEY 1987/88. DEPT. OF STATISTICS AUGUST 1990

From the above data, average monthly income of household and workers both for car-owning and non-car owning household were estimated as shown in Table 11.7.

**Table 11.7 Average Monthly Income of Car-Owning and Non-car Owning Household (1987)**

| ITEMS | CAR OWNING H/HOLD | NON-CAR OWN-H/HOLD | ALL H/HOLD |
|---|---|---|---|
| No. of H/holds (%) | 29.80 | 70.20 | 100.0 |
| Average size of H/holds | 4.74 | 4.26 | 4.40 |
| No.of workers in H/holds | 2.47 | 2.01 | 2.14 |
| Average H/hold income($/mth) | 3553 | 1644 | 2213 |
| Average Income per worker($/mth) | 1436 | 820 | 1034 |

Source: Estimates from Table 11.6

These estimates were updated to 1989/90 price level using the following indicators.

| Items | 1987 | 1989/90 | Changes(%) |
|---|---|---|---|
| Population(thousand) | 2,612.8 | 2,685.4 | 2.78 |
| No. of workers(thousand) | 1,192.9 | 1,277.3 | 7.08 |
| H/hold Size | 4.40 | 4.20 | -4.55 |
| No. of H/holds(thousand) | 593.8 | 639.4 | 7.68 |
| GDP(real terms) ($ million) | 43,387.4 | 52,678.7 | 21.41 |
| Per Capita GDP ($) | 16,606 | 19,617 | 18.13 |
| Consumer Price Index | 98.9 | 102.8 | 3.94 |
| Car Ownership (Car Population) | 223,456 | 258,537 | 15.70 |

The monthly income level at 1990 are then estimated as follows:

| | Monthly Income (S$) | | |
|---|---|---|---|
| Items | Car Owning Household | Non-car owning Household | All Household |
| Household Income | 4,029 | 1,708 | 2,509 |
| Income per worker | 1,709 | 890 | 1,228 |
| Hourly Income per worker | 10.30 | 5.36 | 7.40 |

The value of working time for car passengers should be determined by the average earnings of car-owners. However, all car-owners do not necessarily use their car in working time. The majority of car users in working time were probably those who engage in the professional and technical works or the administrative and managerial works. The average household income of these workers were $4,028 or 1.82 times amount of average household incomes in 1987. Therefore, a value of $19 per hour was adopted for car and taxi passengers in working time.

For public transport passengers in working time, a value equal to the average incomes of all workers (about $7 per hour in 1990) was adopted. The value projected to 1995 and 2010 with the annual growth rate of 5% are as follows:

| | $ per hour | | |
|---|---|---|---|
| | 1990 | 1995 | 2010 |
| Car/taxi passengers | 19 | 24 | 50 |
| Public transport passengers | 7 | 9 | 19 |

### 11.4.3 Value of Non-working Time

The value of non-working time was assumed at one-forth of the average hourly income level based on the review of related studies in the other countries, because there is no available data obtained in Singapore. This indicates a value of $1.85 per hour in 1990, $2.40 in 1995 and 4.90 in 2010 respectively for the purpose of the study.

### 11.4.4 Value of Time by Mode by Trip Purpose

The proportion of trip purpose in working time and non-working time by mode were assumed by the LTS based on the Household Interview Survey in 1981 as follows:

Proportion of Trip purpose

| Trip Purpose | By Car/Taxi Working Time | By Car/Taxi Non-working Time | By Public Transport Working Time | By Public Transport Non-working Time |
|---|---|---|---|---|
| Work Trips | 5.1% | 94.9% | 1.6% | 98.4% |
| School Trips | 0% | 100% | 0% | 100% |
| Other home-based trips | 0% | 100% | 0% | 100% |
| Non-home-based trips | 31.6% | 68.4% | 18.6% | 81.4% |

The value of time for each trip purpose was weighted according to the above percentage. The results were shown in Table 11.8. The same value of time was used for motorcycle users as for public transport.

**Table 11.8 Value of Time** (S$/hour)

| MODE | TRIP PURPOSE | YEAR 1990 | YEAR 1995 | YEAR 2010 |
|---|---|---|---|---|
| CAR/TAXI | WORK | 2.72 | 3.50 | 7.20 |
| | SCHOOL | 1.85 | 2.40 | 4.90 |
| | OHB (1) | 1.85 | 2.40 | 4.90 |
| | NHB (2) | 7.27 | 9.23 | 19.15 |
| | ALL | 3.65 | 4.67 | 9.63 |
| PUBLIC TPT or BYCICLE | WORK | 1.93 | 2.51 | 5.13 |
| | SCHOOL | 1.85 | 2.40 | 4.90 |
| | OHB | 1.85 | 2.40 | 4.90 |
| | NHB | 2.81 | 3.63 | 7.52 |
| | ALL | 1.94 | 2.52 | 5.16 |

Source: Estimate by Study Team

(1)OHB: Other Home-based
(2)NHB: Non-Home-based

## 11.5 Benefits

### 11.5.1 Quantified Benefits

The daily travel cost was estimated for all vehicle movement on the whole road network in the different project cases and do-nothing conditions in 1995 and 2010.

The total daily economic vehicle operating costs were calculated by taking the daily vehicle-kilometres computed in the simulation of the traffic assignment. The vehicle kilometers in different speeds multiplied by the respective vehicle operating costs by speed makes total daily costs.

