HSUEHSHAN TUNNEL ROUTE SELECTION AND STUDY

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ABSTRACT

The Hsuehshan Mountain Range blocked a 13km long section of the Taipei-Ilan Expressway between Pinglin and Toucheng. The mountain range runs more or less perpendicularly to the expressway alignment, and using a tunnel appeared to be the only viable choice for the road corridor to pass through the mountain range. For the West end of the tunnel located in Pinglin area, the land available for route alignment is limited. On the other hand, the East end, which is located in the Lanyang Plain, has more choices for the location of the portal. The feasibility studies completed in 1988 assessed three routes with Ilan, Jiaohsi and Toucheng as the possible locations for the East portal.

During the Route Selection Studies conducted in 1990, investigations on the regional geological conditions and the environmental impact studies were completed. Based on the consideration of factors ranging from geology environmental protection, connection with the island wide freeway system and glare affecting traffic safety, the current route was selected.

This paper presents the processes for various stages of route selection, factors considered, and the comparison of advantages and disadvantages of the various routes.

Keywords: road corridor, route, tunnel and glare.

INTRODUCTION

The narrow strip of the Eastern Taiwan Coastal Plain is barricaded by the Central Mountain Range; communication with the rest of the Island of Taiwan is very difficult. As a result of this semi-seclusion, socio-economic development is quite stagnant, and economic activities are restricted to trades dependent on agriculture, fishing, mining and forestry. These activities predate modern day industrial socio-economic developments. In Ilan Hsien, communication and links to the outside world were limited, and Taiwan Highway No. 9, a tarmac road of miserable condition, was its sole passage to Western Taiwan. In 1924, the Taiwan Railway system extended to Ilan. And at long last, in 1979, the Northern Coastal Highway connected Ilan with Northern Taiwan (Figure 1). Through these connections, traveling from Taipei to Ilan took over 2 hours to complete, even though the town of Nankang on the Eastern flank of Taipei is only 30 km from the town of Toucheng, Ilan Hsien. These two towns would be only 30 minutes apart, if they were linked and served by a thoroughfare of modern standards. Obviously such transportation linkage is of vital importance in developing Eastern Taiwan. Furthermore, when the entire economic development of Taiwan is viewed a new highway bringing the Eastern Taiwan Plain within easier, ready reach of the rest of the Island is a necessity. As early as 1982, the Government commenced evaluation and planning on whether it would be feasible to construct a highway that links Eastern Taiwan with the Western part of the Island.

THE ROAD CORRIDORS

The Town of Nankang on the East side of metropolitan Taipei is only 30 km from the Lanyang Plain. In between, there is the Northern flank of the precipitous Hsuehshan Range and the hilly Western foothills, both presenting formidable inaccessibility that separates the Lanyang Plain from Western Taiwan. Two small communities, Shihting and Pinglin, are situated within this rugged terrain. Pinglin is located on the bank