A similar method was followed in estimating the economic time cost of vehicle users. The total vehicle-hours multiplied by the value of time were applied to the daily time costs.

After converting from total daily costs to yearly costs, the balance of the costs between "with" and "without" project condition were calculated as the saving in travel costs.

The savings were estimated for the years 1995 for PIE and KLE, 2010 for alternative PYE routes. The annual savings were assumed to be constant during the project life. The increase of the traffic would rise the savings, while the congestion would reduce the savings.

A problem had occurred after the calculation of the savings. A tremendous amount of the saving costs were generated in all cases of project as a result. After close examination, it was found that the average vehicle travel speed on the road network was extremely slow in every simulation of traffic assignment. The cause could be that too much traffic was forced to run on the unimproved ordinary road network.

At the low level of average vehicle speeds, even a little change in vehicle speeds produced a big amount of savings in VOC. Also low vehicle speeds increased the level of vehicle-hour on which the savings of time cost was estimated.

For the reasons mentioned above, 20% of saving costs was regarded as benefits of the projects.

### 11.5.2 Unquantified Benefits

It should be noted that there were many unquantified benefits resulting from the completion of the expressway projects. The main unquantified benefits were:

- -Reduction in traffic accidents;
- -Increased comfort and ease of travel;
- -Changes in environmental circumstances;
- -Discard pollution;(e.g.exhaust gas)
- -Changes in land uses and increase in land values and rents;
- -To make easier the provision of community services such as police and fire protection, ambulance, schooling etc.;
- -To add the opportunities for recreation and travel and
- -To assist in national defense.

Most of the benefits listed above were entirely unquantifiable because no reliable quantification method had been developed and no reliable data existed. However, some of them could be quantified if there was adequate data collected.

For example, the cost of the traffic accidents would be estimated by measuring the values of life and property damaged, medical expenses and judicial cost related with the accident rates or accident risk factor.

According to the traffic accident study in Japan, the frequency of accidents on the expressways were 10.3 per million vehicle-km while those on the ordinary road were 80 to 90 in 1980. Such figures could be reduced if the proportion of vehicle-km of the expressways was increased.

Taking the rough estimate for this project, the completion of KLE divert additional 39 million vehicle-km from ordinary roads to expressways. This figure indicated that about thirty (30) accidents would be decreased in a year if the same accident rate is adapted in Singapore. This would produce a benefit for the KLE project.

However, such benefits were not estimated in this study because there are some difficulties of using this kind of assumption.

## 11.6 Results of Analysis

### 11.6.1 Cost Benefit Analysis

The costs benefit analysis were conducted during the period between 1990 and the year twenty (20) after the completion of the project. The residual value was not included in the benefits.

The cost-benefit streams of the alternative projects were shown in Appendix 11.2.

### 11.6.2 Evaluation Results

Table 11.9 showed the results of the cost-benefit analysis.

The improvement project for PIE had a small amount of benefits. Its present value of benefits discounted at 8% which was equal to the market rate of interest did not match the investment cost during its project

**Table 11.9(1) Results of EIRR, NPV & CBR(B/C)**

| Express-way | Alternative Case | Discount Rate at 8% | | Economic Internal Rate of Return (EIRR) % |
|---|---|---|---|---|
| | | Net Present Value (NPV) S$ '000 | Cost Benefit Ratio (CBR,B/C) | |
| PIE | Final Alternative | -12,322 | 0.82 | 6.0 |
| KLE | Route-I(tunnel) | 2,160,490 | 11.31 | 60.0 |
| | Route-II(viaduct) | 2,198,943 | 13.86 | 69.3 |
| PYE | Route-I(Air Base) | 8,633,892 | 51.27 | 76.6 |
| | Route-II(Green) | 10,099,977 | 88.50 | 79.5 |
| | Route-III(Defu Av) | 10,091,366 | 82.34 | 83.7 |

**Table 11.9(2) Results of EIRR, NPV & CBR(B/C)**

| Express-way | Alternative Case | Discount Rate at 4% | | Discount Rate at 12% | |
|---|---|---|---|---|---|
| | | NPV S$ '000 | CBR (B/C) | NPV S$'000 | CBR (B/C) |
| PIE | Final | 18,024 | 1.22 | -25,342 | 0.58 |
| KLE | Route-I | 4,159,507 | 16.00 | 1,185,673 | 8.31 |
| | Route-II | 4,212,592 | 19.79 | 1,215,183 | 10.16 |
| PYE | Route-I | 25,587,210 | 76.08 | 3,146,306 | 35.72 |
| | Route-II | 29,862,419 | 138.80 | 3,691,487 | 58.96 |
| | Route-III | 29,842,891 | 127.33 | 3,687,701 | 55.66 |

life. Therefore, theoretically specking the PIE project was considered not feasible form the result of this analysis. However, a standard discount rate of 4% were usually used for the evaluation of the road construction projects in Singapore. Furthermore, it was noted that the project might have unquantified benefits such as reduction in traffic accident and improvement in accessibility to community facilities and services. Taken as a whole, the PIE project would be evaluated as feasible.

Comparing to the alternative project for KLE, the Route-II(viaduct scheme) had a higher EIRR of 69.3% than the Route-I (tunnel scheme) of 60.0%. Net present value (NPV) and cost benefit ratio (CBR) also indicated that Route-II was more favourable than Route-I. Therefore the viaduct scheme of Route-II was recommended for KLE.

As to the three alternatives for the PYE, an EIRR of 76.6% for Route-I, 79.5% for Route-II, 83.7% for Route III were estimated. Every alternative route has extremely big EIRR value. The reason was due to the low traveling speed obtained through traffic volume forecast. According to the result almost all the sections have the traveling speed less than 10km/h. These indicated that Route-III was most feasible. However, taking the net present value and cost benefit ratio into consideration, the Route-II was the most favorable on the economic terms. The difference of EIRR is mainly caused by land acquisition/ compensation cost in the first year of project.

# CHAPTER 12

# FINAL EVALUATION OF ALTERNATIVES

# CHAPTER 12 FINAL EVALUATION OF ALTERNATIVES

## 12.1 Approach

On a successful planning of expressway project it is essential to assure the feasibility of the project based on an elaborate research. A feasibility study shall warrant that the execution of the project meet the target level of developing effect and that any introduced influence will be within an allowable state. The effect and influence resulted from the execution of expressway project in Singapore are classified as follows;

**a. Influences expected from the execution of the project itself;**

Construction of expressways requires investment in due scale, land acquisition, and compensation. Whether the amount of investment would share a critical proportion to the highway developing budget is an important factor on the taking-off of the project. Land acquisition and persuading to relocation accompany such a difficulty because an agreement will be needed with many concerned people and entitle people. During the construction work, dangers and nuisance will trouble neighborhood and highway users. On the operation of expressways a maintenance system to inspect defects and provide traffic service should be retained.

**b. Economic effect introduced by the expressway construction;**

Realization of fast traveling by road would save time and money, accelerate economic activity, increase productivity and promote development of areas. Quantifiable economic effect should be converted into currency value as fully as possible and evaluated in terms of cost and benefit. Such a route alternative should be adopted as to generate more benefit than the total cost including initial investment and maintenance cost.

**c. Service effect and impact introduced by a toll-free expressway;**

The expressways in Singapore are presently a toll free system. They are used not only for economic activities but also for mass movement such as short trip commuting of people. Seeking for the service effect, interchanges have been contrived in connection with arterial roads and collectors. This effect is unquantifiable and contributory to the time save of city traffic. Since the distance between interchanges is short in Singapore, merging and diverging of traffic flow take place at a short interval resulting in deterioration of traffic safety. Insufficient length for traffic weaving increases the accident danger and decreases traveling speed and traffic capacity of highways.

**d. Local effect and impact of expressway on environs;**

Since the accessibility is emphasized in Singapore expressway network, the effect introduced by its construction would influence the environs where the expressway passed through. Interchanges in short distance would divert the traffic from local arterials and collector roads to expressways. When an expressway is raised on viaduct or lowered into tunnel, then the space left could be utilized and become another local effect. On the contrary, a new expressway often creates such negative effect as noise, vibration, gas exhaustion, and intrusion of privacy. Negative impact on environment is sometimes strong enough to stop expressway project. Fast traffic function requires smooth alignment by means of viaduct, depressed, and tunnel on a long way. Unpleasant structures, however are not admitted as a city asset.

Through the analysis of effect and impact resulted from construction expressways, the most feasible route for each expressway has been recommended in this chapter. View points which are evaluated have been summarized as follows;

(1) Construction and maintenance of the expressways.
(2) Economic effect introduced by expressways.
(3) Service effect and impact by toll-free expressways.
(4) Local service and impact on environs.

The analysis on the economic effect is described in Chapter 11.

## 12.2 Construction and Maintenance Aspect

Construction work and cost and maintenance cost are evaluated. Effects are broken down to the following items;

(1) Construction cost including preliminary and contingency cost.
(2) Area and cost for land acquisition.
(3) Buildings and facilities to be relocated.
(4) Construction period.
(5) Danger and nuisance during construction, location expected to occur.
(6) Annual maintenance cost.

The locations of land acquisition and relocation of buildings are shown in Appendix 12.1 and the locations which are inconvenient or dangerous during construction are in Fig. 12.1. These unquantifiable items are evaluated by the grade such as 'Favorable', 'Acceptable', and 'Problematic' in Table 12.1 together with quantifiable items.

**Table 12.1 Comparison on construction and maintenance**

| Items | Kallang EXP. | | Paya Lebar EXP. | | |
|---|---|---|---|---|---|
| Alternative | I | II | I | II | III |
| Construction cost(MillionS$) | 251.3 | 220.3 | 508.4 | 325.5 | 370.7 |
| Land acquisition (MillionS$) & compensation | 33.1 | 28.8 | 7.9 | 17.2 | 7.3 |
| Construction period (Month) | 46 | 36 | 36 | 36 | 36 |
| Inconvenience & danger | Problem | Accept | Problem | Accept | Problem |
| Maintenance | Problem | Accept | Problem | Accept | Accept |
| Total evaluation | Problem | Accept | Problem | Accept | Problem |