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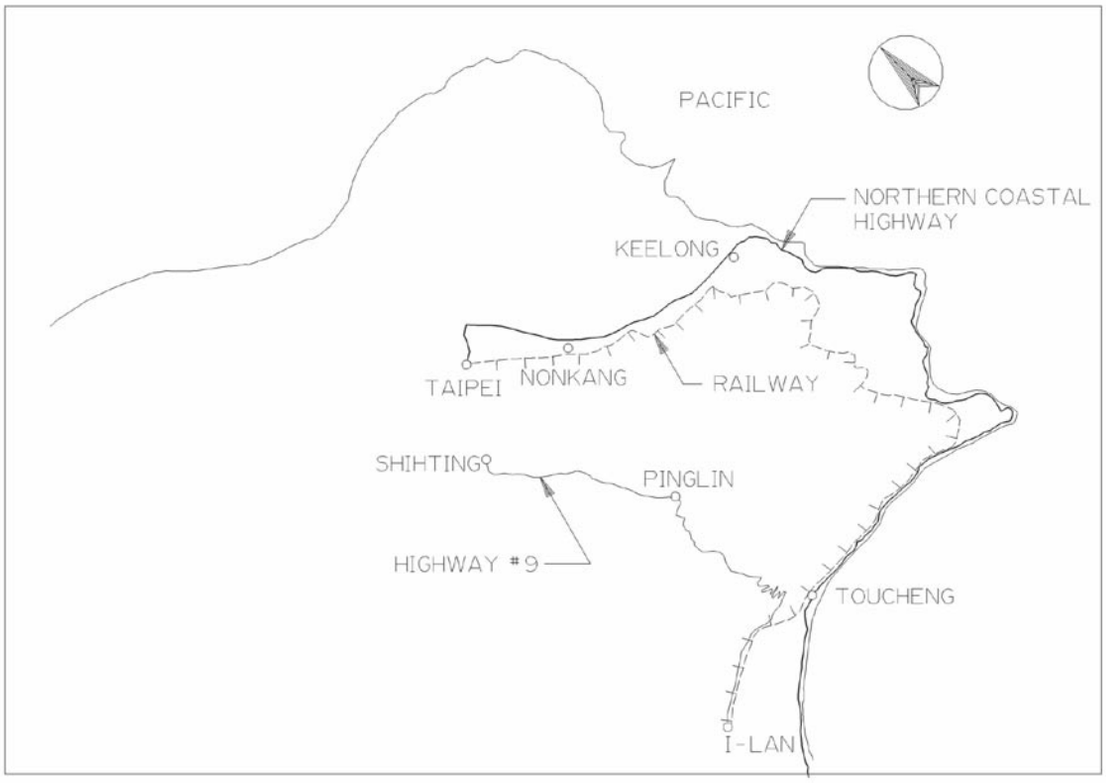

Figure 1. Transportation between Taipei and Ilan before construction Of the Taipei-Ilan Expressway

of the Peishihchi River; it is about midway between Nankang and Toucheng. The Feitsui Reservoir is situated downstream of Pinglin, while the proposed Pinglin Reservoir is situated downstream. An alluvial terrace occurs at Pinglin. This alluvial terrace presents a suitable site for locating interchanges and traffic control centers. Because of these considerations, Pinglin becomes a strategic location that the road corridor has to pass through. The road corridor running from the Second Northern Freeway through Nankang, Shihting to Pinglin is simple and Straight Forward. This Corridor seems to have no competition from other candidate road corridors, nor has there been another alternative corridor proposed by the various expert consultants that worked under various stages of studies over the years. Hence, this paper will not elaborate any further on this section of the road corridor. The section of the road corridor from Pinglin to Ilan is a different story. On the Lanyang Plain, there are, in a north to south arrangement, Toucheng, Chiaochi and the city of Ilan. Thus using Pinglin as a fixed point on the West, there are a number of road corridor selections with each one of these municipalities being the eastern terminal of the route. The route selection for the Hsuehshan Tunnel is thus an important issue in the planning and design studies on the Taipei-Ilan highway. This paper presents some details on studies and investigations conducted in connection to route selection for the Hsuehshan Tunnel. Certain issues of interest are also briefly discussed.

ROUTE SELECTION STAGE

Planning studies of the road corridor between Pinglin and Ilan were divided into three stages, and were undertaken by domestic and foreign consulting firms. The following is a brief record of these studies:

Feasibility Study on the Nankang-Ilan Highway Tunnel

In 1982 the Taiwan Provincial Highway Bureau entrusted Chinese Engineering Consultants Incorporated to perform a "Feasibility Study on the Nankang-Ilan Highway Tunnel". During this study, the status of the highway

was a regular highway, and so there was no geological investigation nor was there any topographic surveying in connection with the project. Two candidate road corridors, Corridor A and Corridor B, were planned.