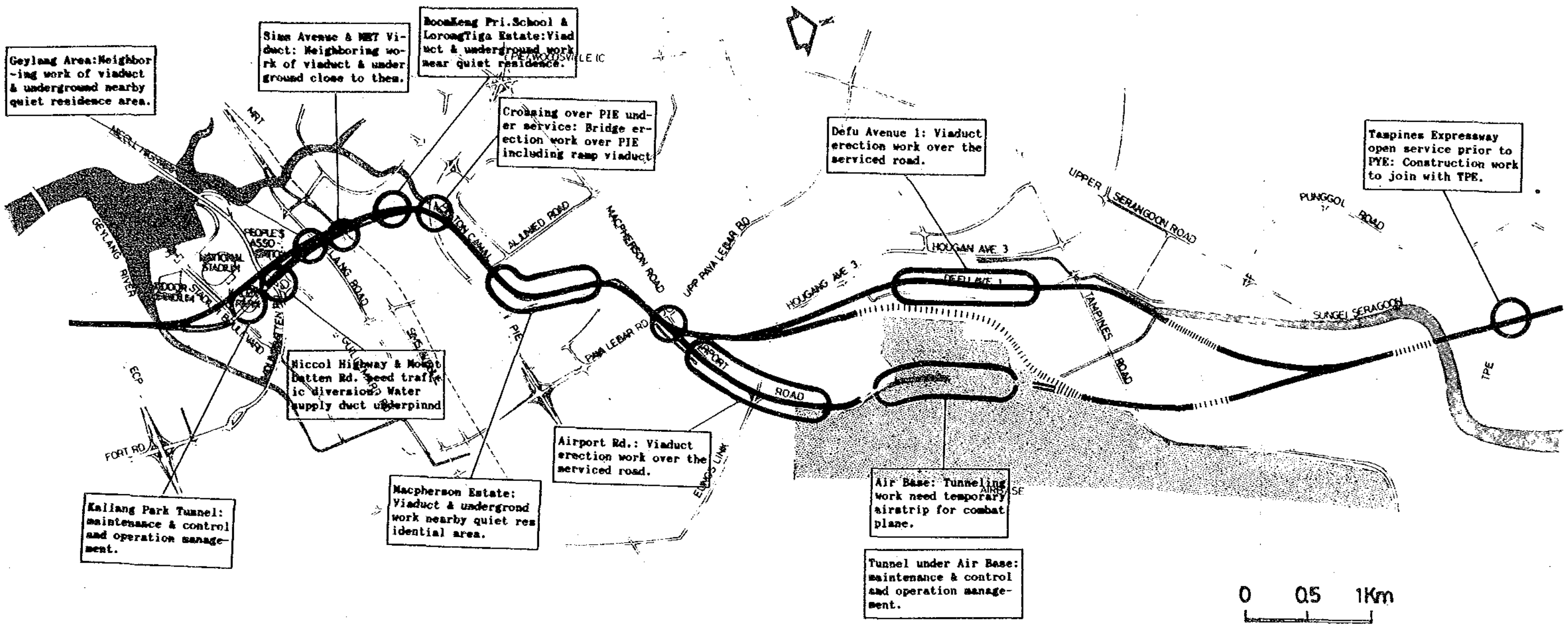



Fig. 12.1 Influences by construction execution

## 12.3 Highway Serviceability Aspects

The construction of expressway is basically to improve the convenience of life (accessibility, speediness) to upgrade the standard of living where the expressway passes. Best indication is the time saving effect in the economic analysis. In terms of macro indicators as B/C ratio, it is not so easy to understand the measurements of the effects. Here, the actual effects of the alternatives are compared in a easy manner to understand.

### 12.3.1 Access Serviceability Aspect

Accessibility typically depends on the location and service directions of the interchange. When the number of interchange is increased, the expressway traffic flow would be disturbed, therefore the interval is an important factor. In principle, the regional traffic is needed to be effectively serviced. As to the KLE, both viaduct and tunnel alternatives are connected at the same place and provide the same service; therefore there is no difference in serviceability.

As to the PYE, the locations of interchanges are different among the 3 alternative routes, ie., Airport Rd. IC for Route-I, Hougang Av. IC for Route-II and Route-III, and Tampines Rd. IC for Route-I to III. The locations of other interchanges are almost the same and there is no difference in the regional access serviceability.

Fig.12.2 shows the location of alternative routes and new towns. As shown in the figure, for the 4 planned new towns, TPE is the most convenient expressway to use. Only the PYE/Punggol IC is in convenient location from/to the Kangkar New Town.

The existing new towns, other than Hougang New Town, are situated almost in the same distance from the alternative routes, therefore the study can be concentrated on the local traffic service for Hougang New Town. Fig 12.3 shows alternative routes, the locations and service directions of the planned interchanges, existing and planned road networks and Hougang New Town. From PYE/Hougang Av. IC, there is a traffic demand to use the PYE toward city through KLE and toward TPE. Route-II and III are the very convenient in serviceability toward city, and Route-III also convenient toward TPE. The study result is evaluated in line with the local serviceability in Chapter 12.4.

### 12.3.2 Traffic Safety Aspect

Higher standard roads, such as expressways are known to reduce the rate of traffic accidents. It is very important to uphold this aspect while designing an expressway.

Although it is difficult yet to calculate quantitatively the accident probability, there has been much efforts to keep record and analyze traffic accidents in terms of alignments, the weather, the factors of the environment along the expressway. From those examples, the road sections in which the probability of traffic accidents is high are as follows;

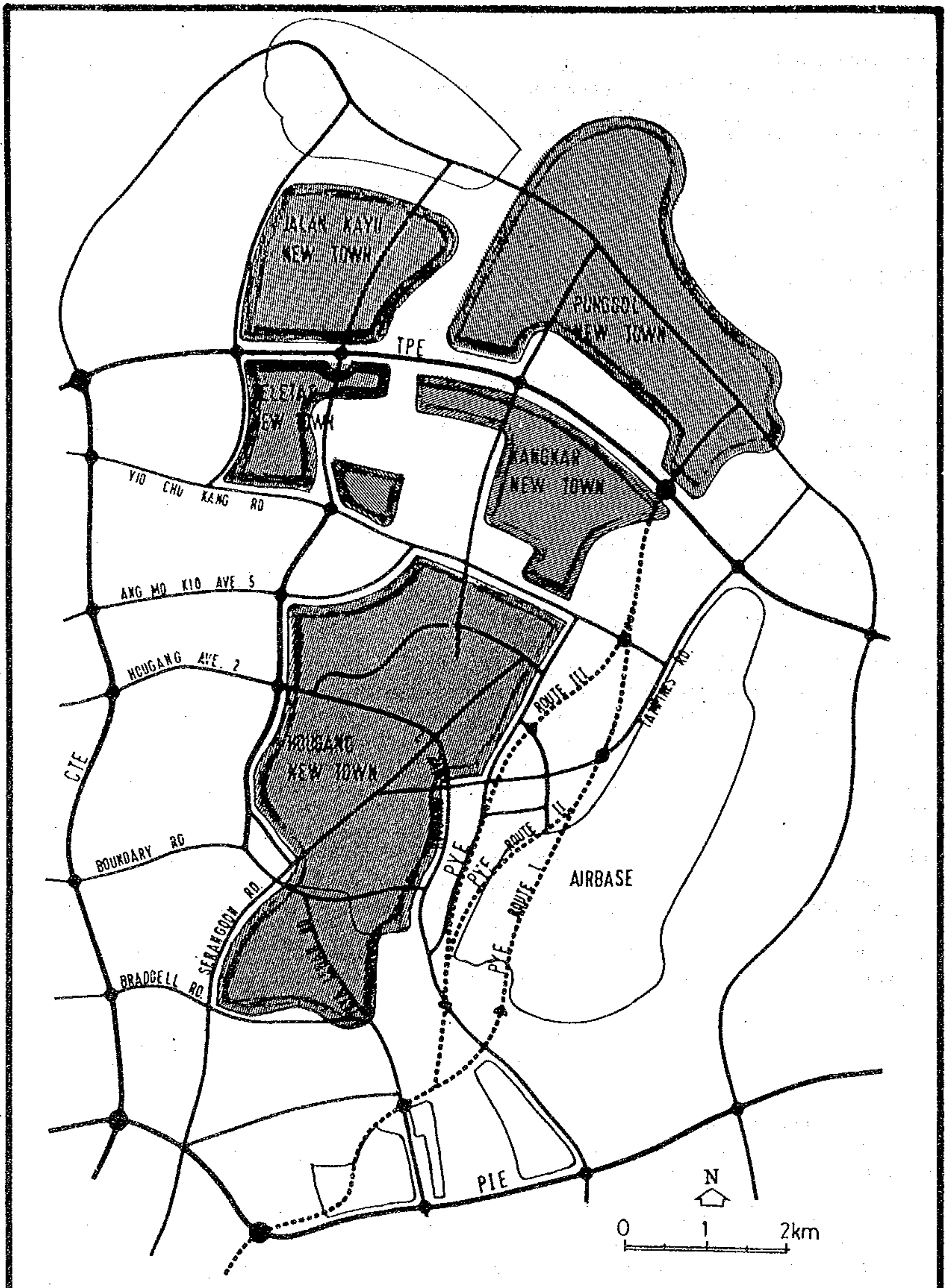



Fig. 12.2 New-town planning & PYE routing

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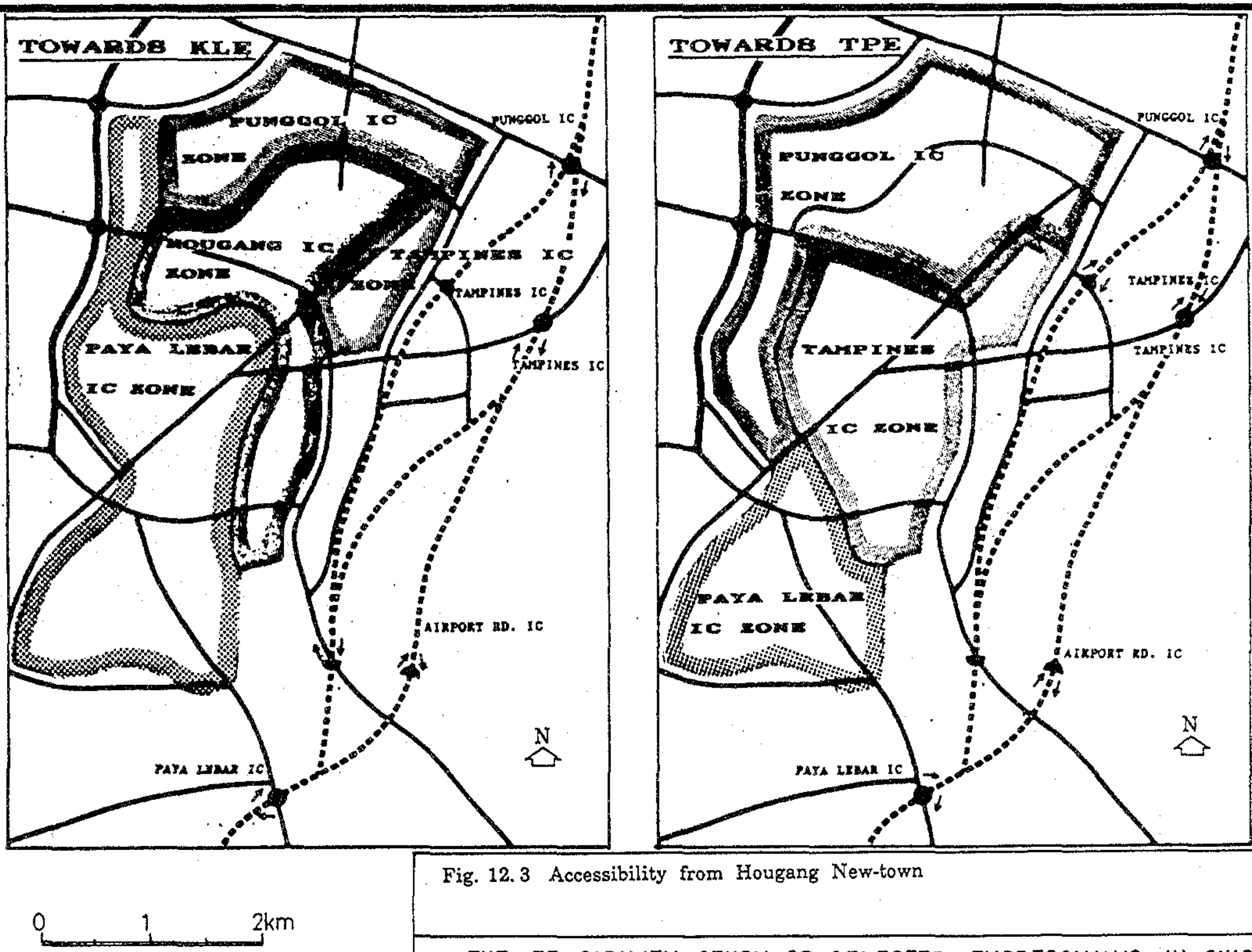


Fig. 12.3 Accessibility from Hougang New-town

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

**a. Throughway section**

- Section with steep (more than 3%) gradient.
- Section with small curve radius (less than 500m).
- Entrance of tunnel and trough section.
- Sudden curve at the end of rather straight stretch.
- Section with insufficient sight distance.