In this Feasibility Study, the recommended Corridor started from the intersection between Nankang Road and Academia Sinica Road in Taipei; and ended at Taiwan Highway No. 190 in Toucheng, Ilan Hsien. The total length was 32.2 km. There were three tunnels along the entire alignment of Corridor A, they were the 2.3 km long Nankang Tunnel, the 2.9 km long Pengshan Tunnel, and the Pinglin Tunnel, 12.4 km in length. Corridor B ran from Nankang to Chiaochi. The section from Nankang to Pinglin in Corridor B is identical to that of Corridor A. Corridor B differed with Corridor A in that after leaving Pinglin heading East, Corridor B went by way of Shihtsao; Pihu then entered the Chiaochi railway station where it ended. The total length was 34.8 km. Refer to Figure 2 for details. The planned road was a 4-lane Bidirectional highway. The width of the highway was 14m. Where topographic

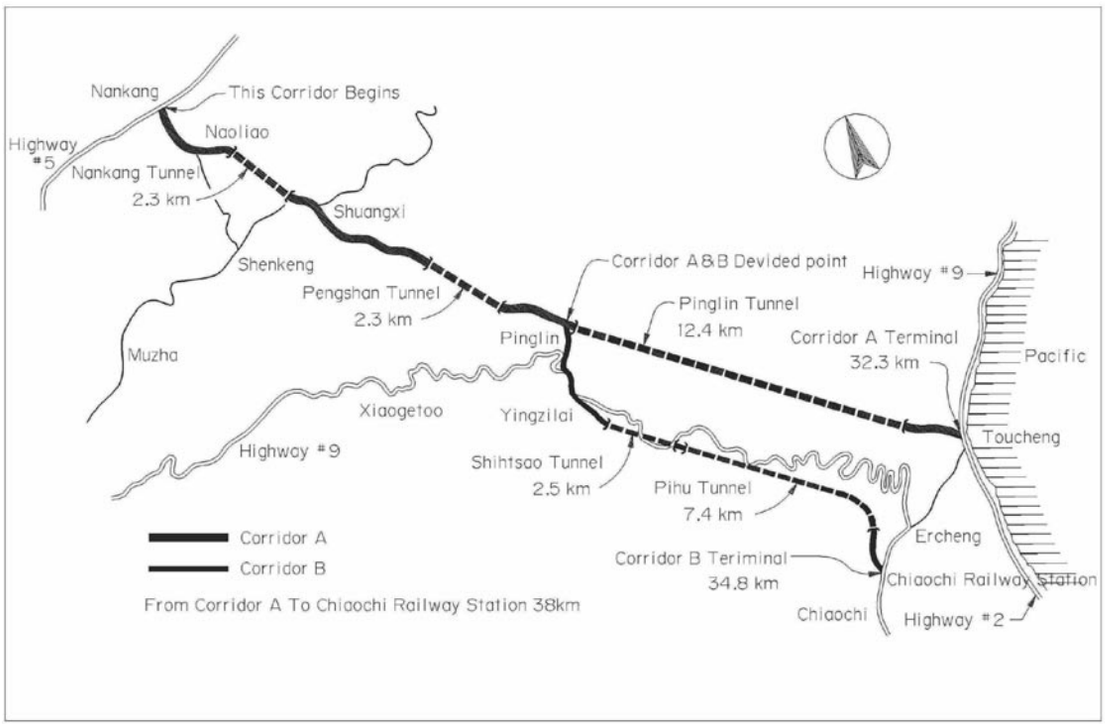

Figure 2 Sketch map of the Nankang Ilan Highway Tunnel

factors did not allow the highway would be two-lanes-two directions. The width would then be 7 m. The tunnels would be excavated through separate tubes. Tubes of the tunnels were twin-lane, with width of 7.5 m. The Centers of the Eastbound and the Westbound tubes were 40 m apart. Maximum longitudinal gradient in the tunnel was 3%. The Mileages of the highways are presented in the chart below.

At the time of the feasibility study, the East portal of the Pinglin Tunnel was located about 3 km north of the East portal of the present Hsuehshan Tunnel, and was shorter by 350m, then the Hsuehshan Tunnel. The feasibility study concluded that the investment for the planned highway would be colossal, and the engineering technique far too difficult, and the project would have a very low cost-to-benefit ratio with a similarly low return rate. It was then suggested that the government should not rush to invest in the project.