- Crest with small vertical curve.

**b. Interchange Section**

- Merging point with big difference in traveling speed and insufficient sight distance.
- Succeeding merging and diverging and weaving section with insufficient distance in between them.
- Acceleration and deceleration lane with insufficient length.
- Lane shifting zone with insufficient distance.

For reference, Fig. 12.4 shows the traffic accident rate for each condition of different combination of horizontal curve radius (m) and longitudinal gradient (%).

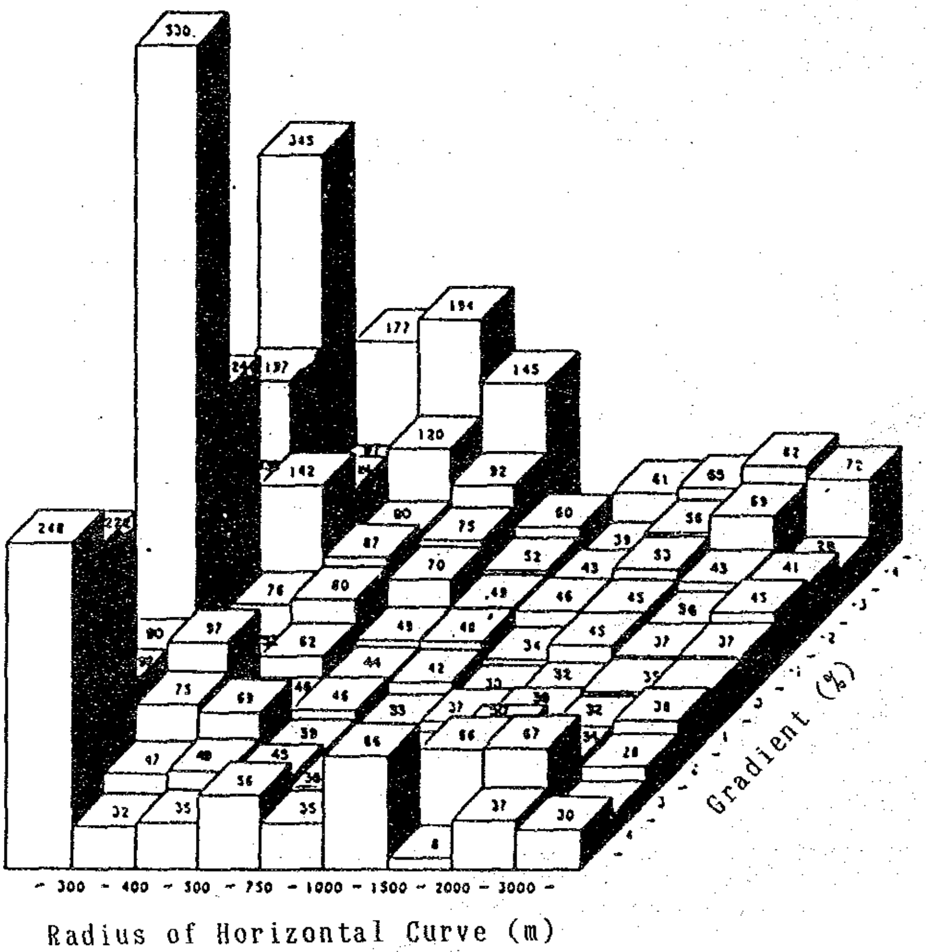


**Fig. 12.4 Accident occurrence in relation to combination of horizontal and vertical alignment**

1) KLE

Fig. 12.5 and 12.6 show the locations and sections where the probability of traffic accidents is high of the 2 alternative routes for the KLE. The result of evaluation is summarized in Table 12.2

There is a big difference in vertical alignment between the tunnel scheme and viaduct one. The former has a section with a 3% gradient at the entrance of the tunnel and the latter covers about the same distance by flat vertical alignment except at the crossing with the MRT.

**Table 12.2 Evaluation of traffic safety (KLE)**

| SECTION | ROUTE- I (TUNNEL) | | ROUTE- II (VIADUCT) | |
|---|---|---|---|---|
| ECP IC | H. Alignment : ○<br>Gradient : ○<br>Psychological Oppression : —<br>Succesive Diverging & Merging : ○<br>Weaving : ○<br>Sight Distance : △ | ◎ | H. Alignment : ○<br>Gradient : ○<br>Psychological Oppression : —<br>Succesive Diverging & Merging : ○<br>Weaving : ○<br>Sight Distance : △ | ◎ |
| ECP IC ~ Nicoll IC | H. Alignment : ○<br>Gradient : △<br>Psychological Oppression : △<br>Succesive Diverging & Merging : ○<br>Weaving : ◎<br>Sight Distance : ○ | ○ | H. Alignment : △<br>Gradient : ◎<br>Psychological Oppression : ◎<br>Succesive Diverging & Merging : ○<br>Weaving : ◎<br>Sight Distance : △ | ◎ |
| Nicoll IC | H. Alignment : △<br>Gradient : △<br>Psychological Oppression : △<br>Succesive Diverging & Merging : △<br>Weaving : ○<br>Sight Distance : △ | △ | H. Alignment : △<br>Gradient : △<br>Psychological Oppression : ◎<br>Succesive Diverging & Merging : △<br>Weaving : ○<br>Sight Distance : △ | ○ |
| Sims IC & PIE IC | H. Alignment : △<br>Gradient : △<br>Psychological Oppression : —<br>Succesive Diverging & Merging : △<br>Weaving : △<br>Sight Distance : △ | △ | H. Alignment : △<br>Gradient : △<br>Psychological Oppression : —<br>Succesive Diverging & Merging : △<br>Weaving : △<br>Sight Distance : △ | △ |
| EVALUATION | △ | | ○ | |

Note; Marks indicate as ◎:favourable,○:acceptable,△:unfavourable,×:unacceptable

2) PYE

Fig 12.6 shows the locations and sections where the probability of traffic accidents is high on the 3 alternative routes for the PYE. Table 12.3 shows that for the Route- III, both horizontal and vertical alignment have hardly any defects and are evaluated high and that the Route-I with the tunnel marked the lowest.

## 12.4 Local Serviceability and Impact Aspect

In this section, the Study looks into rather detailed effects and influence on each alternative. The study is on the alleviation and