Geologic Investigation and Evaluation of the Nankang-Ilan Highway Tunnel

In 1984, the Bureau of Highways entrusted Sinotech Engineering Consultants Incorporated with a contract to conduct preliminary road corridor geological investigation and evaluation on the previous feasibility study project on "The Nankang Ilan Highway Tunnel". The provision was that the road corridors proposed in the previous feasibility study could be adjusted or modified in accordance with geological investigation results, the road corridors, however, would not be reviewed or checked. During this geological investigation stage, in addition to surface geological investigation, subsurface geological exploration was also conducted. A total of 16 geologic boreholes were drilled, with a total length of 1145 m of cores. There were two seismic survey lines totalling 1180 m in length. Most of these investigative measures were conducted on the area in the vicinity of the East Portal of the proposed tunnel; this area was considered to have more adverse geological conditions.

The original site of the West Portal of the proposed Pinglin Tunnel was situated near a gulley and was quite close to the site of the spillway plunge pool for the proposed Pinglin Reservoir. This site was considered not adequate, and needed to be shifted 40 m to the south. The East Portal was located in a gulley underlain with colluvial

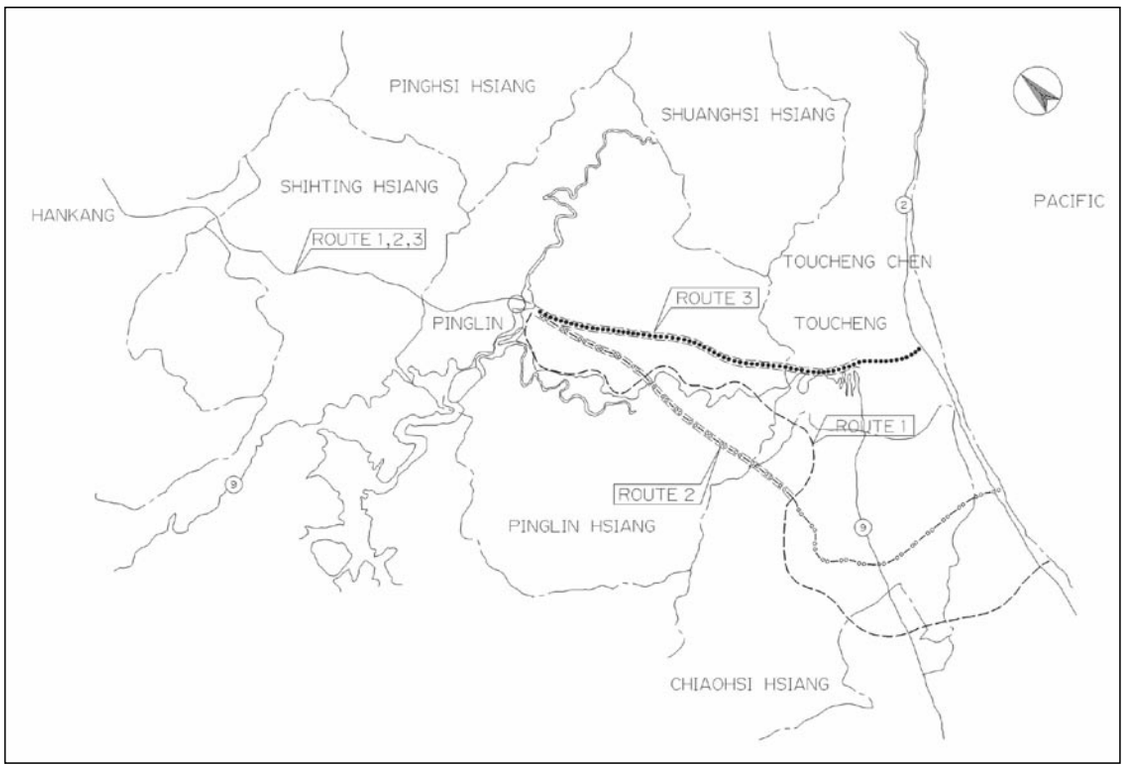

Figure 3 Routes planned during feasibility study

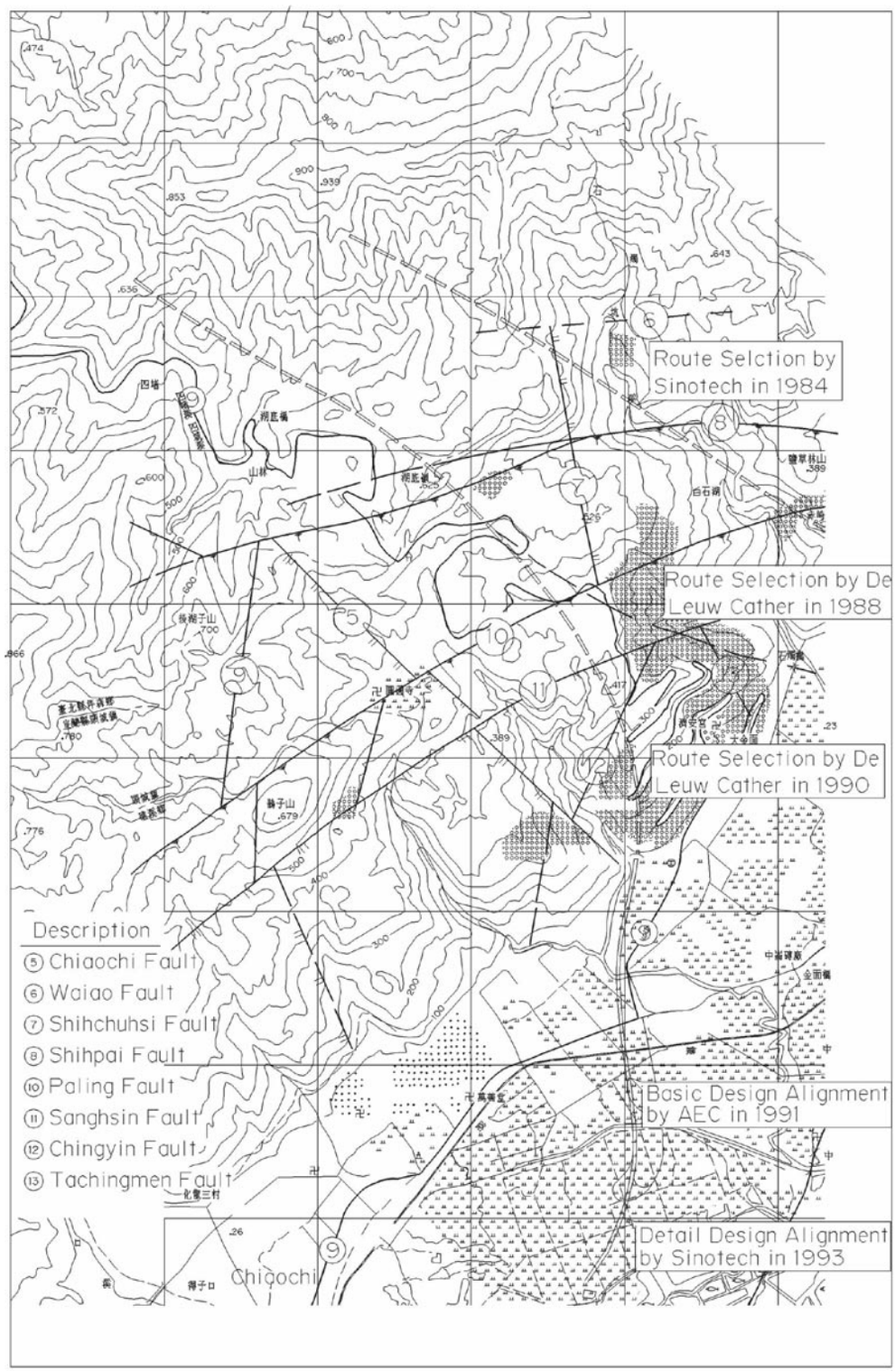

Figure 4 Route planning, Toucheng section of the Taipei-Ilan Expressway

deposits, so the West Portal was shifted 50 m to a rock face to the North. This consequently increased the total length of the Pinglin Tunnel to 12,410 m. It was recommended that the tunnel be excavated using the conventional drill and blast method.

The result of the geological investigation indicated that the geological conditions were good for most of the Pinglin Tunnel, the only exception being the 2.5 km section of inferior geological condition situated within the Argillite of the Kankou Formation and in the Quartzite of the Szeleng Sandstone. The entire alignment of the proposed tunnel traversed three faults at right angles. These were the Shihtsao Fault, the Ssitu Fault and the Paling Fault. All three of these were regional faults. During construction of the Hsuehshan Tunnel, the total thickness of the Kankou Formation Argillite and the Szeleng Sandstone Quartzite reached 4.5 km, and there were 6 regional faults. Thus, overall the geological conditions as revealed in this geological investigation were by far better than those of the present Hsuehshan Tunnel.

During this stage of the study the regional geological investigation, review on construction implementation, planning on mechanical and electrical safety measures, study on construction, study on environmental impacts, project engineering costs and work schedule, it was deemed that the project was technically viable. The direct cost-to-benefit ratio and investment return might be low, but in comparison, and in terms of road corridor geological conditions and road corridor alignment, the plan for Corridor A was better than the plan for Corridor B.

Nankang Ilan Expressway Feasibility Study

In 1987, the Institute of Transportation, Ministry of Transportation and Communications granted a contract to a consultancy consortium made up of De Leuw Cather International Limited of the United States, China Consultant, Inc. Taiwan, and Geoconsult Consulting Engineers of Austria to conduct a feasibility study on the highway. In this stage, the planning and design of the highway were based on the standards for an expressway. Three routes were proposed, but the Eastern terminus of the routes still connected with existing local roads. In these proposed routes, Route#1 is a road corridor that ran parallel to the alignment of Taiwan Highway No. 9. This route called for construction of 11 tunnels of various lengths. The portal of this route was situated to the South, and ran passed the hot spring spa resort town of Chiaochi to Ilan where it connected with Taiwan Highway No. 2. Both Route #2 and #3 were planned using the Pinglin Tunnel, 12.9km in length. The exiting East Portal of the Pinglin Tunnel in Route #2 was located near the Wufengchi Falls. After this, the route ran south to connect with the Taiwan Highway No. 2. The exiting East Portal of the Pinglin Tunnel for Route #3 was located at Hsinfeng Falls. The route then ran south to pass Toucheng and connected with the Taiwan Highway No. 2. Thus these highways led to Ilan, Chiaochi and Toucheng, respectively. Details of these routes are presented in Figure 3.

In this stage there was a shift of all road corridors to the south. Route Corridor #3, the Northernmost of these route corridors, was located within the huge colluvial deposit to the North of the hairpin curve "Chiuwanshipakuai" in Taiwan Highway No. 9, and was about 1 km from the route proposed during the geological investigation study. In this stage, it was recommended to use the drill an Blast method for the construction of the Pinglin Tunnel. Following a comparison, it was found that Route #2 was the best among these three routes. The result was then submitted to the Executive Yuan for review and approval. The instruction from the Executive Yuan was "Make a selection from Routes #2 and #3 following further geologic investigation and evaluation and environmental impact studies". Both Route #2 and Route #3 were planned with the Pinglin Tunnel in their route alignments, thus construction of the Hsuehshan Tunnel was finalized during this stage.

ROUTE FINALIZATION STAGE

In 1989 the government set up The Provisional Engineering Office for Construction of Nankang Ilan Expressway as a move in encouraging construction of the expressway. In 1990, this provisional office was officially inaugurated as the Taiwan Area National Expressway Engineering Bureau (TANEEB). The chief administrative duty of this office was to supervise finalization of the route of the expressway and relevant works. Further geological investigation and environmental impact assessments were among the works to be performed.

Nankang-Ilan Expressway, Route Selection Study

In 1989 the Provisional Engineering Office for Construction of Nankang Ilan Expressway entrusted the consultanting firms of De Leuw Cather, Geoconsult

and Sinotech to perform route selection studies. De Leuw conducted a detailed comparison of Route #2 and Route #3 based on the geological conditions and environmental impacts. It was revealed that Route #2 ran through the hot spring resort area, and it would have too much negative environmental impact on the area. Furthermore, geologic conditions along Route #2 were poorer compared to Route #3, hence Route #3 was selected after evaluation. Nevertheless, after giving due consideration to the extension of the expressway as far as the town of Suao, and with due consideration of the effect of glare on driving safety at the East portal, the East portal of the tunnel was shifted to a location south of Jiuwanshipakuai, and the selected route was named Route #3A. This new site of the portal is the present East portal of the Hsuehshan Tunnel. Whether it was Route #3 or Route #3A, the fact remains that these two routes were situated within a huge colluvial deposit and the geological conditions were inferior compared to the route proposed following preliminary geological investigation. However, De Leuw Cather and Geoconsult thought that route #3 had been officially approved by the Executive Yuan, plus the fact that excavation of the Pinglin Tunnel would be done using the drill and blast method, there was no need to adjust the route alignment. During this stage the design standard of the highway had been elevated to that of an Expressway. The Pinglin Tunnel in Route #3 was 12.8 km in length. The 840 m of portal section at the Pinglin end had a grade of 0.5% going uphill. The rest of the tunnel was going down with a gradient of 1.5%. The planned construction period was calibrated at 8 years following international work standards.

During the same time, TANEEB awarded Sinotech Engineering Consultants Inc. a contract to conduct detailed geological investigation on the area between Pinglin and Toucheng. This geological investigation was aimed at issues relevant to Routes #2 and #3. The result of this geological investigation revealed that the 3.5 km long Eastern section of the Pinglin Tunnel was located in rock formations belonging to the Argillite of the Kankou Formation and Quartzite of the Szeleng Sandstone. Four regional faults passed through this section. As a result, the rock mass was intensely sheared and fractured. Shear zones occurred very frequently, hence, the rock mass was rated "VERY POOR" TO "POOR", thus, once again showing that the routes selected during this stage were inferior in geological conditions as compared to the route proposed in 1985. However, expert consultants invited by TANEEB considered the alignment of Route #3A was the best for an expressway. The route was then finalized. A budget to the total amount of 60.1 billion was also approved. The decision was submitted to the Executive Yuan for approval. The instruction from the Executive Yuan was to conclude all pertinent issues immediately for an early start on the engineering project.

Basic Design, Taipei-Ilan Expressway

In 1990, TANEEB entrusted Asian Expressway Consultants, a consulting consortium made up of Parsons Brinckerhoff International Inc., Sinotech Engineering Consultants Inc., and Electrowatt Engineering Services Ltd. with a contract to perform basic design study on the approved Route #3A highway proposal. At this time, the project had been renamed "Taipei-Ilan Expressway", and was one vital link in the entire expressway network on the island. During this time, consideration was given to issues on the possible pollution of the Taipei water resource area as well as ventilation for a long tunnel. Consequently, the longitudinal gradient of the Pinglin Tunnel was adjusted to 1.25% in a west to east descent while the alignment remained unchanged. At the time, the proposal to extend the expressway further to the town of Suao had not been finalized yet; the route was then extended to Tachuwei with the provision of interchange and service stations to facilitate connecting to the Toucheng-Suao section of the expressway through either the coastal section or the inland section of the expressway in the future. During this study stage most of the engineering aspects relating to the expressway project were completed, these included the level of major engineering works, their types, scale or sizes of structures as well as functional designs. The contract document for construction of the pilot tunnel of the Pinglin Tunnel was also completed during this stage. In July 1991, work started. In principle, the Pinglin Tunnel as well as the pilot tunnel were to be excavated in an east to west direction.

Detailed Design, Taipei-Ilan Expressway

In 1991, TANEEB contracted Sinotech Engineering Consultants, Inc. to perform a detailed design of the expressway. The detailed design would be based on the basic design of the general framework, route alignment, various functioning issues and contract documents which had been approved by the Executive Yuan. The "Pinglin" in the Pinglin Tunnel had since been an issue

of much controversy between Pinglin residents and the people of Ilan County, the government in 2000 renamed the tunnel the Hsuehshan Tunnel. Alignment of the Eastern section of the Pinglin Tunnel is shown in Figure 4.

CONCLUSIONS

1. Eastern Taiwan is barricaded by the Central Mountain Range and had been suffering from inadequate, inconvenient transportation. As a result, socio-economic developments have lagged behind the rest of the island. In view of the economic development of Taiwan in recent years, there is an urgent need for a modern, up-to-date highway to link and bring Eastern Taiwan into the overall socio-economic development of the Island.
2. Ilan is only 40 km from Taipei, and from Nankang to Toucheng is only 30 km, these are distances that would take only 30 minutes by car. However, previously using Taiwan Highway No. 9, the Northern Coastal Highway, or the North-Link Railway, a trip to Ilan would take at least 2 hours. Once the Taipei-Ilan Expressway opens for traffic, Ilan will be within ready reach of Taipei, development and prosperity of Ilan is to be expected.
3. Between Nankang and Toucheng there are the towns of Shihting and Pinglin. These are residential locations that the expressway service has to embrace. Thus over the years, highway planning for the section of highway between Nankang and Pinglin has been simple and straightforward. There are no factors of complication, nor alternative plans. For the Toucheng end of the road corridor, an expressway service can be aimed at Toucheng, Chiaochi and Ilan, all belonging to a different level of municipal hierarchy; hence many alternative plans become possible. This section of the road corridor became the topic of much study.
4. It took 10 years to complete the study and planning of the Taipei-Ilan Expressway. From 1982 to 1991, these study and planning projects had been undertaken by a number of government agencies and many consulting firms, domestic and foreign alike. Since from the very beginning there were differences in highway standards and subjective environmental factors, the route corridors shifted over the years from the north to the south. However, the stretch of road from Chiaochi to Ilan ran past the Chiaochi hot spring spa resort, and the impact on the environment of the area would have been immense. Furthermore, geological conditions and topographic configurations of the area were inferior, and the expressway service to the town of Toucheng would have been too far away. All of this meant that the Eastern portal of the tunnel should be set at Toucheng.
5. The Construction of the Hsuehshan Tunnel is nothing but difficult. The Construction period extended from the original planned 8 years to 14 years, raising general suspicions regarding the adequacy of route selection. In reality, between Pinglin and Toucheng there stands the Northern end of the precipitous Hsuehshan Range, and construction of a tunnel through these mountains is the only way to realize a modern expressway. The backbone of the Island of Taiwan is a series of tightly folded and severely faulted mountain ranges that were the result of island arc-to-plate collision tectonism. The Pinglin Tunnel which is a threshold of this modern expressway has been measured at least 13 km in length through the various stages of investigation and study. It was not possible for the alignment of the tunnel to avoid these faults or folds because that would have imposed tremendous difficulty on a project of this caliber. During construction of the tunnel, it was indeed revealed that the geological conditions improved in a northward direction, thus implying that the geological conditions of the original Northern route corridor would have been better.

   Considerable geological investigation results on the road corridor were available during the route selection stage. The TANEEB advisory board experts also visited the field to view the outcrops and examine cores. It was generally understood that the approximately 3km length of rock on the Eastern section of the Hsuehshan Tunnel was comprised of fractured Argillite and Quartzite of the Kankou Formation and the Szeleng Sandstone. These intensely fractured rock formations contained large quantities of groundwater. Purely from a technical point of view, tunnel excavation should stay clear of these rock formations. However, the extensive spread of these rock formations made it impossible to bypass such spots of adverse geological conditions. If it were possible to shift the alignment northward, the engineering geological risks would have been greatly reduced. However, the Taipei-Ilan Expressway was an expressway with transportation being its sole goal; all engineering layouts and route studies were bent on achieving this priority. Foreign advisory board experts,

based on their experience, considered that adequate engineering technical know-how would overcome this adverse geological setting. A northward shift of the road corridor would require the dismantling of a great number of residential houses, thus creating socio-economic problems. Non-technical problems of this type are the ones engineers in every country are confronted with from time to time; unfortunately a perfect solution has yet to be found.

6. The poor geological conditions at the Eastern section of the Hsuehshan Tunnel proved to be difficult using either the TBM or drill and blast. Taiwan was a greenhorn as far as TBM tunnel excavation goes. The lack of experience was further aggravated by the highly fractured water-rich rock formations that lined the Eastern section of the tunnel. The bittersweet experience thus acquired will be precious in future long tunnel engineering.