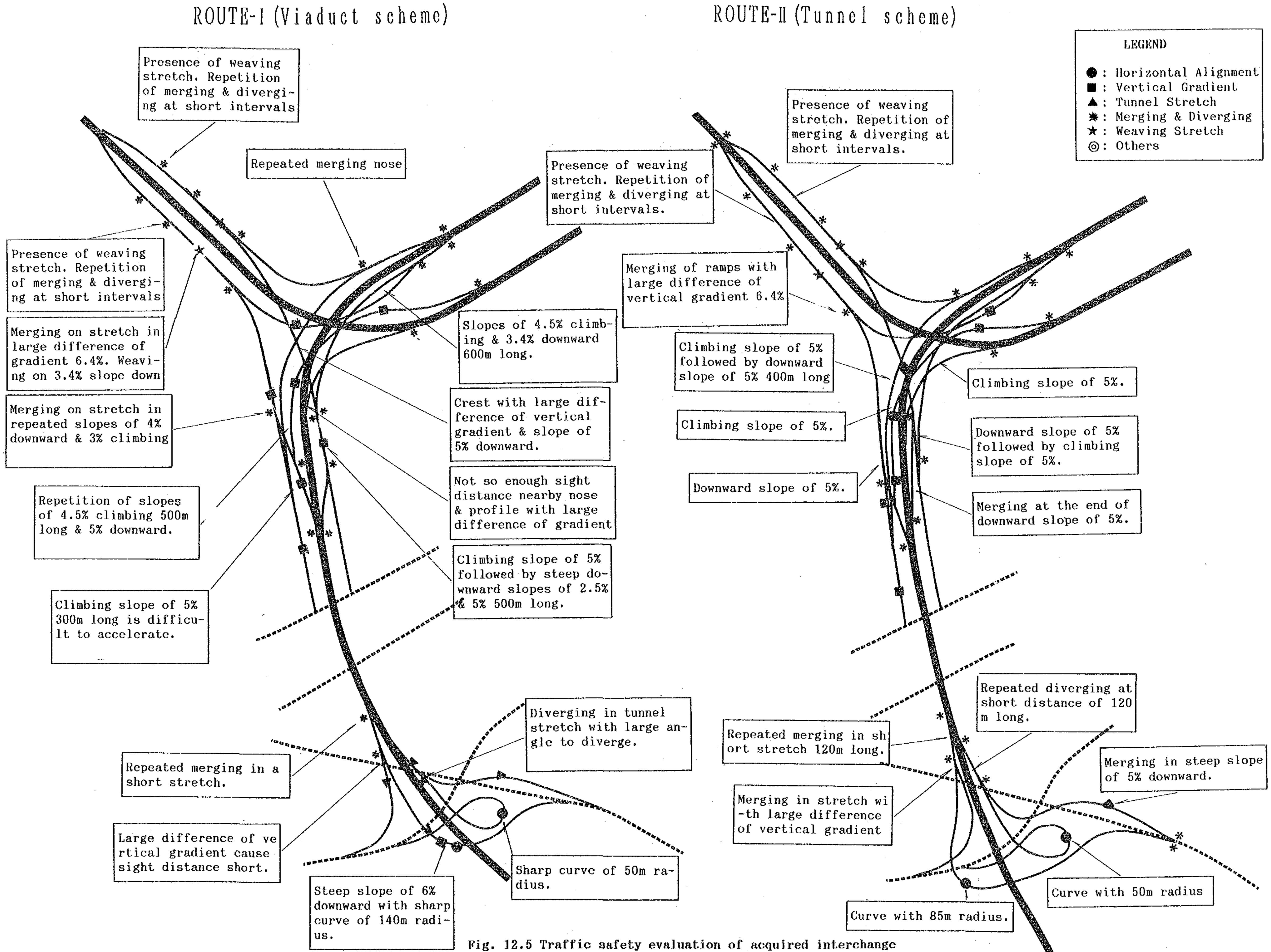


**Fig. 12.5 Traffic safety evaluation of acquired interchange (KLE: Nicoll IC to PIE IC)**

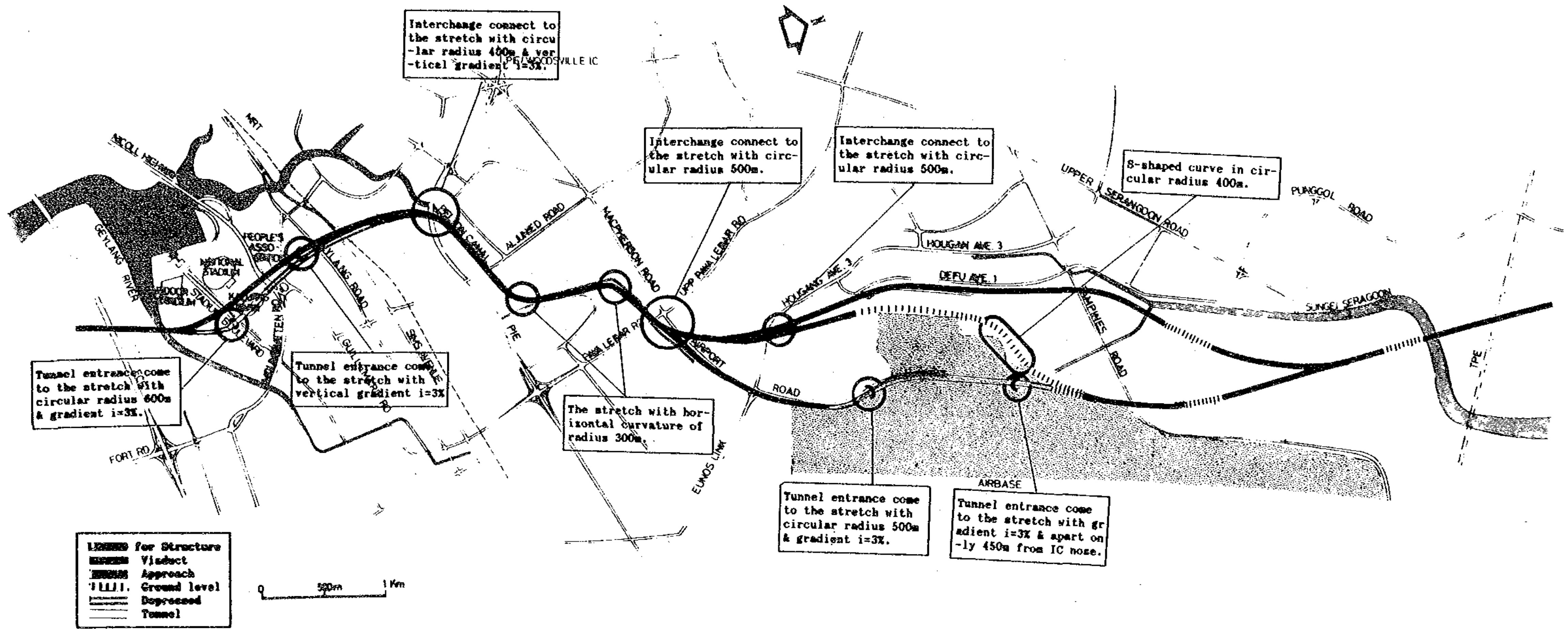


Fig. 12. 6 Traffic safety evaluation of acquired alignment

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE