chapter VI

FORECAST OF FUTURE HIGHWAY TRAVEL

FORECAST OF FUTURE HIGHWAY TRAVEL

Future highway travel volumes were forecast for two alternative conditions to provide a basis for estimating road-user savings. Under the first alternative, future traffic volumes were estimated without the freeway, and under the second, with the freeway. Under the freeway alternative, the effect of railway improvements on future highway traffic was also considered. Procedures for computer analysis of future traffic are shown on Exhibit VI-1.

FORECAST OF FUTURE TRAFFIC WITHOUT FREEWAY

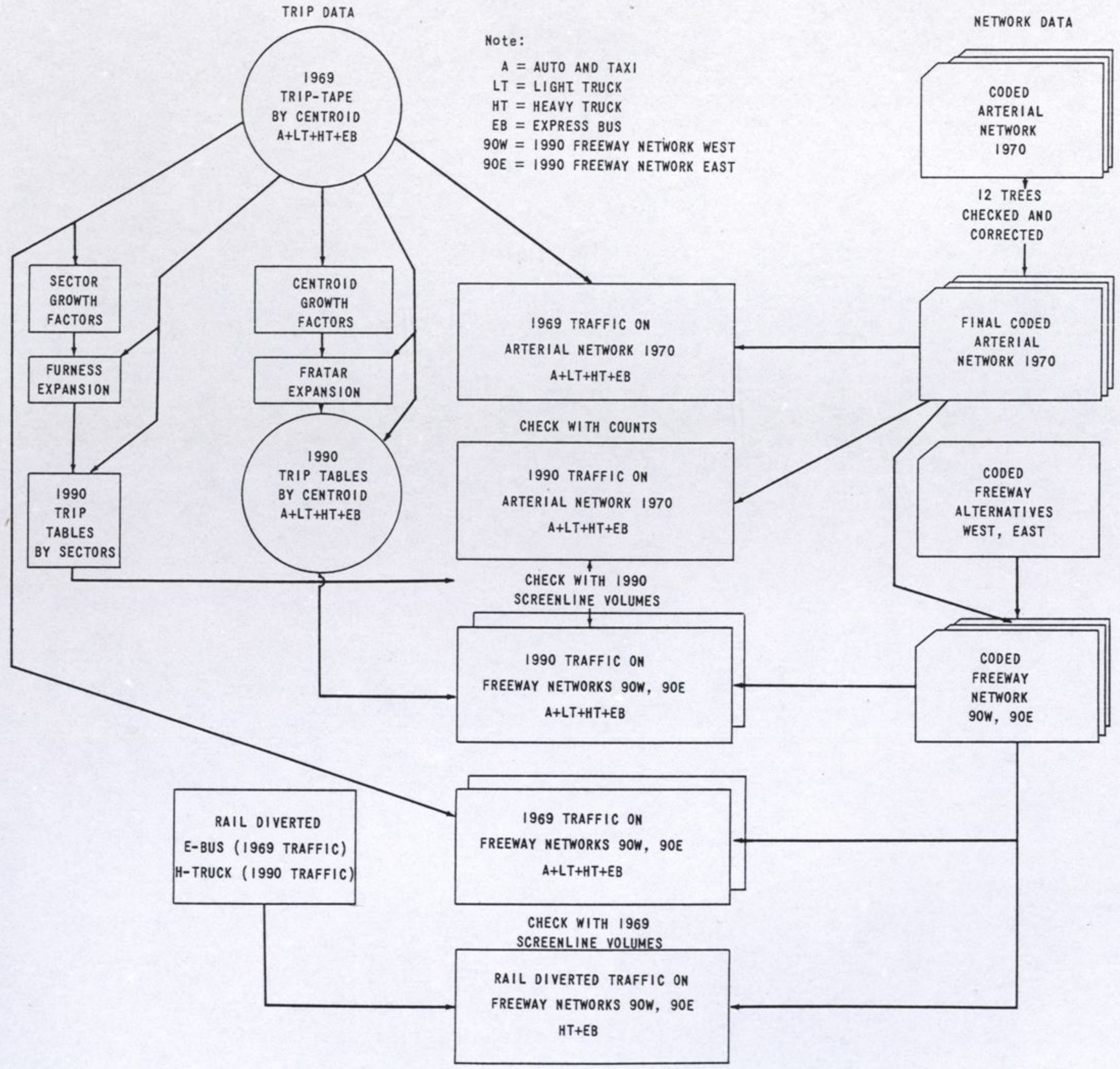
Traffic Growth Factors

The growth of travel demand by each of the four major vehicle types was determined to 1990. These values for each hsien (administrative district) were then refined for each zone. This refinement was based on the planned or anticipated development at specific locations.

Regional development concepts are available for three areas--Taipei-Keelung, Taichung-Changhua, and Tainan-Kaohsiung--the northern, central and southern

Exhibit VI-1

PROCEDURES FOR EXPANSION OF TRIP TABLES AND TRAFFIC ASSIGNMENTS



urbanizing regions, respectively. Of these, only the Taipei-Keelung regional plan was available in published form. The concepts for the two other regions were explained to the Consultant in a briefing by the staff of the Urban and Housing Development Committee (UHDC). The UHDC staff indicated, for example, locations of possible new satellite cities with high traffic growth potential, and areas proposed for high agricultural development with anticipated slow traffic growth. Large planned developments, such as Linkou, the future Taoyuan International Airport, the second Kaoshiung Export Processing Zone, the announced Wuchi and Tamshui harbors, and others, were given special attention.

The hsien traffic growth factors were modified according to zone characteristics such as population or industrial growth. Such modifications were checked, however, to produce the same overall hsien growth as calculated by weighting each zone according to its 1969 trip production.

The traffic growth factors by section were estimated in the few subdivided hsiens in a similar manner. Each zone factor was weighted according to its 1969 trip production, and the average factor for all zones of a sector was calculated.

Growth factors in the four hsiens without known development plans were not refined by zones, but the hsien factor was applied uniformly to all zones in the hsien.

Preliminary Manual Traffic Expansion by Sectors

The sector trip tables for 1969 were expanded manually to 1990 with the sector growth factors. The iteration method of FURNESS was applied with slide rule calculations.

The FURNESS expansion procedure entails multiplying all trips produced in a sector by the sector growth factor. In a rectangular trip table, all volumes in a row are multiplied by the same sector growth factor. The trips attracted to each sector are totaled for each column and a correction factor calculated. The correction factor is then applied to all volumes in a column to balance the sector attraction. Row totals of

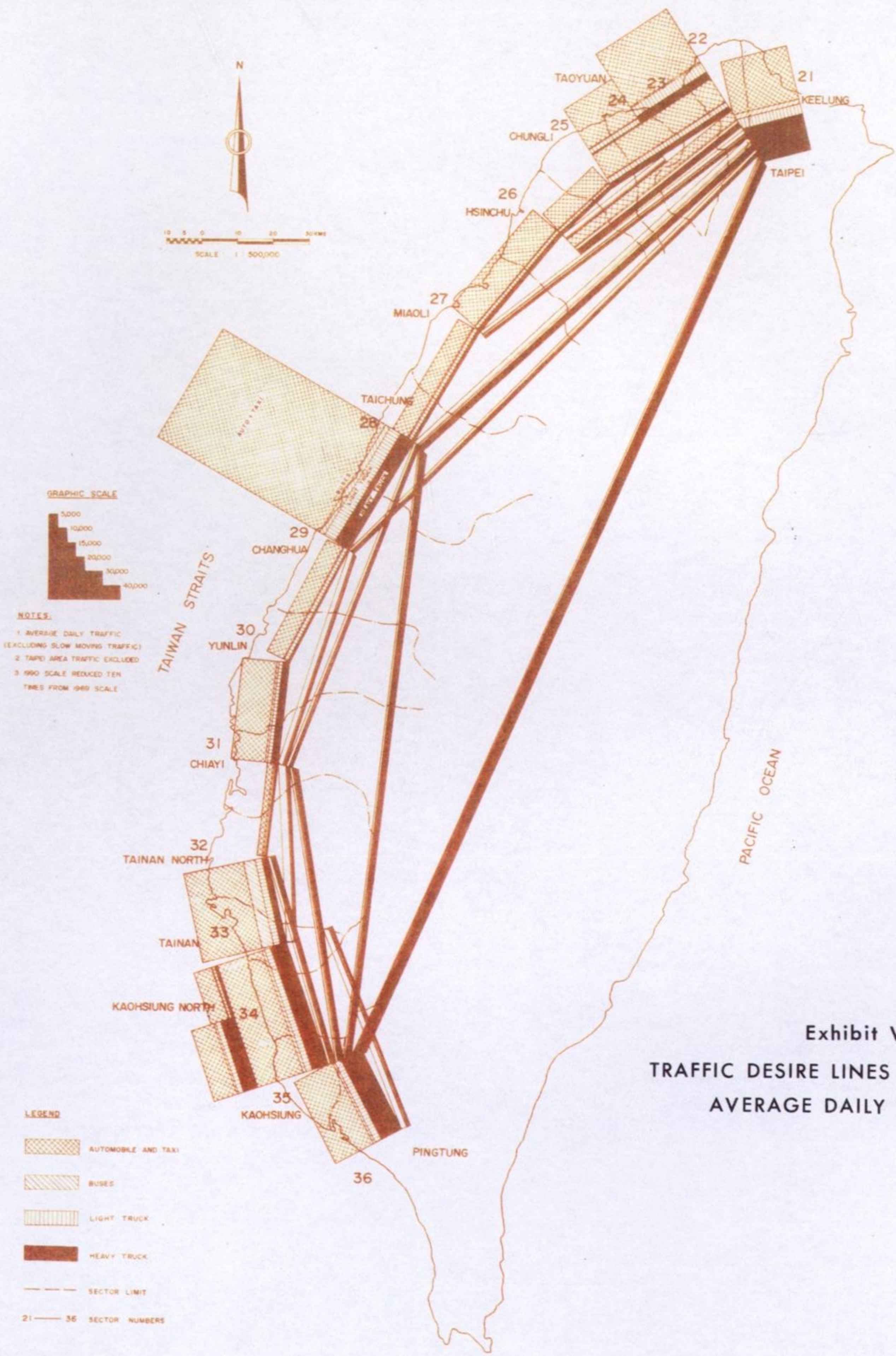


Exhibit VI-2

TRAFFIC DESIRE LINES BETWEEN SECTORS
AVERAGE DAILY TRIPS 1990

trips produced are then obtained for each sector and a correction factor is calculated for sector production. All volumes in rows are multiplied by the appropriate sector correction factor. The process is repeated until the results are balanced.

The four preliminary 1990 trip tables provided an approximate future traffic forecast before the results of the computer expansion were available. Screenline volumes were calculated as listed on Table VI-1. They were used for preliminary capacity estimates. Later the computer results were checked against the manual expansion results.

Trips between sectors are illustrated as desire-lines on Exhibit VI-2. Due to the large increase between 1969 and 1990, the scale on this plan is ten times larger than on Exhibit IV-12 showing 1969 desire-lines. The change in pattern is apparent.

Computer Expansion of Traffic by Zones

The traffic growth factors by zone were applied to the 1969 trips by zone with a FRATAR expansion computer program. The FRATAR expansion is mathematically different from the FURNESS method, but the results are approximately the same. In this expansion procedure, the present trips are multiplied by both origin and destination zone growth factors. An iterative process adjusts the zone-to-zone trips until future trip production and attraction for each zone are balanced.

Future trip tables by the 183 zones were tabulated for the four vehicle types. Total trips between sectors forecast for a 1990 average day were approximately 558,000 auto trips, 16,000 trips by express buses, 99,000 light truck trips, and 153,000 trips by heavy trucks. These did not include 26,000 trips originating at the planned Taoyuan International Airport.

The resulting average growth factors for total traffic were similar to those calculated by the FURNESS method: 16.0 for autos, 9.1 for light trucks, 7.5 for heavy trucks and 4.6 for express buses. Local bus trips were expanded by a factor of 3.6 for capacity calculations.

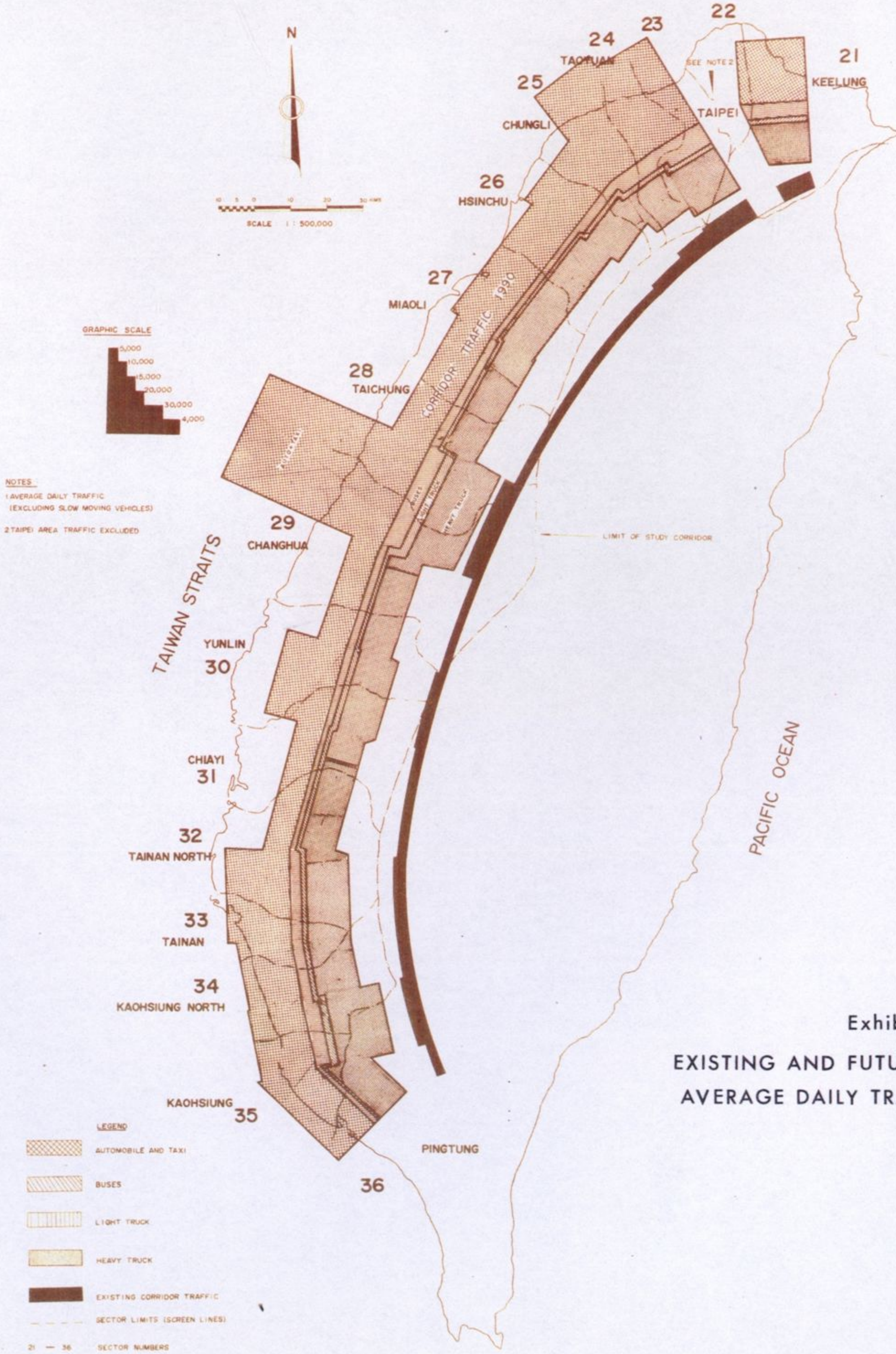


Exhibit VI-3

EXISTING AND FUTURE CORRIDOR TRAFFIC
AVERAGE DAILY TRAFFIC 1969 AND 1990

Assignment of 1990 Traffic to the Highway Network

Assignment of 1990 traffic to the 1970 highway network served to:

1. Check the computer assignment at the screenlines;

2. Calculate the theoretical operating cost of traffic in 1990 on highways "without freeway;" and

3. Calculate the theoretical need for and cost of highway widenings if no freeway were built.

The computer assigned the four 1990 trip tables by vehicle type to the minimum cost routes of the 1970 committed highway network. Traffic volumes at the screenlines were summarized and compared with the results of the preliminary expansion. The similarity indicated correct computer operations, except initially for volumes near Taipei and near Taichung. There, the unexpectedly high auto traffic exceeded the programmed computer capacity. This "overflow" required a change in the program limits to produce a corrected auto assignment printout.

The screenline volumes are represented for each vehicle type on Exhibit VI-3. This so-called "corridor" traffic was representative of total traffic flow along the study corridor. It can be compared visually with the total 1969 corridor traffic drawn on the same plan and at the same scale. The average tenfold traffic growth becomes evident.

The traffic volumes forecast for each major highway are illustrated on Exhibit VI-4. The scales of 1969 and 1990 flow maps are the same. The extremely high traffic of Highway No. 1 is represented by crosshatching overlapping the solid bands of traffic on other major highways.

Some adjustments in the assignments were necessary. These adjustments affected the assigned traffic volumes used for capacity calculations as well as the systems results computed for vehicle-kilometers, vehicle-hours, and vehicle cost. A direct "dummy link" between Taipei and Erhchung was introduced to handle correctly,

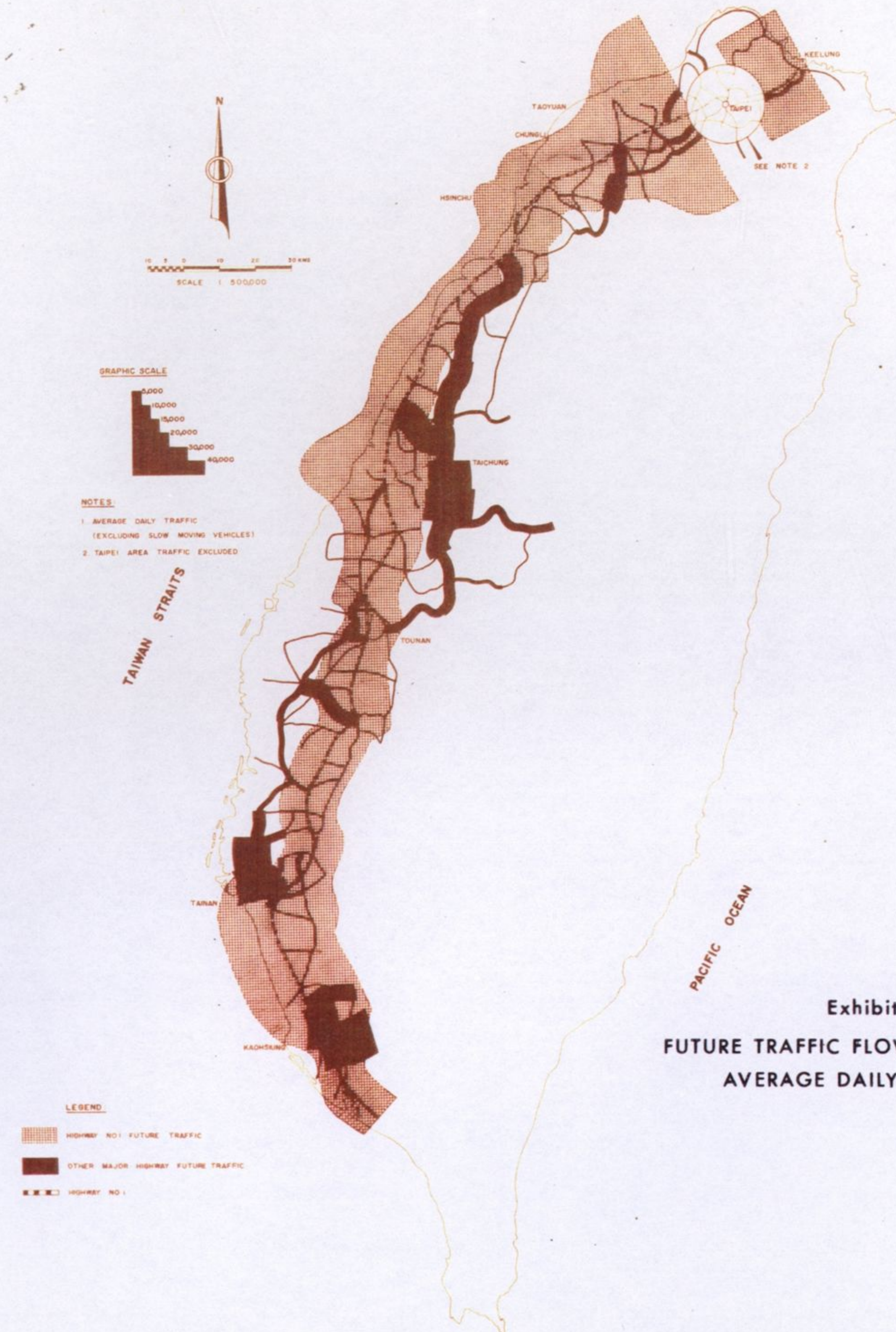


Exhibit VI-4

FUTURE TRAFFIC FLOW WITHOUT FREEWAY

AVERAGE DAILY TRAFFIC 1990

without "double-overflow", the very high urban traffic volumes across the Tamshui river. The affects of its real length, time and cost were manually added to the system results. The limit between Sections 4 and 5 was moved north of Taichung and Wuchi for freeway analysis, and the system results by section were adjusted accordingly. Final system results as shown in Table VI-2 served as a basis for calculation of operating savings.

Table VI-2 includes the system results for the ground traffic to and from the proposed new airport in Taoyuan. The estimated 26,000 average daily traffic for 1990 was based on the forecasts shown in the report on Airport Development in Taiwan prepared by Mr. Leigh Fisher, consultant retained by the CIECD Engineering Consulting Group. Of the forecast 26,000 ADT, 22,500 vehicles are expected to travel to Taipei (20,000 automobiles, 1,600 buses, 300 light trucks and 600 heavy trucks), and the other 3,500 vehicles are expected to travel to Taoyuan, Chungli and the areas to the south of Chungli. It was originally assumed that both international and domestic flights would be moved to this new airport. Later, it was indicated by the Civil Aeronautics Agency (CAA) that the existing airport in Taipei would be retained for domestic and military flights. The Fisher Report forecasts that approximately 20 percent of the ground transportation demand will be related to domestic air travel in 1975. It is estimated that by 1990, this proportion will be reduced to 15 percent. Fifteen percent of the average daily volume to Taipei would be approximately 3,000 vehicles per day in 1990. This number of trips would constitute a small part of the total estimated volume on that section of the freeway, and would be within the margin of error of 1990 traffic forecasts. Therefore, the estimated airport-oriented ADT traffic volumes on freeway links were not reduced.

ANALYSIS OF FREEWAY-RAILWAY COMPETITION

So far, the forecast of highway travel in the western corridor has dwelled on the "without freeway" condition, discussing first the system which exists today, and then extending essentially the same system albeit with a new port and a new airport, into the future. The 1990 pattern of highway traffic "without freeway" assumed that highway traffic would be accommodated by improving the existing highways, but with no major additions to the highway system.

For the forecast of rail traffic for the "without freeway" condition, the same assumption was made with regard to rail investment. Such investment would not proceed at a rate which would allow rail service to achieve marked improvement.

Under the "with freeway" condition, it was assumed that investment in both highways and railways would proceed at a pace that would allow these systems to effectively and efficiently meet all transport demands to 1990. Where highways were concerned, the freeway itself would represent the major portion of investment, and would, by itself, assure a substantial improvement in the operating efficiency of the highway transportation system.

The investment required to bring about marked improvement in railway operations would vary with the plan selected, and therefore could not be estimated exactly. The following discussion of the future rail system attempts to set realistic goals for operational improvements of the railway, and to determine how, and at what cost, these goals might be achieved.

Future Railway System

To compare properly the economic results which could be expected from freeway operations, the alternatives to freeway operations also had to be forecast. It would not be sufficient to base this comparison on a forecast of rail service predicated on the continuation of present rail costs and operating practices. This would deny that cost-reducing investments and more economic operating practices could be used to counter the gains expected from other transport modes. It is also desirable to calculate the most efficient level of rail operation possible within practical budgetary and time limitations. Such an efficiency model would simulate the optimum condition of Rail-Freeway rivalry and permit distribution of traffic on a practical least-cost basis. Such a simulation would also assume that the transport sector would fulfill its economic obligation of distributing the national resources and allocating the factors of production in the most efficient manner. TRA officials supplied details of future investment plans and described the goals established for improved operating economics. Specific goals include improved train speeds, larger train loads, less delay of freight in transit, reduced handling charges, and more detailed statistical analyses. It is expected that attaining such goals will result in reduced costs and, ultimately, permit lowering of rates. TRA has forecast capital expenditures over a 20-year period at NT$ 9.8 billion. These expenditures would cover electrification, heavier track and double-tracking, new and improved marshalling yards, truck freight services, and sidings. The expected costs of equipping for containerization were set at NT$ 400 million, excluding specialized trucks, but including palletization equipment. Electrification and double-tracking expenses over the next four years would reach an annual total of NT$ 500 million if the system met demand at its present level. With rising traffic demands, future annual expenses should increase to NT$ 875 million. Heavier, 50-kg rail would largely replace the 37-kg rail in use on the main line, and heavier ballast and track fixtures would permit heavier trains to travel faster.

Operating practices would benefit from the concentration of cargo loading operations at large stations, resulting in less freight train delay (now 17 hours per day average). The goal for freight train speeds is 50 kilometers per hour as compared with a present average of 19.4 kilometers per hour. Load goals are an average of 2,000 tons per train, as compared with the 1969 average loading of 600 tons for diesel-electric trains, and 300 tons per steam locomotive. Electrification and track improvements are expected to contribute to these improvements. Operating practices, moreover, will be of comparable importance. Scheduling, signalization, and coordination of train movements should be engineered to assure that the capital investments in equipment are adequately transmitted to cargoes and passengers.

Efficiency Index and Train Speeds

Both absolute and relative criteria may be established to identify efficiency, as opposed to lack of it. Absolute criteria would demonstrate actual reductions in costs of operation, per passenger-kilometer and per ton-kilometer. These costs could be separated into time and distance components. The influence, therefore, of cost reductions will be examined in context with the kind of capital investments and operating practices which reduce costs. Relative criteria would measure the potential for changes in practical capacity, speed, and turnaround time of trains in relation to previous experience of the railroad, and to the relative changes taking place on the road system with which the railroad must be compared.

TRA WEST LINE RAILWAY EFFICIENCY INDEX
(Ratio of Annual Traffic Units to Engines Owned)

Year	Annual Traffic Units[1] (Millions)	Number of Engines Owned	Traffic Units[1] Per Engine (Millions)
1955	3,838	260	14.7
1956	4,172	264	15.8
1957	4,902	278	17.6
1958	5,133	278	18.5
1959	5,133	277	18.5
1960	5,172	284	18.0
1961	5,422	313	17.3
1962	5,059	284	17.8
1963	5,195	284	18.3
1964	5,834	284	20.5
1965	6,313	284	22.2
1966	6,507	360	18.1
1967	7,081	360	19.7
1968	7,675	337	22.8

[1]-Ton-kilometers plus passenger-kilometers.

Among relative criteria, the capacity for handling total traffic by the available motive force is primary: i.e., the capability of a given increase in numbers of engines (including the influence of increasing numbers of diesel-electric locomotives) to produce a measurable increase in efficiency in serving the ton-kilometer and passenger-kilometer demand. In the table below, total traffic units of demand are defined as the sum of annual ton-kilometers and passenger-kilometers handled by the West Line Railway. The total number of engines in use on this line at the end of each year is divided into the total traffic units. This produces a ratio which measures the volume of traffic units (in millions) handled annually by the motive force. A rising ratio indicates that increased numbers of engines have been operated in a manner to increase the rail capacity for handling growing demand. The preceding table shows that this ratio for the West Line Railway has been rising over the years. This is particularly true for the years 1962-1965, when, with a constant number of engines, the capacity ratio increased each year as traffic units expanded by 1.5 billion units. This condition also occurred in 1966-1967.

However, it is not possible to conclude from this isolated index that acquisition of new engines alone produces a desirable measure of efficiency. The validity of this measure depends upon average train speeds during the same period. If train speeds tend to increase as well, it may be presumed that traffic was indeed served better by the available motive equipment.

Passenger and freight train speeds have shown only modest improvement in the past 11 years, as indicated in the following table. The compound rate of increase in passenger speeds was only 1.9 percent over the 1958-1968 period, and only 1.6 percent for freight. Further, the low train speeds for both passenger and freight service are an indication of the handicap faced by rail in competition with express bus or truck operations. Rival road vehicles on the existing road system average 43 kilometers per hour, and enjoy lower handling costs and more frequent schedules.

AVERAGE TRAIN SPEEDS ON THE TRA SYSTEM
1958-1968

Year	Average Speed (km/hr) Passenger Trains	Freight Trains
1958	32.1	16.5
1959	32.8	16.1
1960	33.3	15.5 (flood)
1961	35.1	17.6
1962	37.4	17.1
1963	39.0	17.2
1964	38.7	19.2
1965	40.5	20.1
1966	39.8	19.3
1967	40.2	19.3
1968	38.8	19.4
1958-1968 Compound Growth Rate	1.9% per year	1.6% per year

It can be concluded from the relationship between number of engines, units of traffic handled per engine per year, and train speeds that capital investment alone achieves little unless accompanied by improved operating practices. In the forecast of engine requirements which follows, it was assumed that capital expenditures for new locomotives would be matched by more effective operating techniques to achieve the desired goal of increased speeds.

Planned Speed Improvements

The TRA plan to attain higher train speeds is shown in Table VI-3. Speed goals were discussed with TRA and were understood to be attainable only by investment in related marshalling yards, station relocation, and revised handling procedures in addition to improved engine utilization. Higher average train speeds, therefore, would be a function of improved railroad technology as well as investment. Realization of planned train speed improvements was assumed for purposes of this study, and this assumption constitutes a part of anticipated fundamental changes to reduce absolute costs.

Forecast improvements in train speeds shown in Table VI-3 indicate that no change is predicted in non-express passenger train speeds. While express passenger and freight trains will attain substantial gains over present speeds, it would be impossible to effect a simultaneous increase in the flow of all trains, even on an expanded network including side-tracks, double-tracking and central traffic control equipment. It was assumed, however, that attainment of speed goals for express and freight trains would cause minimum disturbance to ordinary passenger traffic, and that this traffic would be carried at present speeds despite increased volumes. The summary effects of these changes are indicated below:

TRAIN SPEEDS ON THE WEST LINE RAILWAY
1968 Actual and 1980 Forecasts
(Taipei-Kaohsiung)

	Ordinary Passenger		Express Passenger		Freight	
Year	Running Time In Hours	Average Speed In Km/hr	Running Time In Hours	Average Speed In Km/hr	Running Time In Hours	Average Speed In Km/hr
1968	9.35	36.3	5.66	66.3	19.3	19.4
1980	9.35	36.3	3.50	107.14	11.2	33.4

The rate of change in speed for all trains was estimated on the basis of the rate of replacement of steam locomotives by diesel-electric units--forecasted at 7.9 percent per year--and relative expected demand. Accordingly, express train speed was forecast to improve at a rate of 4.1 percent, and freight train speed at a rate of 4.6 percent.

Train turnaround times will similarly depend on the changes in train speeds, and on improved handling at marshalling yards and stations. The cost effects of improved turnaround times are difficult to quantify. The influence of train speed changes alone, and its effects on cost, will necessarily remain the principal measure of total rail efficiency. The following section will forecast capital investment requirements foreseen by TRA, with the final objective of comparing these investments with the rise in traffic forecast for the rail system. Only after capital commitments and operating changes are made can it be determined whether their joint product will reduce average passenger-kilometer and ton-kilometer costs of the rising volumes of traffic.

Forecast of Capital Investment Requirements

The capital expenditures of TRA during the period 1963-1966 have been reviewed in detail to determine the kinds of investment and the frequency of such investments in various types of equipment. The capital accounts, shown on Table VI-4, indicate wide variation from one year to the next for most major items. For the four-year period studied, average expenditures on transportation equipment were 89 percent of total expense while costs of land, construction and mechanical equipment were about 11 percent. Rolling stock constituted 36.9 percent of average annual expenditures while expenditures for fixed installations represented 51.8 percent. From these accounts, an average annual total capital expenditure of NT$ 284 million was derived. These costs may be compared, therefore, with the forecast new total levels of capital costs which follow. It is possible to predict the amounts certain changes in capital investments which will be required, therefore, in order to produce the levels of efficiency desired.

Based on unit costs TRA has paid recently for rolling stock, rail equipment, and other materials, estimates were made of capital requirements for major items. Only major and primary equipment costs are known. The following cost estimates, therefore, are considered minimum. Table VI-5 shows required rolling stock as estimated on the basis of rising total traffic demand. Numbers of diesel or electric locomotives, passenger coaches and freight cars are forecast. The rise in locomotives assumes successful attainment of at least part of the electrification program by 1980, which would permit a combined diesel-and-electric motive force to replace all steam locomotives. Further detail of these costs, and their annual total sum by type of rolling stock, is shown in Table VI-6. Total demand-to-vehicle ratios in 1960, 1966, 1967 and 1968 were estimated. This ratio describes the volume of traffic units handled annually by locomotives, freight cars and passenger coaches. With improved equipment, such ratios should increase and more traffic would be accommodated per unit of investment. Rolling stock required in each year was estimated by applying the present demand-to-vehicle ratio to the growing traffic demands for each type of vehicle. Table VI-5 shows the accumulated total of all such rolling stock for 1980 and 1990.

The prices of equipment were estimated on the basis of two sources of data: historic average prices, and recently quoted prices in the World Bank loan negotiations. Both are shown by the footnotes to Table VI-6. Historic prices were used for estimating cost per vehicle of each type in each future year. These prices are lower than estimates used by the World Bank. The lower prices per unit permitted use of a constant demand-to-vehicle ratio to stabilize demand, rather than allow demand to be predicated on improved capacities. This was in accordance with financing criteria dictating investment decisions in the past. The rise in costs, therefore, would neither reflect over-optimistic train-load estimates nor depart markedly from historic trends. Restraints imposed on average capacity by older equipment could not be determined. Rather, speed improvements were forecast separately, with diminished delay times of freight, to give effect to the observable influence of larger unit capacity and improved operating conditions generally.

The final four columns of Table VI-6 show the separate annual capital costs associated with passenger service on one hand and freight service on the other as a result of the division of costs detailed in preceding columns. The use of locomotives by service was split 58.6 percent passenger and 41.4 percent freight.

There is some tendency for the computed traffic demand-to-vehicle ratio to understate gains which would arise from purchase of larger-capacity rolling stock than that now used on the rail line. The present ratio responds directly to the current mix of vehicles. The forecast rates of replacement of old vehicles and addition of new vehicles would alter the average total capacities of the freight and passenger fleet, but by unknown amounts. Such changes should be estimated, however, to explain more accurately the derivation of efficiency improvements. Indeed, capacity changes will contribute to the chief factor of speed changes and thus have a bearing on potential cost reductions. On the other hand, World Bank cost estimates for future rolling stock are at higher unit costs than those historically paid by TRA. This would cause the expected gains to come at a higher total cost. The relation of the added costs to the added capacity and speed changes, therefore, might provide a comparison of the higher potential level of costs which may be incurred in connection with the forecast gains.

World Bank cost estimates for rolling stock are compared below with the costs used in this forecast:

COMPARATIVE COST ESTIMATES
FOR ROLLING STOCK

World Bank Estimates
Vs.
Costs Used by Consultant

Estimate	Locomotives	Passenger Coaches	Freight Cars
World Bank	9800	2200	500
Cost Used	7774	1800	210
Difference	2026	400	290
World Bank Cost As Percent of Cost Used, Less 100%	26.1%	22.2%	138.1%

It was estimated that electric locomotives would show a 20 percent gain in capacity over that of existing diesels. Freight car capacity would increase from an average of 17 tons to 35 tons, or by a factor of 2.06. Passenger coaches, mainly first-class and express, would increase 110 percent in capacity. The large number of freight cars in service would modify the overall effect of capacity improvement offered by new cars. It is estimated that, to 1980, this fleet restraint would reduce average capacity increase to about 140 percent. The resulting incremental cost per incremental efficiency gain (in capacity) may be expressed as follows:

	Locomotives	Passenger Coaches	Freight Cars
Cost increase [1]	26.0%	22.0%	38.0%
Capacity increase	20.0%	10.0%	40.0%

[1] - World Bank Estimate as Percent of Cost Used, Less 100%

The foregoing table shows that capacity gains would be less than the probable added costs according to World Bank estimates, if total average fleet restraints were permitted to absorb much of the gain. If speed improvements forecast by the Consultant were added to these capacity gains, however, a better result would follow. This result is forecast by using lower unit costs than World Bank estimates, and anticipated higher speeds. The percentage gains in operating performance are shown below:

Speed	Express	Freight
1980 km/hr	107.1	33.4
Present 1968 km/hr	66.3	19.4
Difference	40.8	14.0
Increase in Speed Related to Present Km/Hr	63.0%	72.0%

These gains compared with the percent increases in costs, show that efficiency investments would result in larger percentage gains in speed than in capacity. The costs used in this forecast may be understated whereas the final product of improved speeds would result as much from planned operational changes as from capacity improvements.

Estimated capital cost of improvements in addition to new rolling stock scheduled for future years totals NT$ 4,200 million for heavy rails, track fixtures, signal equipment, traffic control devices, and electrification. Total costs were derived from unit costs estimated for such facilities as shown in Table VI-7. The division between passenger and freight service of such capital expenditures is shown according to the average 1966-1968 ratio used by TRA. The forecast capital costs by years to 1980 may be compared with the prevailing historic relation of capital costs to total costs, and with the rise in capital costs during the period 1958-1960 to 1966-1968. Capital costs increased 1.91 times from the 1958-1960 level to 1966-1968. In 1970, the first year of major new investment forecast for TRA, passenger costs will be 2.68 times, and freight costs 2.40 times the 1958-1960 level. In succeeding years to 1980, annual capital costs will decline on average, their multiple over the period 1958-1960 to 1966-1968 reaching relatively higher levels for freight than for passenger service. The annual investment multiple is expressed as a relation to the 1966-1968 average. On average, capital expenditures will be much higher than experienced historically.

Estimate of Future Costs

The forecast investments shown on preceding tables have been translated into capital depreciation charges based on a six percent average charge. These charges are later combined with estimated maintenance costs to form a basis for estimating total operating costs. For comparison with the estimate of future total operating costs, the period 1958-1960 witnessed a total operating cost 4.369 times the average gross capital investment. In the period 1966-1968, the ratio expanded to 4.769 times gross capital investment. The calculations shown in Columns 3 and 4 of Table VI-8 presume continuation of this trend, which would exist in the event that cost-reducing efficiency investments were not achieving their purpose, as, indeed, they have not in the past. Total operating costs were forecast to increase at a constant multiple of gross capital investment of 4.769 times, therefore, to reflect the potential rise in costs if administrative and operating practices should actually fail to relieve congestion of track facilities, give faster train speeds, and reduce cost of operation. These columns may be compared with the last two columns which show the alternative expected total operating costs, based on attainment of the goals set for future operation. The expected results of capital investment and of operating efficiencies are shown to produce operating cost reductions which would greatly decrease the existing 4.769 ratio.

The average charges for passenger and freight depreciation are shown for prior years, and forecast as annual cumulative amounts to 1980 by adding across the net annual depreciation charges from Columns 1 and 2. Such charges rose only from the annual additions of depreciated new capital investments. To cumulative capital charges were added cumulative maintenance charges, which are estimated to increase initially at four percent annually to give effect to higher maintenance costs of workshops and labor during the changeover to new and unfamiliar equipment. After 1972, the rate declines at four percent annually. This, to some extent, would offset the parallel rise in depreciation charges. Historically, combined depreciation and maintenance charges have been 46 percent of total operating costs. Any improvement in operating costs could be expressed as a change in this percentage. In calculating this, it was noted that passenger costs have been at higher levels of combined maintenance-depreciation charges, the latter being 43 percent of total costs. The rate of change in passenger service would be favorably reflected only in express passenger service, i.e., the anticipated speed improvement from 66.3 kilometers per hour to 107 kilometers per hour, while ordinary trains would continue to operate at present average speeds of 36.3 kilometers per hour. Therefore, total passenger operating costs could be expected to decline more gradually than freight costs since freight train speeds are expected to rise from 19.4 kilometers per hour to 33.4 kilometers per hour. The forecast ratio of total costs to basic capital and maintenance charges, therefore, would be different for passenger and freight services. The rise in the ratio for each indicates a relative decrease in total operating costs.

On this basis, the resulting forecast shows a decline in total operating costs as a function of capital-and-maintenance costs for both passenger and freight operations. This reflects a lowering of operating costs as a result of improved efficiency of operations. That is, operating costs decline as a function of capital investment and good management. The consequences of such investments and of the resultant reduction in operating costs may now be restated in Table VI-9. Here, forecasts of passenger and freight demand are compared with the forecasts of future total costs which were incurred to satisfy these demands with improved efficiency of operations. As a basis for final estimates of the costs per passenger-kilometer and per ton-kilometer, historic cost levels are shown for comparison with forecast unit costs. In summary, the following data are obtained for passenger and freight services:

TRA WEST LINE TRAFFIC DEMAND AND UNIT COSTS
Actual 1958-1968 and Forecasts 1970, 1975 and 1980

	Passenger Service		Freight Service	
	Passenger-Km (Million)	Cost per Passenger-Km (NT$)	Ton-Km (Million)	Cost per Ton-Km (NT$)
1958-1960	3328	$ 0.1526	1817	$ 0.2204
1966-1968	4742	0.2187	2329	0.2402
1970	5685	0.2018	2639	0.2854
1975	7528	0.1870	3368	0.2531
1980	9786	0.1529	4528	0.1952
Average Cost 1976-1980	-	$ 0.1649	-	$ 0.2166

Passenger demand was forecast to grow at 3.2 percent per year compounded. Passenger-kilometer demand was forecast to increase under the "without freeway" condition at 5.3 percent. An assumption of lower passenger-kilometer growth, at 3.6 percent, was used for comparative purposes only to test the resulting effects on costs per passenger-kilometer which might result from disruption of service or delayed passenger response. Unit costs decline in both cases below the levels prevailing in 1966-1968, and to the approximate level of unit costs in 1958-1960. Total passenger-kilometers by 1980, however, are expected to be three times those of 1958-1960. Freight service is forecast by the Consultant to grow more rapidly than expected by TRA. The compound rate of growth of freight tonnages, which was used to forecast the improvement of rail operations, was 5.2 percent in contrast to 3.1 percent historically. The growth in ton-kilometers of demand reflecting longer distances of haul, rises more steeply at 5.8 percent annually. The rise in freight demand was based on the expected strategy of concentrating cargoes at main stations to shorten the 17 hours of delay per day presently experienced by shippers. The delay was estimated to decline to 11 hours, several hours below the average delay over the past 18 years. Speeds above 33 kilometers per hour are not expected despite a goal of 50 kilometers per hour. This will be due to the inability of the advanced system to do more than merely cope with rising ordinary (and discount) passenger demand, and to modernize express services in the face of congestion induced by discount policies, which are presumed to continue. The important cost reductions shown could be passed on still further to cargo and passengers if price policies reduced the volume of discount passengers below the expected level. Student discounts will soon expire. Restrictions on students in traveling from one school district to another will be prohibited. The slack in train scheduling will be absorbed by gains in increased speed and/or frequency of express trains.

TRA forecasts of future growth show that demand is expected to grow by 1978 to 8,660 million passenger-kilometers and 3,316 million ton-kilometers (both for West Line only). The forecasts in Table VI-9 shows passenger-kilometers in 1978 to be 8,814 million, and ton-kilometers to be 4,022 million. TRA forecasts of capital equipment investments needed for expansion over the 20-year period were NT$ 9.8 billion. This forecast indicates a total of NT$ 13.2 billion comprised of NT$ 4.5 billion passenger service rolling stock, NT$ 4.5 billion for freight service rolling stock, and NT$ 4.2 billion in related track facilities.

The unit costs per passenger-kilometer and per ton-kilometer which result from forecast efficiency investments, as shown by Table VI-9, were not carried beyond 1980. The investment of TRA in equipment other than rolling stock cannot reasonably be forecast beyond 1980. All electrification and modernization requirements other than rolling stock, therefore, were confined to the ten-year period 1970-1980. The earliest impact of such capital commitments was sought for comparison with the expected unit costs and traffic demands that could reasonably be expected from freeway operation. These would begin before 1980. Because relative costs of transport services will affect relative prices, the level of costs of rail passenger and freight services, which are identified as an average 1976-1980 cost level, may be taken as the basis of competition with road vehicle costs during the same period. These average costs were NT$ 0.1649 per passenger-kilometer and NT$ 0.2166 per ton-kilometer.

Estimate of Future Prices

With the attainment of reduced costs, TRA would be in a position to reduce fares and tariffs. Only by such reductions could the benefits of rail investments and modernized operating practices be transmitted to the economy in the form of user benefits. This would assure least-cost transport and improve the allocation of national economic resources. Table VI-10 presents the effects which would result from a continuation by TRA of its present price markup over costs for each category of cargo service. If, in other words, TRA retained its previous share of profits, and lowered fares and freight tariffs only by the same multiple over costs as in the past, the savings would not be fully passed on to rail users. This table compares the same situation as it may confront truckers which, with lowered unit costs per ton-kilometer, nevertheless may apply price markup equal to the percentage existing in 1969. The resulting rivalry distances of 40 kilometers and 100 kilometers show that truck costs would be cheaper than rail costs (assuming that rail handling costs remain at their 1969 levels), but that truck prices would still be higher than rail prices at the 100-kilometer distance. In short, the competitive cost situation which now exists would be unchanged in 1980, except that the absolute level of costs and prices would have indeed fallen for users. These prices would have decreased by controlled amounts, however, and would retain the rigidity and arbitrary quality of regulated price structures.

These cost-price relationships will be modified in the analysis of freeway-railway competition. For both road and rail services, prices as multiples of cost will be lowered by equal percentages. By such price rationalization, the real economic gains which will accrue to the economy from efforts to improve the total transport network will be determined. The effects of such price-cost relationships will provide the basis for analysis of future distribution of passengers and cargoes between the transport services, according to their least cost, and will measure the total levels of gain achieved by investments in the respective services.

Analysis of Conversion of Railway Traffic to Freeway

It has been shown that the increasing efficiency of the railroad would achieve important cost reductions. These would result from efficiency improvements and the growing levels of forecasted passenger and cargo traffic. In combination, these would produce lower ton-kilometer and passenger-kilometer costs for the system. The basic cost per passenger-kilometer would become NT$ 0.1649, and the cost per ton-kilometer would become NT$ 0.2166. The equivalent changes in highway traffic costs which would result from freeway operation may now be examined and compared with forecast rail costs.

Rail-Bus Rivalry

Table VI-11 compares forecast passenger-kilometer costs of the expressway with costs on the improved railway system. Time and distance costs of vehicle operation are shown in Columns 1 and 2. The significant changes which would result from freeway operation of road vehicles would consist mainly of time savings. The average system-wide freeway speed improvement, after considering differences in sectional design requirements, reflects an increase to 87.31 kilometers per hour for all vehicles. Table VI-11 compares this speed with the average "efficient" rail passenger train speed of 107 kilometers per hour. As a result of the speed change, buses on the freeway will travel over 44 kilometers per hour faster than under the existing "without freeway" system. Table VI-11 translates the speed change into a time cost per kilometer, based on the equivalent kilometers per minute represented by the speed itself. Adding distance costs to the time costs, both stated in costs per kilometer, gives total cost per vehicle-kilometer. Dividing by the average number of passengers produces the average total cost per passenger-kilometer. As shown in Column 7, this becomes NT$ 0.089 for express bus passengers and NT$ 0.425 for taxi passengers.

It is noted that time costs of railway operation can be presumed included in the distance costs per kilometer. Such costs include capital depreciation, wages and salaries, and interest charges. Reconstruction to separate time and distance costs would be possible but is not deemed necessary to determine total rail costs. For rail passenger-kilometer costs, prior calculation of total costs and total passengers produced the average NT$ 0.1649 per passenger-kilometer which was entered in Table VI-11 for comparison with equivalent road vehicle costs.

The effects of reduced costs on prices is shown in the last two columns. Prices in 1969 reflected arbitrary markups established by regulatory agencies. If these markups were forecast to continue, a rational price policy could not be introduced into this analysis. The forecast level of markup was set according to the analysis reflected in Tables VI-12 and VI-13, therefore, which will be discussed shortly. The results of that analysis suggested a markup which would have as its minimum, 110 percent of cost, and as its maximum, 150 percent of cost. This range of price mark-up is reflected in the estimated 1980 markup shown.

Rationalized prices designed to more adequately represent actual costs were introduced into Table VI-14 as a new standard for price levels which would prevail under a management with authority to set fares and tariffs.

The reduced cost-price levels examined in Table VI-11 are restated in Table VI-14 to show, for an average passenger trip by any mode or vehicle type between Taipei and Kaohsiung, that passenger-kilometer prices will decline for both rail and road passengers. In Table VI-14 existing rail and road systems are compared with forecast rail and road systems after improvements. The freeway would provide distance savings as well as higher design speeds, reducing the Taipei-Kaohsiung road length from 375 to 334.4 kilometers. Rail realignment would decrease rail distance from 375 to 360 kilometers. The combined influences of realignment, speed changes, cost, and prices may now be examined by multiplying the old and the new prices per passenger-kilometer by the distance of the average journey. This gives average fare by type of conveyance between Taipei and Kaohsiung. Considering the faster speed, the average minutes in transit may be compared by type of conveyance, and the average cost to the passenger per minute of travel can be estimated.

The total fares per passenger-kilometer by existing systems, and by freeway and more efficient rail, by type of vehicle, are summarized below:

	Fares Per Passenger-Kilometer		
Service	Existing Systems	Freeway	More Efficient Rail
Rail--ordinary	NT$ 0.265		NT$ 0.189
Rail--express	0.487		0.244
Bus	0.328	NT$ 0.178	
Taxi	0.667	0.574	

With these changes in absolute prices, the relative costs to the passenger which will influence his choice of conveyance will also change. Prices will be based on costs, and both prices and costs will be reduced. The price reduction obtainable by freeway and by more efficient rail will become, in terms of the new price as a percentage of the old: 71.32 percent for ordinary rail, 50.10 percent for express rail, 54.26 percent for express bus, and 86.05 percent for taxi.

Table VI-12 shows present TRA passenger fare markups over cost. The present fares charged to TRA's various passenger classes may be compared with the average total costs which are related to these fares. The percentage relationship of price to cost for the various passenger classes ranges from 256 percent for tourist class to 8.8 percent for student commuter class (91.2 percent discount).

If a price markup over cost were continued into the forecast period according to these present rates, the forecast passenger fares which would be introduced into the comparative road vehicle cost analysis would place the rail at a disadvantage. The extent of the comparative disadvantage can be measured. Table VI-12 shows passenger-kilometer fares for the forecast period with the current markup for two potential average cost levels: NT$ 0.1649 and 0.1958. The lower price reflects the expected average future costs (see Table VI-9) if present trends of rail passenger traffic continue, and an alternative highest cost if disruption of facilities due to construction interrupts the trend.

Price Policy

Table VI-13 shows, in the center section, the new fares by passenger class which would result from application of a price markup policy which had a minimum markup of only 110 percent for full-fare passengers and a maximum of 150 percent. Number of discount passenger fares would need to be increased as shown to compensate for the revenue loss, therefore, to cover total costs according to the estimated future average traffic distribution calculated in the final columns. The forecast passenger-kilometer fares show a substantial drop, it will be noted, from the levels shown by Table VI-12. The table shows that the influence of disrupted traffic on costs and on existing markup in passenger fares, is of less significance to the railway perhaps, than would be the ultimate effects of a rationalized price policy. If improvements are costs is the initial objective, care should be taken lest disrupted service incur higher unit costs. Equally great concern should attach to a price policy which more closely relates to unit costs.

A disrupted service, with high markups, would produce an average express fare of NT$ 0.416 per passenger-kilometer. An uninterrupted service, with high markups, would produce an average express fare of NT$ 0.354. A rationalized price for uninterrupted service would produce an average express fare of NT$ 0.244. Ordinary fares on the postulated railway would similarly be reduced on average (ordinary and through passengers) from the 1969 fare of NT$ 0.265 to the 1980 fare of NT$ 0.189.

Express Passenger Diversion

Table VI-14 shows that, under conditions of freeway operation, reduced bus costs (from NT$ 0.328 to 0.178), would result from improved speeds and shortened distances of freeway travel. Time and distance cost comparisons with the improved efficiency rail model reflect an improvement in express train speeds from 66 kilometers per hour to 107 kilometers per hour, against bus speeds which rise from about 43 kilometers per hour to 87 kilometers per hour. Bus distances would be 334 kilometers between Taipei and Kaohsiung, and train distances would be 360 kilometers. The ability of rail express operations to compete effectively with buses would be constrained, however, by the fact that the average rail express passenger trip length would be only 147 kilometers. With lower express bus costs (NT$ 0.178 versus rail express at NT$ 0.244 average), the express rail passenger would be vulnerable to diversion. This would be true even though the express bus fare markup were 200 percent of cost, and the rail markup were 147 percent of cost. Table III-9 showed that rail express passengers were only 4.5 percent of total rail passengers, but these passengers traveled the longest distances of all full-fare passengers and paid the highest fares. Rail express passengers depend on train departure schedules which are limited in frequency by the bulk of total rail demand on rail facilities of fixed capacity. Bus frequency depends only on the number of buses available. Discount passengers carried by rail are not subject to diversion, even though these show longer distances traveled, because the relative fare per kilometer of travel would be below that of express bus. No local buses are expected to use the freeway. Thus, express bus passenger fares would largely determine the relative potential for diversion.

Although average fares by freeway bus would clearly indicate lower fares for express passengers than by rail, other factors would be significant in rail express developments. The efficiency rail model of reductions in passenger-kilometer costs (shown in Table VI-9) shows that costs would fall to NT$ 0.1529 by 1980, as compared with an average total cost per passenger-kilometer of NT$ 0.1649 for the period 1976-1980. The decrease in cost would be reflected in lower fares for average express passengers. This lower fare should tend to reverse the rail diversion process by 1980, because the average fare of express rail passengers would decline by 1980 to a level competitive with freeway bus fares. Therefore, rail diversion to freeway buses would begin sometime after opening of the freeway, but terminate sometime in 1980 with the attainment by the rail of lowered average costs. The potential diversion of rail passengers to the freeway, therefore, was forecast only from a hypothetical 1969 value through the year 1980. Only rail express passengers (of all rail passengers) were considered as potentially divertible from rail. Thus, the maximum amount of diversion would entail a shift from rail of only 4.5 percent of total rail passenger traffic, or the equivalent of around 18.1 percent of rail passenger-kilometers.

It was estimated that, were the freeway open in 1969, the maximum amount of passenger traffic that might be diverted from rail, i.e., 100 percent of express passengers, would be diverted. It is a generally accepted standard of diversion analysis that, when the cost (including time cost) of one travel alternative becomes twice the level of a second alternative, there would be 100 percent conversion of traffic from the first to the second alternative. Thus, in 1969, with freeway bus service costing passengers NT$ 0.178 per passenger-kilometer, compared with NT$ 0.487 on the railway, and with the bus also saving passengers 13 seconds per kilometer because of higher speeds, and, finally, with buses providing greater convenience (although, perhaps not greater comfort) than the railway, there should clearly be 100 percent conversion of passengers from rail to highway.

The situation with both systems improved, i.e., the situation in 1980, would not be so clear. At that time, the highway would still have a cost advantage, but the railway is foreseen to have a time advantage (as express passenger trains would average 107 kilometers per hour, while freeway buses would travel at about 87 kilometers per hour). Freeway buses should still have an advantage over the railway, with regard to convenience (since reservations should not need to be made, and there would be no limit on the frequency of bus trips), but this edge of highway buses over the railway should be counterbalanced by the greater comfort (especially, the freedom to move about) of the railway. Thus, total comfort and convenience benefits by each of the modes, would be approximately equal after both transport modes had been improved.

The differences that would exist in 1980, then, can be measured solely in terms of passenger fares and travel times. As indicated in the discussion of the hypothetical 1969 situation, the bus fare per passenger-kilometer would be NT$ 0.178. The railway fare in 1980 would still be higher than bus, with a fare of NT$ 0.244 per passenger-kilometer. Thus, the fare differential between rail and highway bus would be NT$ 0.066 per passenger-kilometer in favor of the bus.

Partially offsetting this advantage of highway buses, the railway would have a time advantage of seven seconds per passenger-kilometer. Thus, if the value of saving one second per passenger-kilometer were approximately NT$ 0.01, the 1980 highway bus fare advantage and railway time advantage would cancel each other out, and express passengers would be expected to be divided about equally between rail and freeway bus.

To estimate the value of one second per passenger-kilometer to long-distance express passengers, the situation in 1968 was considered. At that time, the railway had a cost disadvantage of NT$ 0.159 per passenger-kilometer and a time advantage of 26 seconds per passenger-kilometer. If there had been a 50-50 split of long-distance passengers, in that year, it would have appeared that 26 seconds was considered to be worth NT$ 0.159, or one second was worth approximately NT$ 0.006.

The railway transported only about 42 percent of long-distance passengers in 1968, however, so either 26 seconds were worth less than NT$ 0.156, or buses had net advantages in total comfort and convenience. This latter possibility was discarded, since, despite being less convenient than bus transportation, railway travel was much more comfortable than travel by bus.

A diversion curve was plotted to estimate the value of time savings via rail. The curve was also used to estimate the distribution of auto traffic between alternative routes. The curve indicated that a 42:58 split of traffic would be expected when the cost of traveling by one mode was approximately 105 percent of the cost of traveling by the other.

Thus, the cost of traveling by rail in 1968, viz., NT$ 0.487 per passenger-kilometer, should be about 105 percent of the sum of the bus fare per passenger-kilometer, viz., NT$ 0.328, plus the value of 26 seconds. The latter sum would equal NT$ 0.464, and the value of 26 seconds would therefore amount to NT$ 0.136, or NT$ 0.0052 per second. Using this value for the 1980 situation, when the railway would have a time advantage of seven seconds per passenger-kilometer, the time advantage would translate into a cost advantage of NT$ 0.036 per passenger-kilometer. Freeway buses would have their cost advantage reduced, therefore, when time disadvantage was taken into consideration, from NT$ 0.066 to NT$ 0.030. The cost of traveling by rail, therefore, would be approximately 114 percent of the cost of traveling by highway bus, and the passenger split on this basis would be about 28:72 (compared with 42:58 in 1968).

There are inaccuracies inherent in this method of analysis, however, and it is difficult to measure the value of comfort and convenience. Passenger time, moreover, will undoubtedly be worth more in the future than it is at present. It was concluded, therefore, that the comparative costs of traveling by rail and highway bus in 1980 and thereafter were too close to permit the forecasting of any passenger conversion from rail to highways. Thus, it was forecast that the express passenger split between rail and highway bus by 1980 would revert to the split of 1968.

To obtain a regional distribution of passengers which might be diverted to highways until 1980, a rail passenger trip table served as a guide to location of the stations where loaded express rail travelers boarded. The volumes at each station served as an index for presumed relative volumes up to 1980.

The temporary loss to the rail system of its smallest but most profitable passenger market, nevertheless, reflects a gain to the economy in moving passengers by least cost. It could be expected that rail economics affecting full-fare passenger demand might usefully be accelerated in light of this anticipated event. The forecast continuation of (modified) discount fares could be increased gradually to a level somewhat below freeway bus fares, and still retain a large market. No cheaper alternative remains for this market, as local bus fares will continue to exceed fares of ordinary rail and of express freeway bus. Higher distance and time costs will cause this condition to continue in the future.

Rail-Truck Rivalry

As discussed earlier under the "without freeway" condition, heavy truck ton-kilometers might be expected to grow at an average annual rate of 9.5 percent to 1990, and total 7,243 million in that year. The West Line Railway, on the other hand, would be expected to exhibit an average growth of ton-kilometers of only 2.9 percent per annum, reaching a total of 4,235 million in 1990. The ton-kilometers split between trucks and all railways in 1990 would be approximately 62.6:37.4. Trucks would be expected to handle an even higher percentage of land freight service tons, reaching a level of 88.8 percent in 1990.

Any cargoes which would be converted from one transport mode to another had to be added to or subtracted from these totals to obtain the final forecast of ton-kilometer growth to 1990. The higher projection of ton-kilometer growth for the railway, which was used to lower ton-kilometers costs for the more efficient rail system, was not used elsewhere. As a result of the analysis of rail-truck competition, the forecast of West Line Railway ton-kilometers was revised downward to 2,982 million, and thus would exhibit a growth of less than one percent per annum over the 1968-1990 period. The remainder of this discussion covers the process by which these revisions were arrived at.

It was seen earlier that present-day rail freight costs (per ton-kilometer) were well below equivalent trucking costs per ton-kilometer. The advantage which rail provides to shippers, however, is lost entirely for distances under 90 kilometers, due to the high handling charges on freight traveling short distances. A heavy truck traveling the freeway will enjoy cost savings as does the express bus. These cost reductions derive from the same sources, as shown on Table VI-15. Although time and distance costs would not change for the vehicle itself nor on a per kilometer or per minute basis, average speeds would increase to 87.3 kilometers per hour. This would result in less total time in transit, which would reduce total time costs. Heavy truck time costs would decline from NT$ 1.50 per kilometer to NT$ 0.687. The lower time cost should be added to total distance costs (NT$ 2.43, unchanged) to arrive at total costs per kilometer of NT$ 3.117. Previous total costs per kilometer were NT$ 3.93. Estimated changes in the average truckload, which may be expected to result from technological factors as observed in other economies, and also from better utilization of truck capacities due to expanding volumes of national production, would combine with increased speeds to produce higher loadings per truck. The average truckload is estimated to rise from 4.3 tons to 6.0 tons, with the further result that the average ton-kilometer cost would decline from NT$ 0.914 to NT$ 0.519.

The equivalent rail costs were forecast to fall from NT$ 0.2528 to NT$ 0.2166. The effect on prices would depend, as before, on rationalized pricing. Column 7 of Table VI-15 shows the price per ton-kilometer which would result from applying the new lower range of cost markup (Column 9) to both rail and truck ton-kilometer costs. The more efficient rail is expected to charge a markup of 110 percent to 166 percent, and trucks approximately the same at 109 percent to 163 percent. This estimate of potential markup is based on the analysis shown in Table VI-16. The resulting ton-kilometer prices would be NT$ 0.24 to 0.36 for rail and NT$ 0.566 to 0.844 for truck. For the sample Taipei-Kaohsiung freeway trip, shorter freeway distances (334 kilometers) and faster truck speeds (87.3 kilometers per hour versus rail speeds of 33.4 kilometers per hour) indicate a distinct time advantage for trucks. However, as before, rail transit costs would be significantly lower. Thus, on a cost basis, excluding the influence of the value placed on time by the cargo shipper himself, the cost per ton-kilometer by truck would offer no competition to the railway.

Before reviewing the changes in total costs per kilometer which include handling charges, the price policy which identifies the relevant costs to shippers will be examined.

Freight Markup Policies

The diversity of rail and truck cargo types, and the incidental costs which may attach to transit costs of such cargoes, may include costs of car damage due to corrosion, floor abrasion, or other similar damages. These costs may not be recovered in handling charges. The regular inclusion of a markup, by both rail and truck service, depending on the type of cargo, was seen earlier in the comparison of present costs. In order to evaluate the potential for reduced cargo tariffs in the future, based on lower transit costs, it was decided to provide a wider latitude than that established for passenger fare markups. As shown by Table VI-16, the 1969 markup is presumed to be carried forward to the forecast period (1976-1980 average). The resulting markup, despite cost reductions, can be compared with a recommended markup of 110 percent to 166 percent. For the standard markup, rail cargo tariffs would range between NT$ 0.21 and NT$ 0.47. Standard truck markups would produce a price range between NT$ 1.12 and NT$ 1.69 per ton-kilometer. The recommended markup of 110 percent to 166 percent would produce rail prices of NT$ 0.24 to NT$ 0.36. Truck markups would yield a price range of NT$ 0.566 to NT$ 0.844 at 109 percent and 163 percent.

Potential Cargo Diversion

The preceding price evaluations affecting ton-kilometer costs to cargo shippers is combined on Table VI-17 with the estimated future handling costs per ton of cargo. Together, these dual costs establish the rivalry distance at which rail cargoes might profitably begin, and truck cargoes most economically should terminate. For the forecast period, handling charges per ton of cargo are expected to remain relatively fixed for both modes of travel. However, rail handling costs are presumed to exclude the average valuation registration charges of NT$ 3.98 on agricultural tonnages, NT$ 1.12 on mining tonnages, and NT$ 28.13 on manufactured tonnages. In addition, the cargo delay charge of NT$ 2.65 per ton was presumed to be reduced to NT$ 1.87 on average as a result of the change in train speeds from 19 kilometers per hour to 33 kilometers per hour. The valuation in NT dollars of both speed conditions results from application of the time charges per unit of time. As may be seen in Table III-11, the rail handling costs would be reduced in the following amounts from those now prevailing:

	Present Handling Charges	Forecast Handling Charges
Agriculture	NT$ 76.13	NT$ 71.37
Mining	73.27	71.37
Manufactures	100.28	71.37

Equivalent truck handling charges were presumed to continue as before at NT$ 19.89 per ton.

Table VI-17 combines these handling costs per ton with the transit costs per ton-kilometer to determine the comparative range of prices which face the cargo shipper over distances from 40 kilometers to 160 kilometers. Whereas earlier comparisons of the existing system showed that a 90-kilometer distance rivalry existed between rail and truck service, the forecast distance rivalry may be seen to increase to 160 kilometers on average. The method of arriving at these final costs, as before, was to multiply the transit costs by the kilometer distance. To this cost was added the handling cost per ton.

Freeway Impact on Rail and Highway Rivalry

Prior to construction of the freeway, the ton-kilometer tariffs of rail and truck cargoes established a zone of rivalry at about 90 kilometers. Beyond this limit, cargoes are carried more cheaply by rail than by truck. The present freight traffic distribution between truck and rail reflects these characteristics. Detailed West Line Railway cargo reports for 1967 show 72 different types of cargo carried by rail, of which only two traveled an average distance less than 90 kilometers. These consisted of 3,000 tons of cotton cloth and 720,000 tons of limestone. The average distance for all West Line cargoes was 164 kilometers, while average distances were 373 kilometers for carbide and 357 kilometers for fruits. Average truck distances were 38.5 kilometers for all freight, ranging from an average of 63.3 kilometers for machinery to 13 kilometers for vegetables.

With extension of truck rivalry to a 160-kilometer distance, the types of cargo now carried by West Line Railway could be determined from the number and kinds of cargoes which travel an average distance of less than 160 kilometers, and are vulnerable to the lower total tariffs, including handling, offered by trucks within that distance. From the list of 72 different cargoes, 25 were potentially divertible. These cargoes in 1968 represented 40.4 percent of total West Line rail cargoes, and were distributed as follows: agricultural, 1,247,000 tons; mineral, 857,100 tons; and manufactures, 3,569,000 tons, as shown by Table VI-18. Their distribution was 22 percent, 15 percent and 63 percent of the total 5,673,000 divertible tons. Of total West Line cargoes of 14,043,300 tons, they were 8.6 percent, 6.1 percent and 25.4 percent. The ratio of 1968 divertible tons to total rail tons, i.e., 40.4%, was assumed to remain the same throughout the period to 1990.

Rail-Divertible Cargo Origins

Total tonnages of 1968 and 1990 divertible cargoes (based on 40 percent of total rail cargo) were compared with the West Line rail-loadings index to determine their probable origins by hsien and city. The assumed geographic distribution of divertible cargoes, therefore, was made equal to total distribution. This was preferred to a production index, which was alternatively available, because the detail of regional source of production by type of commodity did not in many cases compare with the rail-loadings index by the same type of commodity. Actual rail-loadings, therefore, presumably reflect the changed locations of loadings based on local processing before shipment, local truck deliveries, and factory deliveries to the main West Line Railroad in a different proportion than indicated by immediate source of origin (raw production). These loadings are shown on Table VI-19 by hsien and city, and converted by average daily truck traffic. This rail index is described elsewhere and compared with other indexes used in a similar way in this study.

Destinations of Rail-Divertible Cargoes

The destinations of rail-divertible tonnages remained unknown, even after finding probable loading points by the above method. Again, alternative methods of finding the most likely destinations included a consumption index, a truck destination index, or the rail-unloadings index. Since these cargoes moved by rail, and according to some indicated routing which would have continued in the absence of competition with trucks, it was again preferred to obtain destinations by the rail index. This was done for each major industry sector represented by the cargoes diverted: agriculture, mining and manufactures (as was done for the rail-loadings). With O-D tables thus prepared, traffic volumes on freeway links and system results were calculated by computer assignment.

Transportation of Imports and Exports

As discussed earlier, a third major port has been recommended by a Japanese Harbor Study Group at a mid-coast location. Such a port would markedly alter the split of export and import cargoes between rail and highway. With the current 90-kilometer rivalry existing at Keelung and Kaohsiung, imports and exports originating or terminating within a radius of 90 kilometers of the harbors tend to move exclusively by truck. If the same 90-kilometer rivalry (without freeway) were to apply to the mid-coast harbor, substantial new diversion to trucks would take place. This would be so because the harbor would serve a central region of the country in a previously secure rail domain far removed from the two existing harbors.

The influence of the freeway itself in diverting freight shipments of exports-imports from rail to trucks would not be as marked as the influence of the new harbor. An extension of the radius of competition (with freeway) to 160 kilometers from each of the three ports would eliminate all potential for rail handling of exports-imports. However, this would amount to only a fraction of the harbor-created diversion. The overall freeway effect would be to establish competitive 160-kilometer rivalry at any origin. In the absence of the mid-coast harbor, the freeway would create the same rivalry condition for exports-imports at Keelung and Kaohsuing and an alternative northern harbor, but an important area of central Taiwan would continue to be served by rail.

Exhibit VI-5 shows the influence of the alternative central harbor location on rail activity within 90-kilometer and 160-kilometer competitive perimeters. It indicates that loading and unloading of cargoes at Wuchi harbor (with origins or destinations within economical trucking distances), would permit the rail to serve only a meager share of regional freight under conditions of a 90-kilometer rivalry, and result in total loss of export-import cargoes for the railway with 160-kilometer rivalry.

The influence of the new harbor location on rail-highway competition was tested by construction of export and import matrices. The matrices showed the origin of exports from Keelung and Kaohsiung, and the destinations of imports received at either harbor. Production and consumption indexes were used to allocate exports and imports, respectively. A consumption index, Table VI-20, was constructed on the basis of four main categories of economic activity thought to be reasonably good indicators of the relative dispersion of consumption demand throughout the country. These categories consisted of the value of input demand by region, total commercial assets in operation (service and trade industries), commercial employment, and total population. As with the manufacturing production index, it

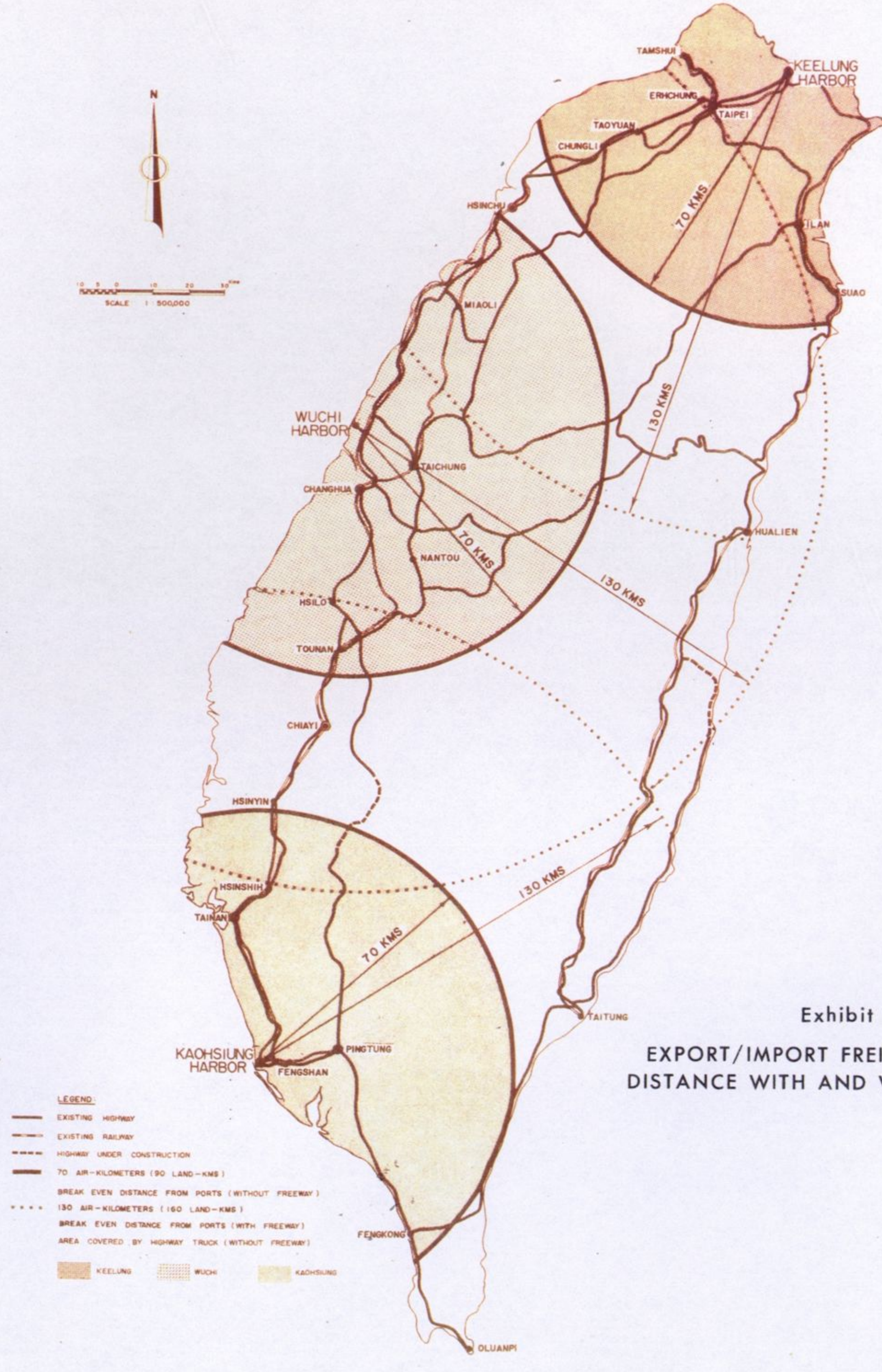


Exhibit VI-5

EXPORT/IMPORT FREIGHT BREAK EVEN DISTANCE WITH AND WITHOUT FREEWAY was desired that the variation which exists between regions in each category be taken account of, and for this reason each category was weighted equally at 25 percent of total value, and all percentages in each category transmitted their influence to the final weighted consumption index shown in the last column. The product of the consumption index yielded the following conclusions:

North:	57.8%	South:	19.0%
Central:	20.6%	East:	2.6%

Among the cities, Taipei represented 42.5 percent, Kaohsiung 6.7 percent, and Tainan 3.0 percent of consumer demand.

The 90-kilometer and 160-kilometer rail-truck rivalry would show trucks carrying exports and imports originating at or destined to points within 90-kilometer or 160-kilometer distance of the ports. The railway would carry cargoes originating or terminating at greater distances. It was found that, for 1968 (90-kilometer rivalry), imports and exports at Keelung would be handled by trucks for distances up to and including 80 percent of Ilan cargoes, all of Taipei and Taoyuan hsien cargoes, and about 10 percent of Hsinchu hsien cargoes. Rail would be the predominant carrier of cargoes arriving at or departing from Miaoli hsien and Taichung hsien. The southern port of Kaohsiung would yield rail cargoes for Changhua, Yunlin, Nantou, and Chiayi hsiens, and 30 percent of Tainan hsien, i.e., for distances beyond the 90-kilometer trucking limit.

Assuming the freeway built and only two harbors, trucks would dominate for distances up to 160 kilometers, and the previous rail advantage would be greatly reduced. Trucks would carry cargoes to or from the ports for all of Hsinchu and Miaoli hsiens and half of Taichung. In the south, cargoes to and from all of Tainan, Chiayi and Yunlin hsiens, together with the southern area of Nantou, would also be carried by trucks. The only rail cargoes would consist of foreign trade originating or terminating in the southern half of Taichung hsien, most of Changhua hsien, and northern Nantou hsien.

Rail domination over central region foreign trade cargoes would virtually cease with the opening of the third harbor at Wuchi. With this harbor, the current 90-kilometer limit for economical use of trucks would deprive the railway of all 1990 export traffic except for approximately 17,000 tons in Hsinchu hsien and 866,000 tons in Chiayi hsien. With the freeway, trucks would carry all cargoes within 160 kilometers of Wuchi harbor and no tonnages would remain to be carried by rail. For forecast 1990 import traffic with Wuchi harbor, and with the 90-kilometer limit for trucks, rail would carry only 23,000 tons to Hsinchu and 1,065,000 tons to Chiayi hsien, of a total 14.6 million tons moved. With the freeway and the 160-kilometer limit for trucks, no import tonnages would move by rail.

Tonnages Converted From Rail to Freeway

Using the estimate of 40 percent of total rail cargo as the potential rail cargo divertible to truck with the freeway, the tonnage was distributed by matrix and converted to ADT. The conversion of tons to average daily traffic (ADT) was made on a 333-day basis and at 4.3 tons per truck. The matrix was prepared on the basis of origin and destination of cargoes which showed the relative ADT per hsien; shipments destined for points within 90 kilometers or beyond 160 kilometers were disregarded, reflecting the pattern of traffic on which diversion was based. ADT in 1990 as derived by these methods was 7,000 heavy trucks.

Effects of Containerization on Rail-Highway Rivalry

Container cargoes were estimated for exports and imports on the basis of existing studies which showed the assumptions back of the calculations. The National Maritime Development Institute of Taiwan prepared a study of containerization based on the findings of two container studies by the Japanese, and one by Matson Steamship Company. The National Maritime Development Institute of Taiwan lists the kinds of cargoes suitable for containers, and their relative amounts in the base year 1967 in trade of Taiwan with Japan and the United States. This list shows 28 commodities which cover the entire range of a standard industrial classification. Comparing this list with the average volume of 1967-1968 exports-imports, it was found that containerized exports appeared to be 19 percent of total exports, while containerized imports represented 12 percent of total imports.

The itemized list was restructured according to the standard classification used herein. From this list could be measured the relative percentages for each sectoral category of total exports and imports at harbors. This is shown on Table VI-21 along with the 1990 forecast of such containerized cargoes, based on a continuation of these same percentages applied to forecast exports-imports by category. Based on these data, several matrices were prepared showing the tonnage of containerized cargo which could be expected to move either by truck or by rail, depending on either the 90-kilometer or the 160-kilometer limit of trucking advantage.

Containerized rail cargoes are affected in the same way as exports and imports by rail, i.e., by the location of the third harbor. A linear index which shows the routing (origin and destination) of containerized cargoes entering and leaving the harbors of Taiwan reproduces for container cargoes the same potential for diversion to truck as was earlier seen for exports-imports generally.

Containerizable exports are compared below for 1967 and 1990, according to their distribution into geographic regions by the production index. The data are in thousands of metric tons, and comparisons assume that Wuchi Harbor did not exist in 1967 but that it will be built by 1990. The limit on economical use of trucks was assumed to be 90 kilometers.

CONTAINERIZABLE EXPORTS
Metric Tons--Add 000

	1967 (without Wuchi Harbor)		1990 (with Wuchi Harbor)	
Region	Truck	Rail	Truck	Rail
Northern	143	42	809	48
Central	-	401	280	31
Southern	144	28	284	6

Comparable figures for containerizable imports are shown below, with the same assumed conditions governing potential future diversion of rail tonnages to trucks.

CONTAINERIZABLE IMPORTS
Metric Tons--Add 000

Region	1967 (without Wuchi Harbor) Truck	1967 (without Wuchi Harbor) Rail	1990 (with Wuchi Harbor) Truck	1990 (with Wuchi Harbor) Rail
Northern	375	22	837	73
Central	-	193	316	-
Southern	119	11	298	8

It should be noted from the above data that the proportional distribution of total tonnages was by production (export) index and consumption (import) index, rather than by the proportionate redistribution of such tonnages which would result from use of the Japanese Harbor Study. The latter shifted the balance of Keelung tonnages to Wuchi, based on congestion at Keelung, and diverted substantial tonnages from central areas of the country to Kaohsiung. In the Consultant's earlier export-import third harbor analysis, the tonnages were shifted according to the Japanese Study. However, for a different view of such foreign trade, the consumption and production indexes may provide a perspective of the origin-destination characteristics which would otherwise be lost by redistributing cargo with consideration for congestion at ports. Any desired redistribution of these tonnages may be made by reference to the total exports distribution (north to south) of 9 percent, 17 percent and 74 percent; and for imports, 32 percent, 16 percent and 52 percent.

The relative number of trucks and rail cars needed to haul these tonnages is as yet a matter of conjecture. An average container truck today may range in capacity from 10 to 15 tons. Special rail cars may carry much more, but will be limited by overhang restrictions imposed by height and width of tunnels and bridges as well as by couplings. No estimate was made of the present average capacities of trucks and rail cars, nor of the economies (or wasteful practices) of manufacture which might exist, and which would influence relative cost-price competition for these cargoes. This estimate was omitted because the locational influence of the third harbor, of itself, would strategically alter the basis on which such rivalry might exist. In addition, the above comparisons would be further affected by the 160-kilometer rivalry imposed by the proposed freeway. Furthermore, by 1990 all containerizable foreign trade cargoes (as well as all other foreign trade cargoes) would be handled by trucks.

FORECAST OF FUTURE TRAFFIC WITH FREEWAY

Coding Freeway Alternatives

In order to simulate future traffic on the highways and on the proposed freeway, the freeway network was coded for computer usage. In a manner similar to that used for the present highway system, future interchanges were located and numbered, and the freeway links were characterized by length, grade and speed. Some highway links were modified and some connections were added. The detailed network is shown on Exhibit VI-6.

Freeway speeds were assumed at two levels, 90 kilometers per hour for rural areas, and 77 kilometers per hour near urban areas, where high traffic volumes would make some reduction in speeds acceptable.

Two alternative freeway locations were coded in Sections 2, 5 and 7. These are the sections Erhchung-Chungli, Taichung-Tounan, Tainan-Kaohsiung. They were designated as Alternative West (nearer the coast) and East (inland). The four other sections had only one freeway location each.

Centroids, intersections, and interchanges were numbered and coded. The computer processed the data and determined for each vehicle type the minimum cost networks, as explained earlier for the highways "without freeway."

Assignment of 1990 Traffic to the Highway Network

Two complete freeway networks were processed separately by computer. These were the Freeway West and the Freeway East networks. In four sections the alignment was common to both alternatives, but the networks differed in the three most important sections.

The 1990 trip tables by four vehicle types were assigned to each network. Traffic on the freeway and highway links at the screenlines was summarized. The screenline volumes were compared with those on the highways "without freeway" and on the preliminary expansion, and were found to be compatible. Some computer overflows and system results had to be adjusted manually.

Manual Adjustments

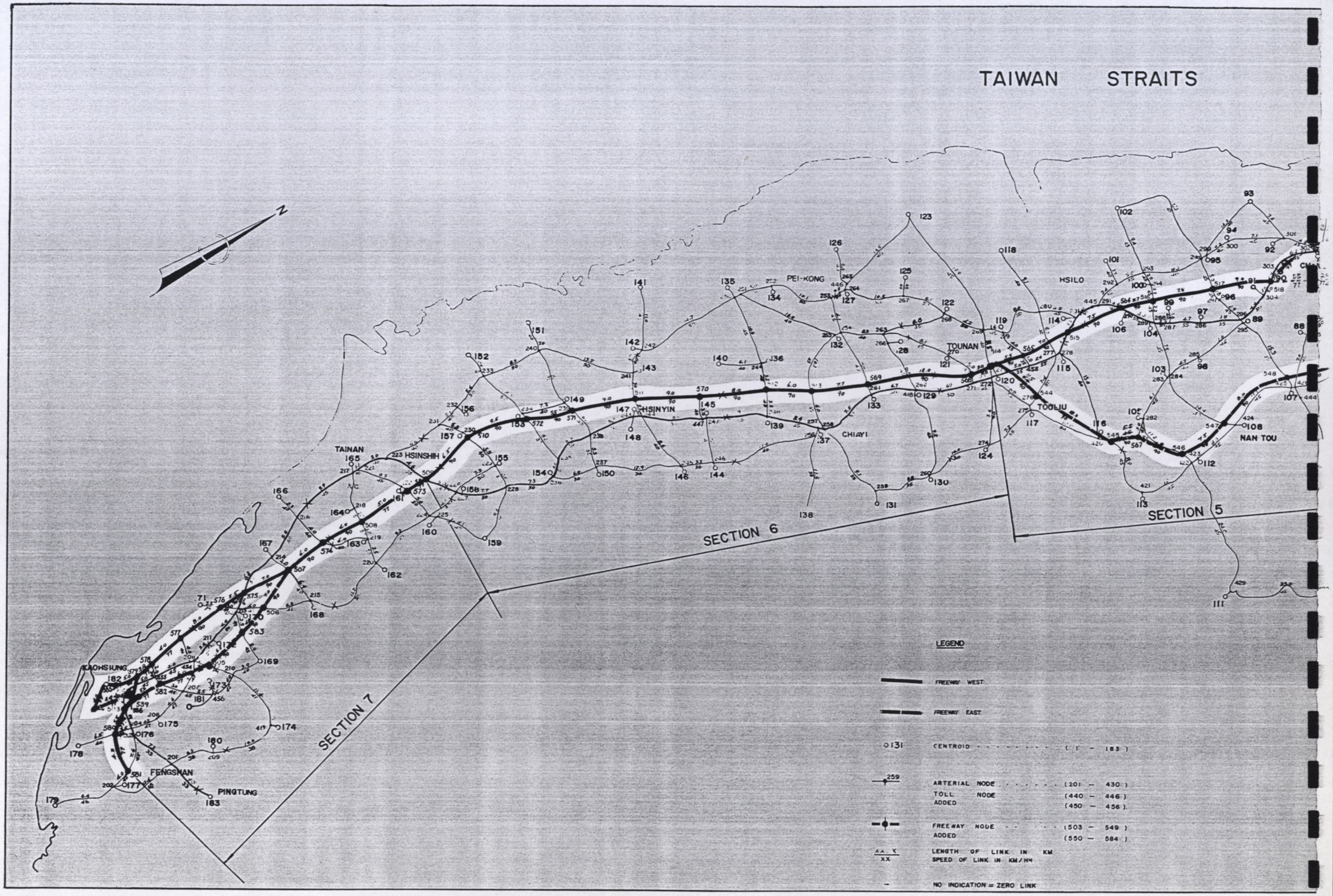
The assigned 1990 vehicle traffic was plotted on the whole network, and particularly on the freeways. Some adjustments were performed on the traffic volumes and on the resulting operating characteristics. They concern "overflow", "overassignment" and correction of length, speed, and grade on some links.

As explained earlier, the computer "overflow" was corrected by program revision, but some "double-overflow" was still corrected by hand. This concerned the bridges west of Taipei and traffic between Taipei and Erhchung.

The known "overassignment" onto the freeway was corrected only at three locations where the assigned traffic exceeded the proposed freeway capacity but could be handled by parallel highways.

The boundary between Sections 4 and 5 was moved to include Taichung and Wuchi in Section 5. The freeway alternatives starting in Taichung were coded entirely in that section, but highways between the new boundary and the previous natural boundary at the Tatu River had to be transferred. This made the economic analysis between with and without freeway alternatives compatible.

Due to continued study of the freeway alignment during the computer processing period, a few locations, lenghts, grades, and speeds required some manual correction for the traffic operating results. Usage of the freeway



TAIWAN STRAITS
N
PEI-KONG
HSILO
TOUNAN
TOULIU
NAN TOU
CHIAYI
HSINYIN
HSINSHIH
TAINAN
KAOHSIUNG
FENGSHAN
PINGTUNG
SECTION 5
SECTION 6
SECTION 7
LEGEND
FREEWAY WEST
FREEWAY EAST
CENTROID (1 - 183)
ARTERIAL NODE (201 - 430)
TOLL NODE (440 - 446)
ADDED (450 - 456)
FREEWAY NODE (503 - 549)
ADDED (550 - 584)
LENGTH OF LINK IN KM
SPEED OF LINK IN KM/HH
NO INDICATION = ZERO LINK

CODED HIGHWAY NETWORK WITH FREEWAY

alternatives by the Taoyuan International Airport traffic was calculated separately.

The resulting traffic volumes forecast for 1990 on the freeway are illustrated on Exhibit VI-7 for the Alternative West. The systems results in vehicle-kilometers, vehicle-hours, and vehicle cost are summarized on Table VI-22, by section, for each vehicle type and for arterials and freeways separately. For the Taoyuan International Airport, a separate table, Table VI-23, summarizes the traffic operating results which were later handled separately from all other traffic.

Rail Diverted Traffic

A new freeway would attract traffic from the railways, as has been derived in the preceding discussion. Only two major types of traffic have been considered. These are bus passengers and truck cargo. The other types are quite real, but of negligible size.

The forecast truck trips and bus trips were assigned by computer to the freeway alternatives West and East. The truck volumes add up to 3,000 trucks per day to the freeway near Taichung but fewer elsewhere. This represents a maximum of 15 percent of the freeway truck traffic, and as little as two percent elsewhere.

The bus trips due to diverted rail passengers were calculated theoretically for 1969, assuming that improved rail passenger service would recover all passengers by 1980. Around 1975, when the whole freeway might be completed, this rail diversion would represent about 200 buses per day on the freeway on the northern sections and about 100 on the southern freeway sections, or about one-tenth of the freeway bus volumes. These volumes were taken into consideration in the capacity analyses. Their operating characteristics on the freeway are summarized on Table VI-24.

Assignment of 1969 Traffic to the Highway Network

If the freeway had been in operation in 1969, how many vehicles would have used it? The answer to this question, though hypothetical, permits an evaluation of freeway traffic for any year of opening of the freeway by interpolation between 1969 and 1990.

The 1969 trip tables by four vehicle types were assigned to the minimum cost routes of the two alternative freeway networks. The resulting traffic volumes at the 15 screenlines were compared with the 1969 counts and found compatible.

No manual adjustments were made to 1969 traffic assignments because minor changes of the 1969 volumes would be unimportant to results over the 20-year period. Direct comparison between the alternatives with freeway and the existing highway network, however, is not entirely accurate. The inaccuracy was corrected only at the changed boundary between Sections 4 and 5 for the 1969 traffic results in the same manner as for the 1990 traffic previously explained.

Traffic operating results are summarized by sections in Table VI-25. The overall average costs per kilometer and average speeds on arterials and on the freeway, serve as indicators of efficiency and as a check on calculations.

Comparison of 1969 and 1990 Traffic

After completing all forecast and traffic computations in detail, it is interesting to compare traffic volumes and to show the major traffic characteristics under various conditions. The traffic operating results are analyzed later in Chapter VIII. Only average trip length, speeds and costs are discussed here.

Average trip lengths calculated apply only to trips between sectors. They cannot be compared directly to national averages including short, regional or metropolitan trips. Here, they were derived from the origin-destination survey of 1969 and its expansion to 1990. The length of each trip was calculated on the coded network by computer and accumulated to total vehicle-kilometers. Dividing by the total corresponding number of trips yielded the average trip length by vehicle type, as listed on Table VI-26. No average trip length was calculated for each section, or separately for freeway versus highway.

The effect of the freeway on average trip length was not marked, and can be neglected. The freeway would shorten many long trips. Shorter trips might be lengthened, however, for freeway users, considering point to point distances over freeway connectors and the freeway itself. However, many drivers would accept the greater distances to save time. For these short trips, the medium vehicles (autos and light trucks) would have significant cost advantages over large vehicles (heavy trucks and buses). That characteristic remains almost the same for 1990. Experience elsewhere indicates that average trip length usually increases with improved freeway facilities. In Taiwan, more long-distance trips would be made, such as present rail traffic diverted to trucks and buses but such traffic was not included in the above averages.

A more sophisticated "gravity model" forecast could have been calibrated to simulate the longer trips. For a feasibility study of a freeway, however, the "expansion model" forecast used by the Consultant provides more conservative results and does not tend to exaggerate the advantage of freeways.

The average speeds and kilometer costs on highways and on freeways concern trips between sectors only, and not local trips within sectors and cities. Average speeds and costs per kilometer were calculated by relating the vehicle-kilometers, vehicle-hours and vehicle costs accumulated by computer on the coded network in each section.

Values by sections and by arterials or freeways can be compared to measure relative efficiency. They are not as clear as the analysis of economic values. They are shown here only as a summary of section ranges and averages on Table VI-27. The rural Sections 3 and 6 indicated high speeds and low cost, whereas Sections 1, 2 and 7 indicate low speeds and high costs mainly due to metropolitan traffic conditions. Sections 4 and 5 have averages in the middle range.

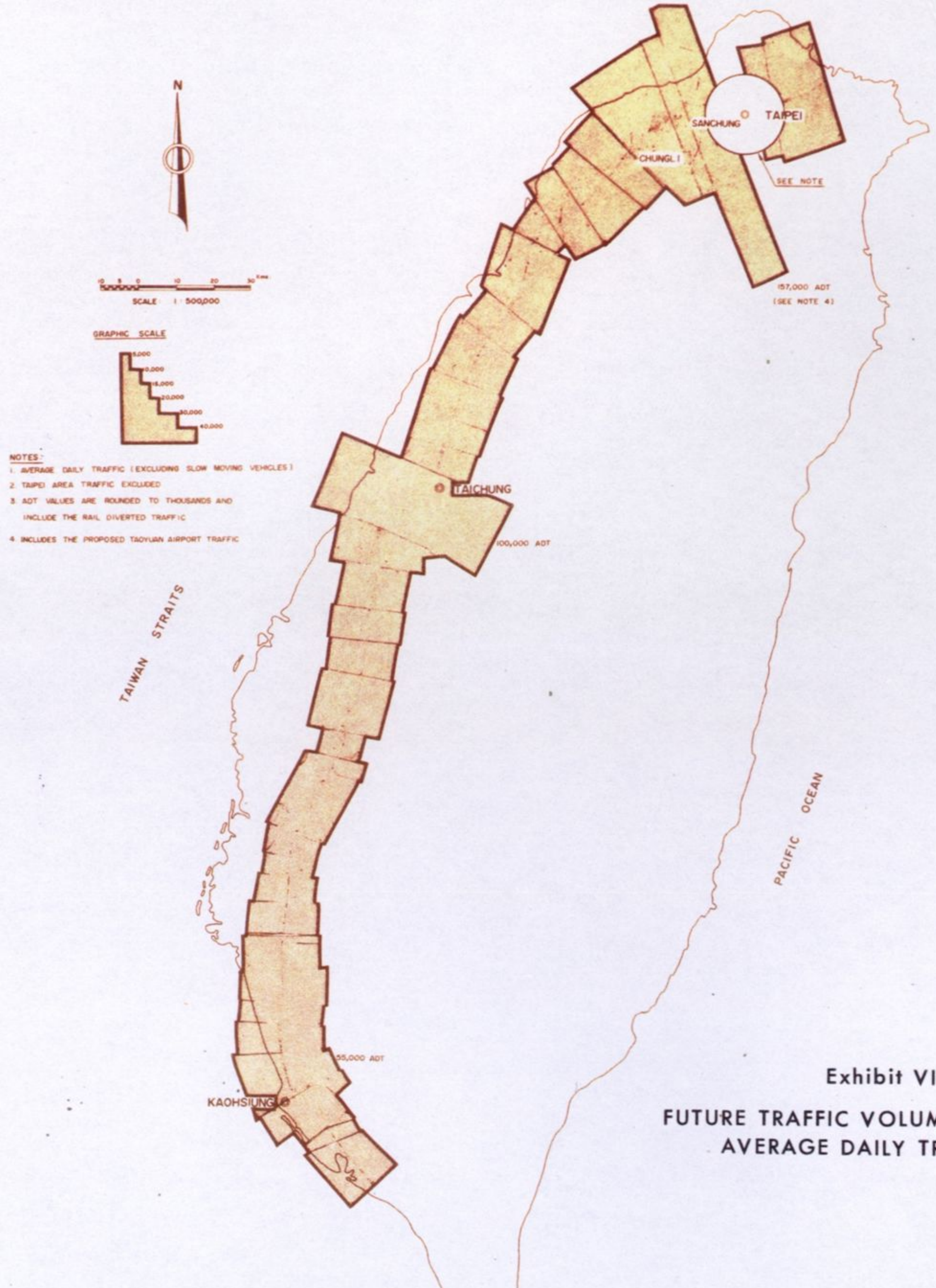


Exhibit VI-7

FUTURE TRAFFIC VOLUMES ON FREEWAY
AVERAGE DAILY TRAFFIC 1990

chapter VII

HIGHWAY ENGINEERING STUDIES

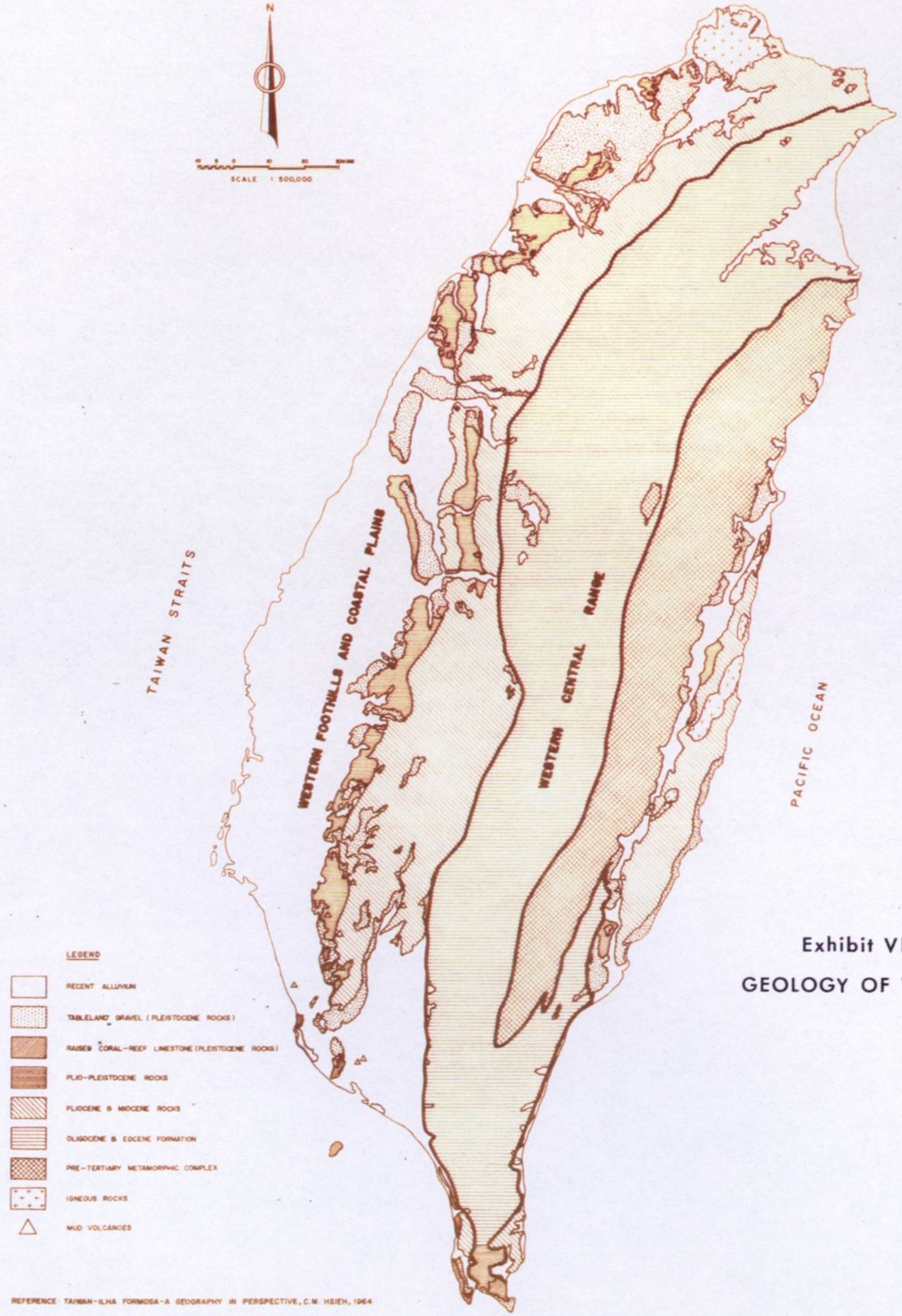


Exhibit VII-1

GEOLOGY OF TAIWAN

HIGHWAY ENGINEERING STUDIES

For the analysis of the feasibility of the proposed freeway, the highway improvements needed to handle future traffic volumes in the study corridor were compared for two conditions:

1. With freeway;

2. Without freeway.

The required design criteria as well as highway and freeway features were determined and cost estimates were prepared for both with and without freeway conditions. Freeway location studies considered all possible routes and established the alternative routes for further economic evaluation. The latter routes are referred to as "Alternative West" and "Alternative East". All other alternatives are designated by letters.

The data pertaining to geology, land forms, soil conditions, climatology and hydrology given in the following pages provide background information for the engineering studies and cost estimates.

GEOLOGY

The island of Taiwan is the site of tertiary sedimentary deposition on a basement of metamorphic rocks. A general geologic sketch of Taiwan is shown in Exhibit VII-1. Its structural evolution can be divided into pre-Tertiary, pre-Miocene, and post-Pliocene orogenies. After the pre-Tertiary orogeny, and the accompanying metamorphism, the Tertiary geosyncline was formed. The earliest sediments laid down on the metamorphic basement were predominantly dark gray shales and

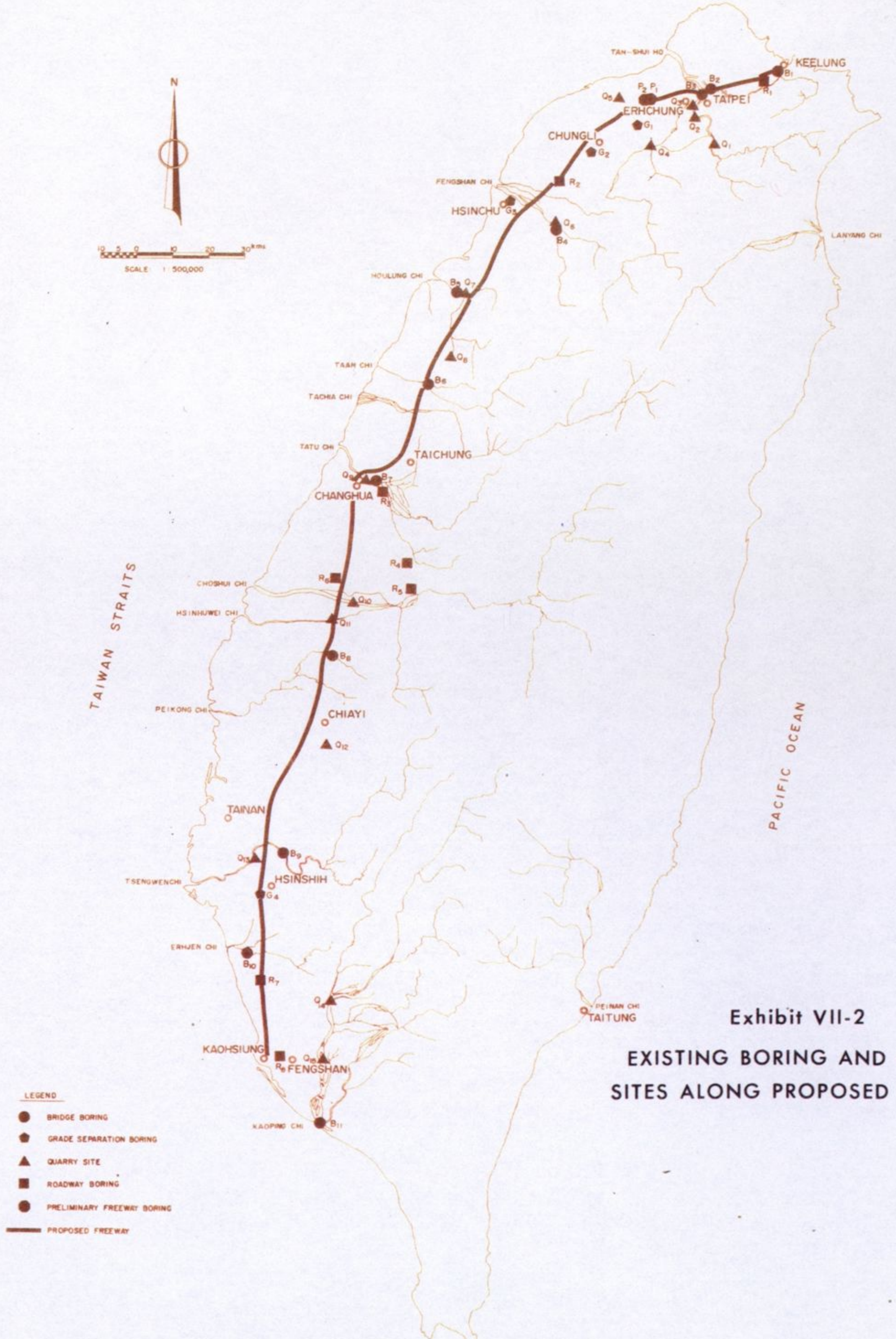


Exhibit VII-2

EXISTING BORING AND QUARRY SITES ALONG PROPOSED FREEWAY

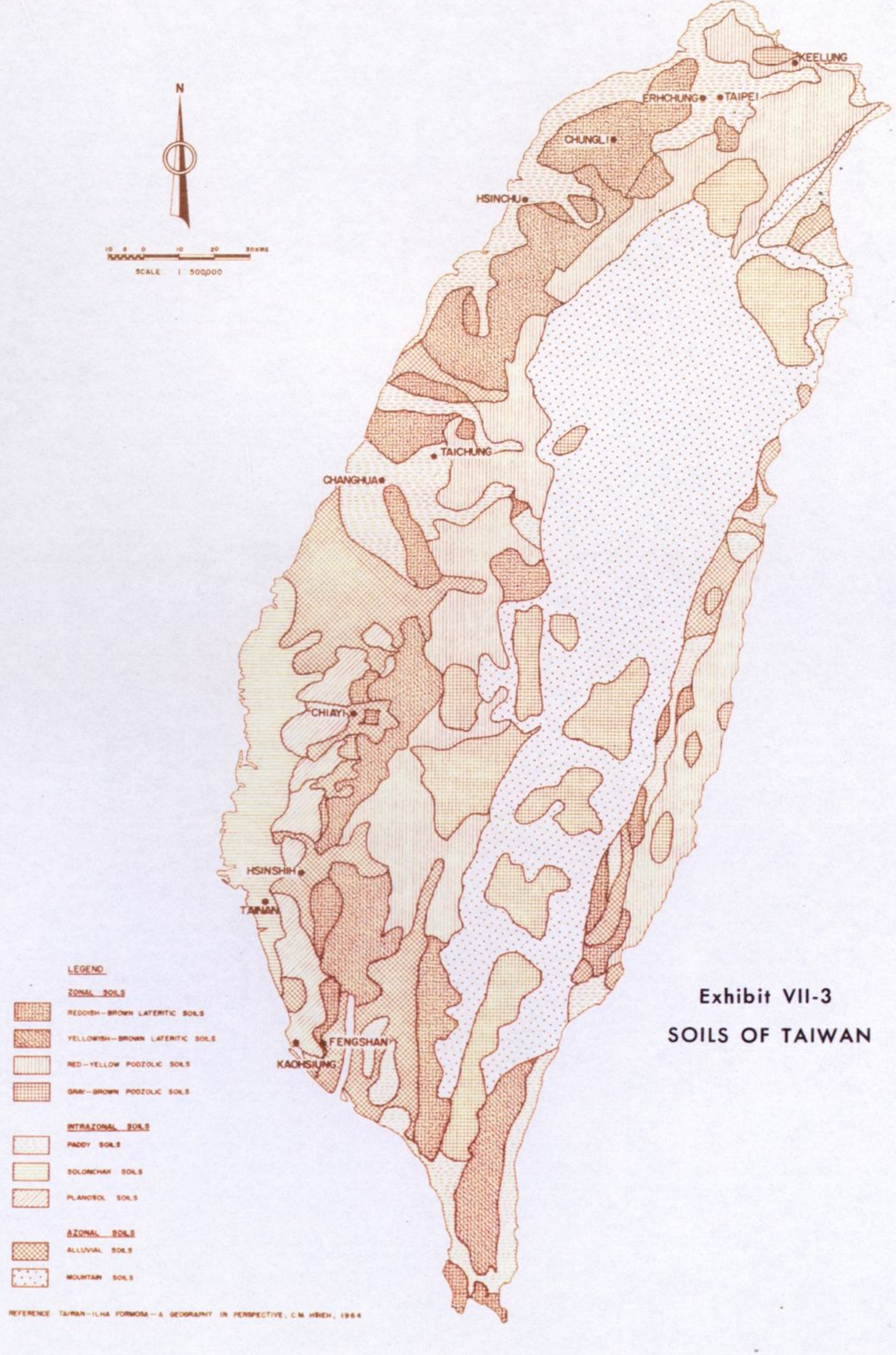


Exhibit VII-3

SOILS OF TAIWAN

Zonal Soils

Certain soils that are found in great areas or zones are called zonal soils. They are classified according to climate and vegetation, and they can be developed from a wide variety of parent materials. The soils are found where the land is well drained, and the slopes are not excessively steep. The zonal soil is mature, with a well developed profile. The long period of leaching in Taiwan's humid climate has removed the soluble minerals and basic salts from the soil, leaving it with only a concentration of iron and aluminum. Consequently, the zonal soils are strongly acid in reaction. Within the zonal classification, two major soil groups can be found. These are the lateritic and podzolic soil groups.

The lateritic soils of Taiwan range in color from reddish brown to yellowish brown. These are found near Linkou, Hsinchu, Taichung, Tainan, and Kaohsiung. These lateritic soils can be classified generally as inorganic silty clays of low to medium plasticity, and their physical properties can be estimates as follows: low permeability, fair to good shear strength, and fair to good construction workability.

The podzolic soils of western Taiwan are mainly red and yellow. They cover a land belt running from north to south throughout much of the Island's length, and they are found from about 500 to 800 meters above sea level. These soils, like the lateritic soils, are used extensively as paddy fields. The red and yellow podzols can be classified as clayey silts and silty clays of medium plasticity. Their physical properties are typically low permeability, fair shear strength, and fair construction workability.

Intrazonal Soils

Intrazonal soils are distinguished from zonal soils by the reflection of the influence of local conditions such as parent rock, drainage, alkali salts, or some other special characteristics. In western Taiwan, three major soil groups can be found within the intrazonal classification. These are paddy soils, the solonchak and planosol soil groups.

The paddy soils have developed from a long period of cultivation, and they are unique in that the topsoils are highly dispersed, and have become virtually structureless. As a result of this dispersing action, much of the soluble material has been carried to the solum, thus creating a mottled and streaky effect. The paddy soils appear along the coastal plains, in the local basins, and along the river banks. Paddy soils can be classified as clayey silts and silty clays, with medium to high plasticity. Their physical properties are typically low permeability, poor to fair shear strength, and poor to fair construction workability.

The solonchaks exist along the southwestern coast, where the activity of the tidal waters adds to the soils' existing salinity. These soils are some of the few on the western side of the Island exhibiting alkaline reactions. The predominant salts are calcium and sodium sulphates. The solonchaks can be classified as silty fine sand to sandy silt, with low plasticity. Their physical properties are typically medium permeability, fair shear strength, and fair construction workability.

The planosols are found on the alluvial plains near Chiayi, Tainan, and Kaohsiung. These soils are strongly leached and cover siltpan or claypan. The subsoil is brittle and tends to resist infiltration. The planosols can be classified as clayey silts, with low to medium plasticity. Their physical properties are typically low permeability, fair shear strength, and fair construction workability.

Azonal Soils

Azonal soil is a relatively young soil with a poorly developed profile. It has been formed largely from the influence of parent materials, and its characteristics have not been altered by the forces of climate and ground cover. In western Taiwan, one major group of azonal soils can be found. This is the alluvial type soil.

The alluvial soils have been developed in the basins and along the river banks. These soils make up the fan of the Choshui River, and they are also found north of Taichung, and near Tainan and Kaohsiung. In the northern region, the soils are acid in reaction, whereas in the south they are alkaline. The differences reflect the reactivities of the parent materials. The alluvial soils can be classified as sands and silty sands, with little or no plasticity. Their physical properties are typically medium to high permeability, fair to good shear strength, and fair to good construction workability.

Local Soils

Throughout western Taiwan, there are soils that exhibit one or more characteristics that have been derived from local influences. Lithosols, Regosols, Groundwater Laterites, and Rendzines can be found in many locations. They do not cover a large percentage of the land area, however, and do not have a major influence on the soils evaluation.

Summary

The soils of western Taiwan range from very fine sands to highly plastic clays. However, the majority of the soils can be classified as sandy silts, clayey silts, and silty clays. The fertility of these soils is rather high, and their physical properties are well suited for growing crops, but, as structural materials, they are lacking in many of the essentials necessary for good highway construction. An important factor in the behavior of these soils is their moisture content. The presence of excess moisture makes them extremely difficult to work with.

Although the rivers of Taiwan are not normally thought of in terms of soils groups, they do furnish the primary source of materials for road building in western Taiwan. With the exception of the rivers and streams near Tainan and Chiayi, the river materials are of excellent quality, and can be used for all construction purposes. The rock is generally very hard, but it is also well rounded and must be crushed before being used as a structural material. When used for embankment or as an uncrushed aggregate subbase, the material can be made to serve very well.

In the areas where quality river materials were not readily available, the sources of borrow would be the

nearby hills and tablelands. Haul distances for construction materials have been estimated as follows: 10 kilometers between Keelung and the vicinity of Tounan; 20 kilometers between Tounan and Tainan; and 15 kilometers between Tainan and Kaohsiung.

CLIMATOLOGY

Climatic Conditions

The climate of Taiwan is influenced considerably by the northeast and southwest monsoons, and they are as different in nature as they are different in season. During the winter, the northeast monsoon prevails from October to March. The cold air, mixing with high pressure centers on the Continent of Asia, notably eastern Siberia, develops a thermal anticyclone which creates a wave of dry, cold air which blows out to sea in a southeasterly direction. This is known as the northwest winter monsoon in China. Due to the deflection force from the earth's rotation, the northwest monsoon, upon reaching Taiwan, becomes the northeast monsoon. On its way over the East China Sea, the monsoon absorbs an abundance of moisture which precipitates when it comes inland over the northeastern part of the island. The northeast monsoon is intensified during this period, because it also coincides with the northeast trade wind. Due to these conditions, the north part of the island during the winter has excessive rainfall, cloudy weather, and strong winds. The central mountain range, which extends from the northern to the southern part of Taiwan, however, tends to prevent the moisture-conveying wind from reaching the southwestern part of the Island which, throughout the five-month-long winter period, has little rain and prolonged drought. Because of this condition, this area of Taiwan is known as a rainshadow area.

In summer, the southwest monsoon predominates from May to September. A low pressure condition replaces the thermal anti-cyclone which prevails in the winter. The air masses originating over Southeast Asia blow northwesterly to the Asiatic Continent and, as with the northeast monsoon, the original direction is changed to southwest by the deflection force of the earth's rotation when it reaches Taiwan. The southeast monsoon brings intense rainfall to the south of Taiwan during the summer months, while the northern part often enjoys fine weather.

Temperature

The summer is long and consistently hot in Taiwan, while the winter is short and mild. The mean annual temperature of the whole Island is generally higher than 21° C. Snow is rarely found in the lowlands, even if the summits of high mountains are temporarily covered with snow.

The hot season of the year is from June to September, and July is the hottest month. The temperature variation during this month between the northern and southern part of Taiwan is not great. The mean temperature in July at Keelung is 28.3° C. and 28.1° C. at Kaohsiung, showing a difference of only two-tenths of a degree.

The coldest month in Taiwan is January. The difference in mean temperature between the northern and southern portion of the Island for this month is more than that of the hottest month. The mean temperature during January at Keelung is 15.5° C. while at Kaohsiung, it is 18.8° C., giving a difference of over three degrees.

Mean temperatures during January along the North-South Freeway corridor is as follows: Taipei, 15.2° C.; Hsinchu, 15.0° C.; Taichung, 15.8° C.; and Tainan, 17.1° C. From Hsinchu, the mean temperature during January increases gradually the farther south one goes. At the same latitude, the mean annual temperature on the Island is higher compared with that of the mainland. This is due to the fact that the Island is under the influence of strong ocean currents. Exhibits VII-4, 5 and 6 indicate the Island isotherms.

Rainfall

Rainfall in Taiwan is abundant. The mean annual rainfall over the whole Island is almost 2,600 mm, varying from 6,600 mm in the mountain regions to 1,200 mm in the coastal areas.

The monsoons contribute an essential part to the seasonal distribution of rainfall in Taiwan, as previously noted. The northern part of the Island has an abundance of rainfall during the winter, but during the same period of time, the southern and western parts of the Island suffer from drought. Mean precipitation in January at Keelung is 319 mm while Kaohsiung has a rainfall of only 12 mm. This remarkable characteristic is explained by the fact that the Central Mountain barrier provides the south with a rainshadow area.

On the other hand, during the summer, the south of Taiwan receives much more precipitation than in the winter. This part of the Island faces directly to the southwest monsoon. Rainfall at Kaohsiung during May to September, the rainiest season, constitutes up to 89 percent of the annual rainfall. Mean precipitation during July at Kaohsiung and Keelung is 492 mm and 137 mm, respectively. It is during this period that the northern part is dry. The summer rainfall comes primarily in the form of thunderstorms with heavy downpours. From May to September, thundershowers are frequent, and occasionally they are accompanied by typhoons. After September, if there is no typhoon activity, there is a sharp decrease in rainfall.

The mean annual precipitation along the North-South Freeway corridor is as follows: Keelung, 3,162 mm; Taipei, 2,112 mm; Hsinchu, 1,724 mm; Taichung,

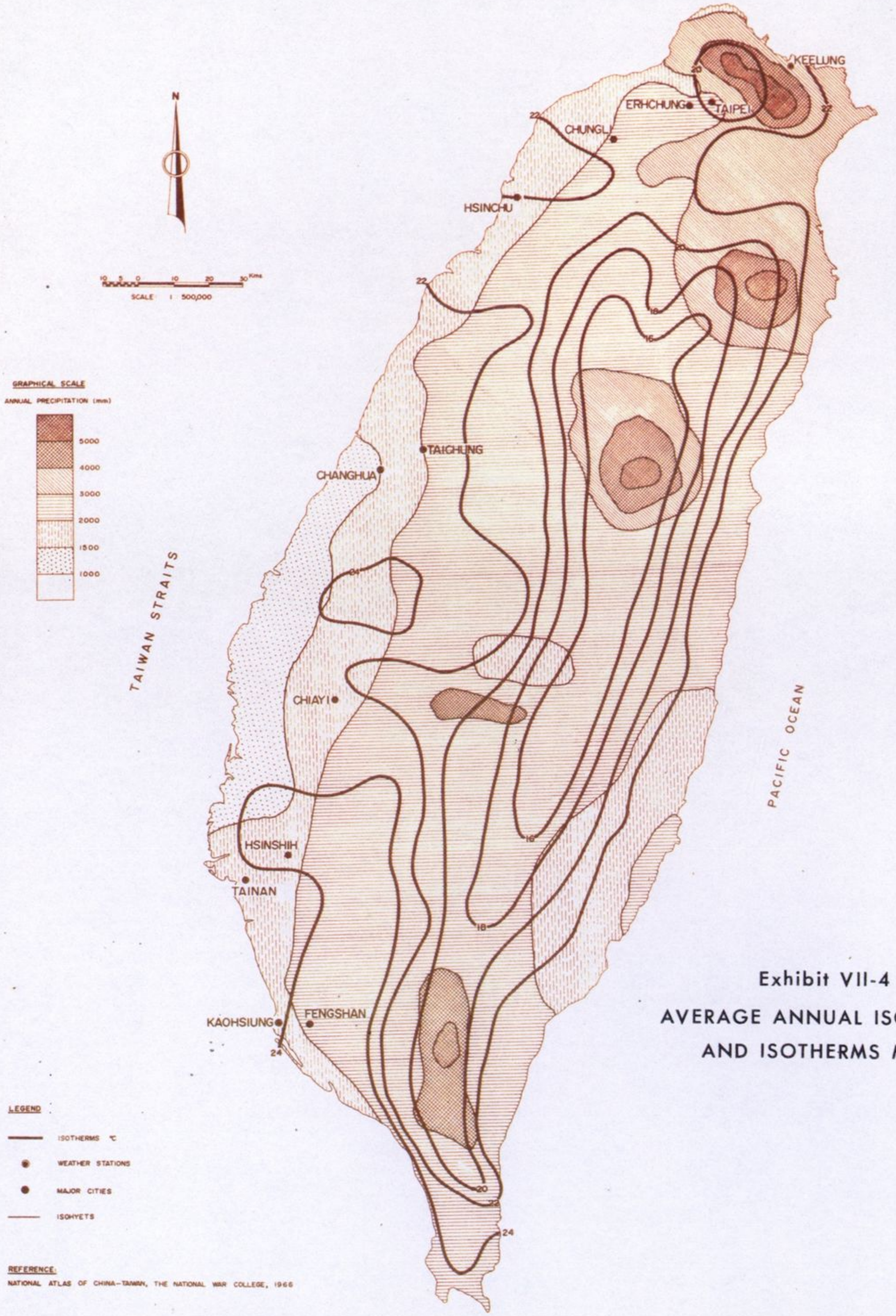


Exhibit VII-4

AVERAGE ANNUAL ISOHYETS AND ISOTHERMS MAP

Exhibit VII-5

AVERAGE JANUARY ISOHYETS AND ISOTHERMS MAP

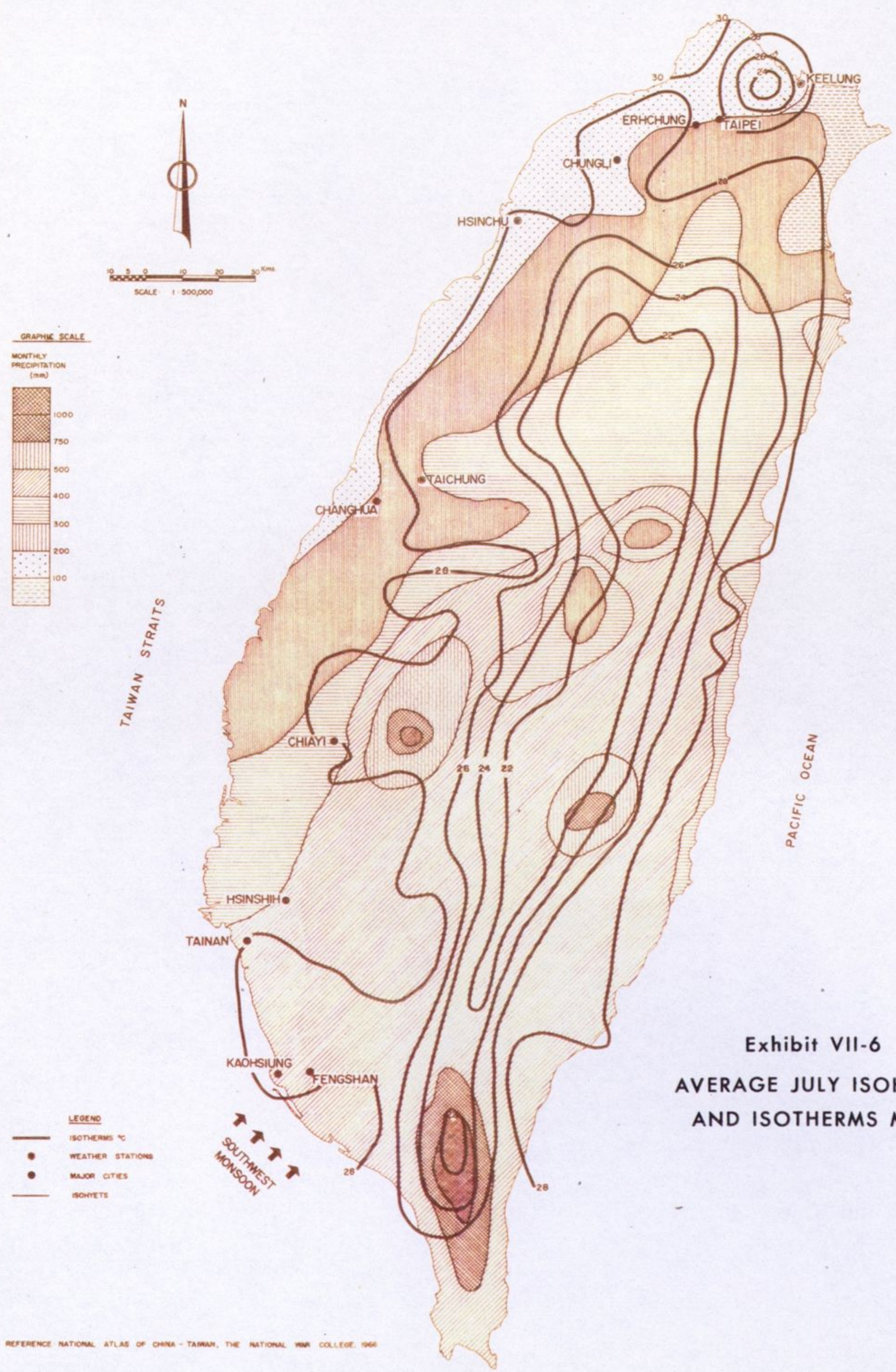


Exhibit VII-6

AVERAGE JULY ISOHYETS AND ISOTHERMS MAP

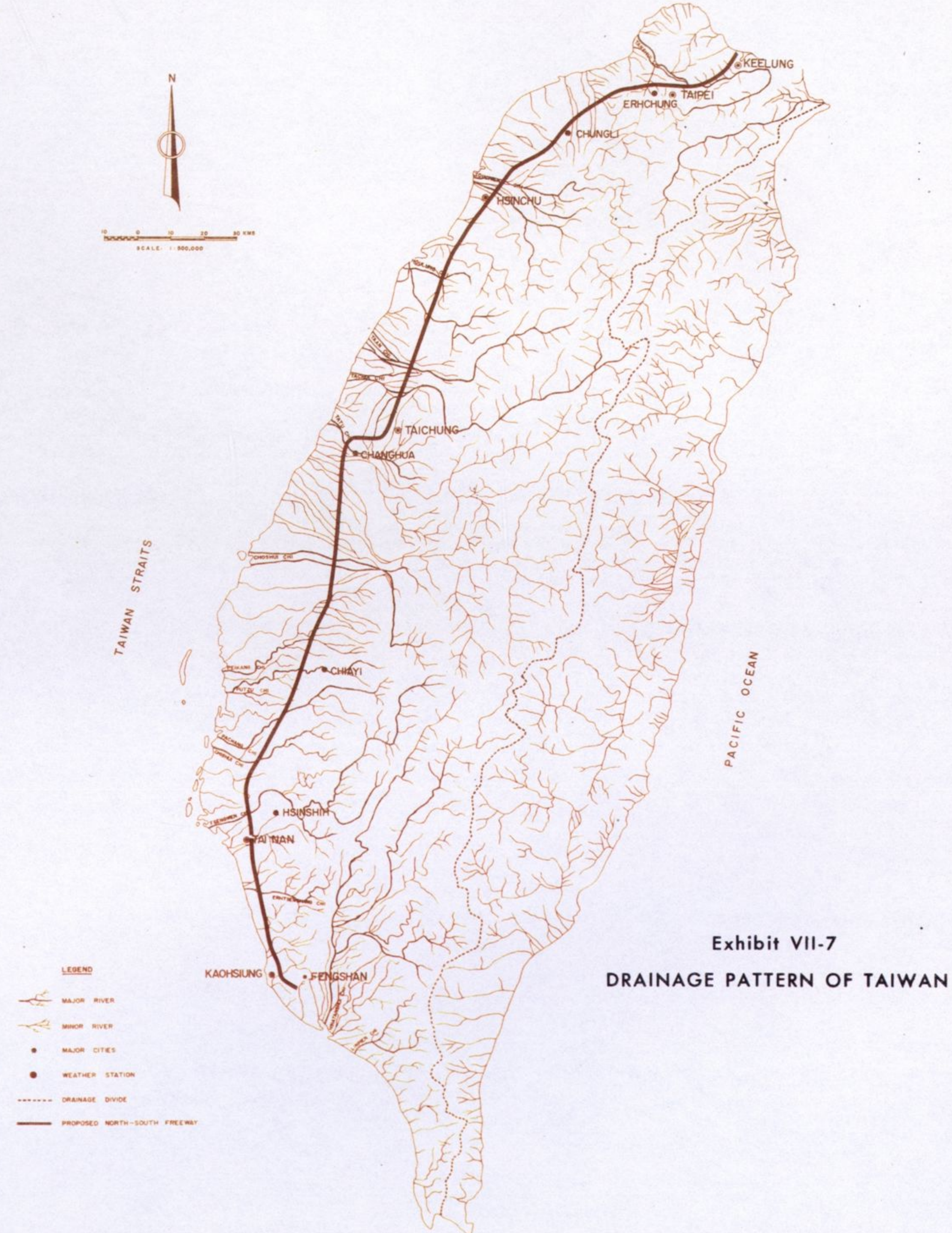


Exhibit VII-7

DRAINAGE PATTERN OF TAIWAN

1,781 mm; Tainan, 1,842 mm; and Kaohsiung, 1,882 mm. Isoheyets of Taiwan are shown in Exhibits VII-4, 5 and 6.

Evaporation

Annual evaporation over the entire Island averages about 1,500 mm. Mean annual evaporation along the North-South Freeway corridor is as follows: Keelung, 1,421 mm; Taipei, 1,316 mm; Hsinchu, 1,482 mm; Taichung, 1,588 mm; Tainan, 1,584 mm; and Kaohsiung, 1,908 mm. It is apparent that the average annual evaporation, in general, increases from north to south. It is only for the three-month period from June to August that the rainfall is in excess of evaporation in southern Taiwan. For the rest of the year, monthly evaporation exceeds precipitation.

In the northern part of the Island at Keelung, a water shortage occurs only in July and August, the hottest months. At Hsinchu, water surplus exists from February to June while Taipei has water surplus almost the year round. At Taichung, in the central part of the Island, the water surplus prevails throughout the summer season.

Relative Humidity

The relative humidity in Taiwan ranges from 75 to 85 percent. In both Keelung and Taipei, the relative humidity amounts to 84 and 78 percent in January and July, respectively. The relative humidity of Kaohsiung is 75 percent in January and 84 percent in July. It is obvious that the relative humidity is low in the summer and high in the winter in the north of the island, and that this characteristic is reversed in the south. In Taichung, in the central part of the Island, the relative humidity does not vary greatly between summer and winter. It is 81 percent in both January and July.

Typhoons

Typhoons are the tropical cyclones typical in this part of East Asia. They are the most violent and destructive natural force, other than earthquakes, on the Island of Taiwan. They consist of a circular area of low atmospheric pressure which develops into a revolving storm. When they are approaching, humidity rises and atmospheric pressure drops abruptly, followed by raging wind-driven rainstorms. Flash floods caused by such tremendous downpours of rain from typhoons, added to the violent winds, cause extensive damage to properties and crops, and take many lives. Taiwan lies on a direct and normal path of the typhoons, most of which originate east of the Philippines. After passing over the Island, the storms generally remain on a northwesterly or westerly course, and deplete themselves upon the east coast of the mainland. Some typhoons change course to a northeasterly direction and move toward the southern coast of Japan and Korea. The typhoon season in Taiwan lasts approximately five months, from June to October. Based on 70-year, 1897-1966, records maintained by the Taiwan Weather Bureau, there were 1,422 typhoons in the west Pacific Ocean, and 257 of them reached Taiwan, averaging approximately three typhoons per year.

HYDROLOGY

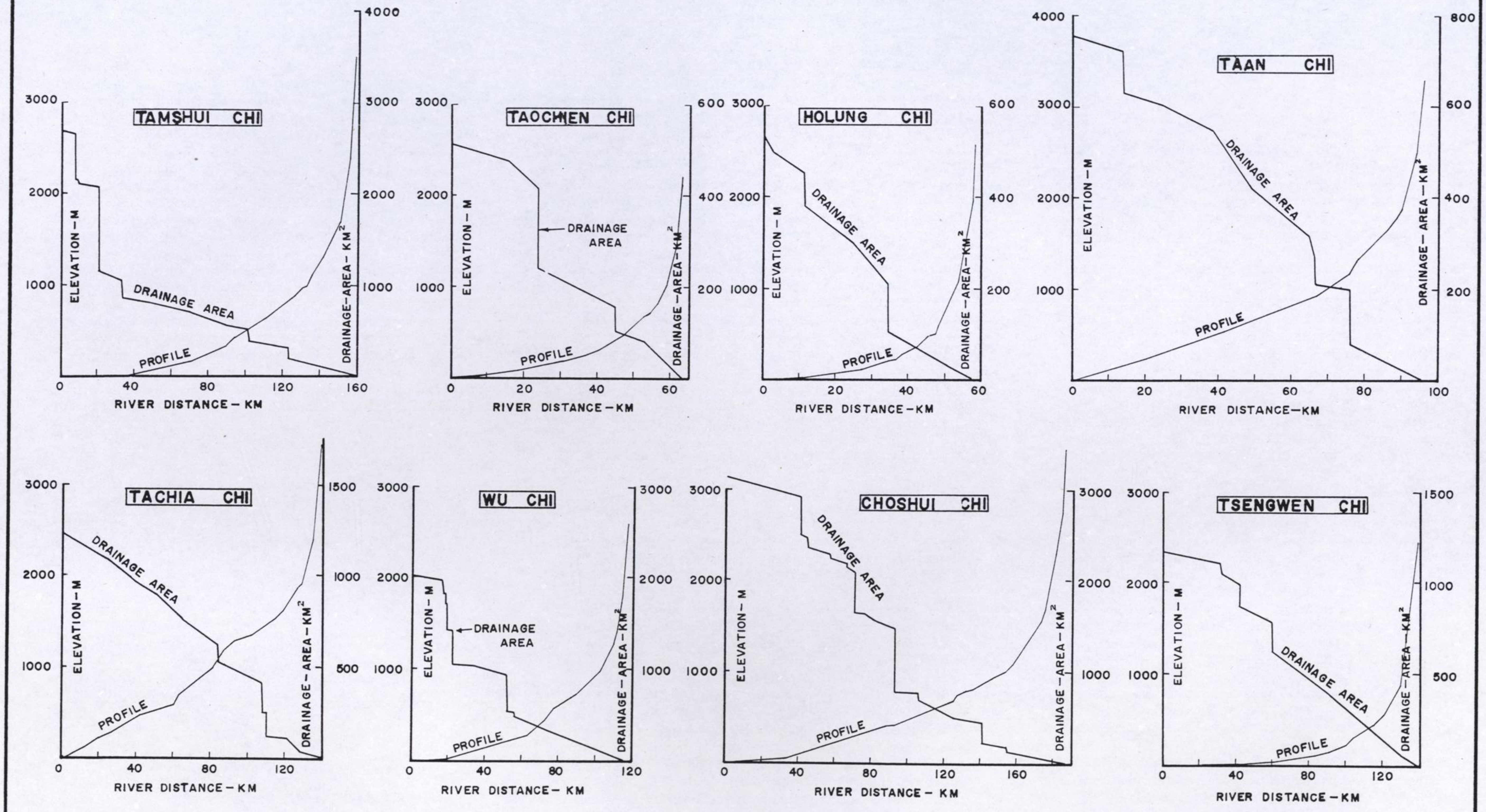
Characteristics of the Rivers

According to the Water Conservancy Bureau classification, there are 19 major rivers in Taiwan in addition to 32 secondary and 100 minor streams. The proposed North-South Freeway crosses 13 major rivers in the western part of the Island. Their physical characteristics are given in Table VII-1. In general, Taiwan rivers are basically characterized by shortness, steepness, and seasonal hydrographical change.

The distance between the western coast line and the crest of the mountains provides a very small drainage area averaging some 80 kilometers wide. As a result, the rivers in Taiwan are quite short and the flow of the water is swift, providing the Island with a radial drainage pattern. See Exhibit VII-7. The Cho-shui River, the longest river in Taiwan, is only 186 kilometers long. The rivers of western Taiwan are longer and less swift than those of the east because of the broader drainage belt between the west coast and the mountain ranges. Of the 19 major rivers on the entire Island, only six are longer than 100 kilometers, and five of these are in western Taiwan.

Steepness is the next characteristic of the rivers in Taiwan. The peaks of the mountains, where most of the rivers originate, are on the order of 1,500-3,500 meters elevation. This height of source, combined with short lengths, results in relatively steep slopes of river beds. Table VII-1 shows that major rivers in the west have river bed slopes in the range of 1:23 to 1:161. They descent from the high mountains at a steep gradient which changes abruptly upon reaching the coastal plain, causing the transported sand and boulders to build up alluvial fans at the outlets of the mountain area and in the deltas near both coasts.

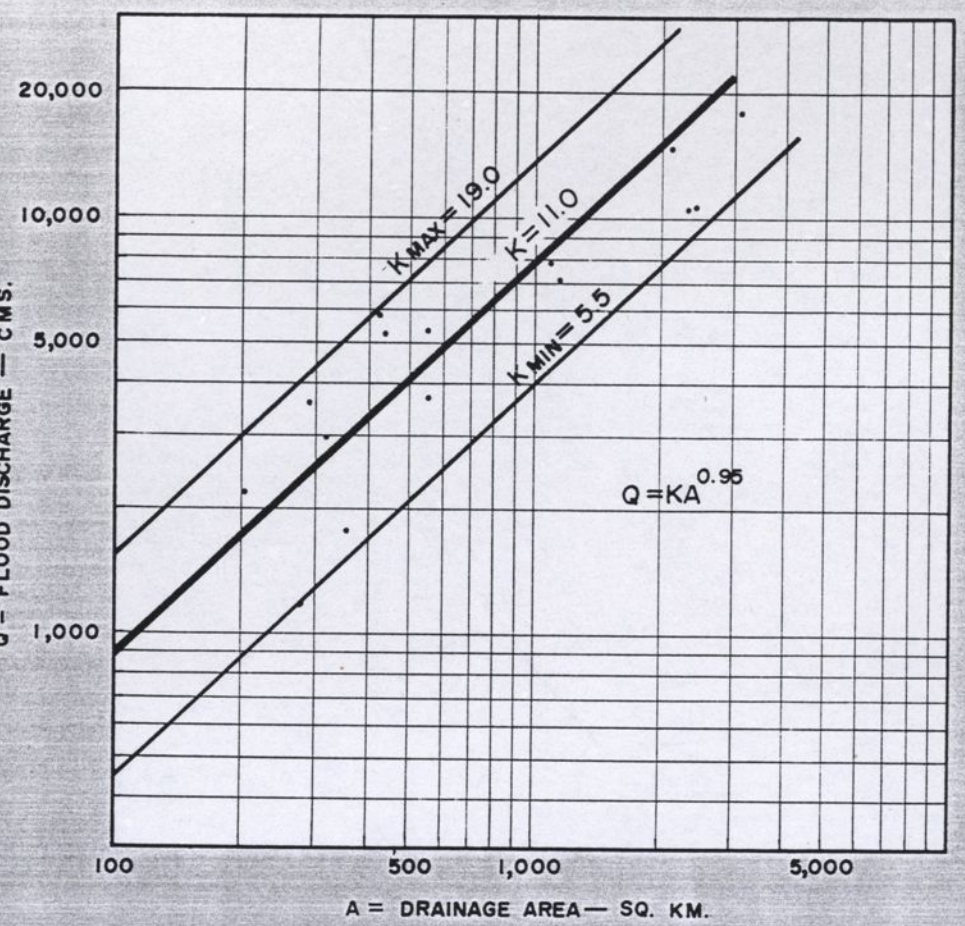
The third characteristic of the rivers is their seasonal hydrographical change. The flow of rivers in Taiwan fluctuates widely between wet and dry seasons. In summer, the rainfall is intense, with the exception of the northeastern part of the Island, and the rivers reach their maximum discharge. The water surface of the rivers rises to the highest level from July to September. The maximum flow during this season is considerably higher than that in the dry season from



PROFILES AND DRAINAGE AREA CURVES OF MAIN RIVERS

REFERENCE: WATER CONSERVANCY BUREAU

Exhibit VII-9



CORRELATION BETWEEN FLOOD DISCHARGE AND DRAINAGE AREA IN WESTERN TAIWAN

REFERENCE: WATER CONSERVANCY BUREAU

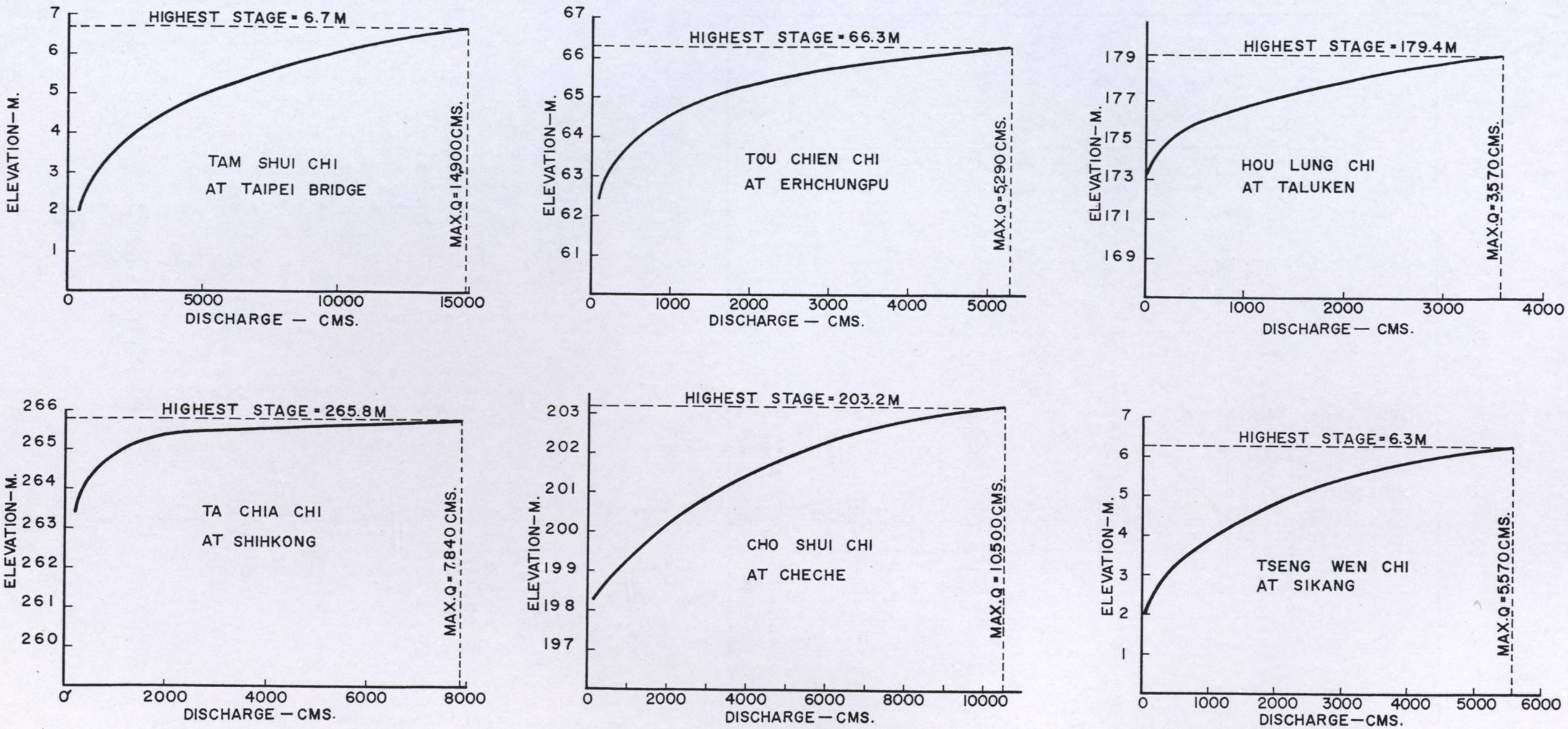
December to June, when flow in many of the rivers becomes intermittent. During the long dry season in the south, the flow of all rivers except major streams is chiefly within the river bed gravels. The Choshui Chi, the longest river, was once recorded as having a discharge of only 0.1 CMS. Due to the seasonal change in hydrography, the rivers, except the lower part of the Tamshui River, are not navigable. This condition of seasonal change is also unfavorable to agriculture.

Floods

In general, floods in Taiwan are caused by the combination of the distinct physical features and climatic conditions of the Island. Physical features contributing to floods are the steep slopes of mountains with short rivers producing rapid runoff, limited drainage basins, and alluvial plains at the river outlets. Most of the destructive floods are brought about by severe summer thunderstorms or by infrequent typhoons. The limited drainage areas, combined with intense convectional storms, cause stream water level to rise rapidly in a short period. The soil or vegetative cover is only a minor factor in absorbing the surface runoff. Rains of long duration occur mostly in the northeastern region, and are caused by the northeast monsoon. This situation occurs on the average of once in three to five years. Maximum flow of main rivers in the west of Taiwan recorded by the Water Conservancy Bureau are as follows: Tamshui River, 14,900 CMS.; Choshui Chi, 10,500 CMS.; Wu Chi, 8,900 CMS.; and Ta-Chia Chi, 7,840 CMS.

High Water Levels

The high water levels recorded by the Water Conservancy Bureau in flooded areas along the North-South Freeway were used to determine the height of embankments. The high water levels at river crossings for proposed bridges were estimated from computed or observed high water levels of the nearest existing bridges upstream or downstream. With the exception of the main rivers, there were no direct high water level elevations at existing bridges on primary highways and no record of high water levels on secondary highways. High water elevations along the



RATING CURVES OF MAIN RIVERS

REFERENCE:
WATER CONSERVANCY BUREAU

North-South Freeway are presented in Table VII-2. Rating curves of Taiwan's main rivers are shown in Exhibit VII-10.

Empirical Formula

In general, the empirical formula for flood estimation is expressed in the form of $Q = KA^n$. The flood discharge "Q" is directly dependent on the drainage area "A"; the constant "K" is a coefficient depending on the rainfall and runoff characteristics of the basin; and the exponent "n" is a constant for a specific region.

To evaluate "K" and the exponent "n", the maximum flow observed at 16 rivers in the western region of Taiwan have been plotted as ordinates versus corresponding drainage areas as abscissae on a log-log scale, see Exhibit VII-8, 9 and 10. The coefficient "K" represents the intercept of the mean line when "A" equals one square kilometer and "n" represents the gradient of the mean line.

The formula for the large drainage area flood estimation in the western region of Taiwan was found to be $Q = 11A^{0.95}$, "Q" being the flood discharge in cubic meters per second and "A" being the drainage area in square kilometers. Upper and lower limits of the band lie between $K_{min} = 5.5$ and $K_{max} = 19.0$ whose ratio of $\frac{K_{max}}{K_{min}}$ equals to 3.45.

HIGHWAY SYSTEM WITH FREEWAY

The discussion of the "with freeway" condition sets out the criteria and features that were adopted for the proposed freeway, and reviews these criteria and features as applicable to the freeway in seven study sections.

FREEWAY DESIGN CRITERIA

Certain design criteria have been adopted, based on the standards of the American Association of State Highway Officials (AASHO), Japanese Industrial Standards, and the standards of the Taiwan Highway Bureau. Only the basic design criteria are discussed here, and the detailed criteria will be more appropriately developed during the preliminary and final design stages.

a. Types of Facility

1) Access controlled with no at-grade crossings or connections with other highways or railways.

2) Access control to be effected by fencing the entire freeway, including interchanges.

3) Access to the freeway from local roads to be permitted only at interchanges.

b. Horizontal Alignment

1)

	Type of Terrain: Flat	Rolling	Mountainous
a) Design speed (km/hr)	120	100	80
b) Average running speed (km/hr)			
Urban	90	77	66
Rural	98	85	71
c) Maximum roadway superelevation (m/m)	0.12	0.12	0.12
d) Minimum radius (m)	600	375	230
e) Spirals to be used when R(m) is less than	3,500	2,000	1,750

2) The proportions for transition curve lengths should be 1:2:1 for spiral to circular arc to spiral.

3) "Broken back" curves to be avoided. A broken back curve is defined as one with short tangents between two circular curves in the same direction. Minimum tangent length varies with design speed.

4) Curves should be at least 250 m long for a central angle of five degrees, and the minimum length of curve should be increased by 30 m for each one degree decrease in the central angle.

5) Compound curves may be used where topography is critical and curves are flatter than R = 700 m but curves should not tighten up too quickly, especially on loop ramps.

c. Vertical Alignment

1)

	Type of Terrain: Flat	Rolling	Mountainous
a) Maximum grade (%)	3	4	5
b) Stopping sight distance (m)	220	160	120
c) K value for sag curves	49	35	23
d) K value for crest curves	102	58	27
e) Critical length of grade (m)	500	350	250

2) The grade of a freeway with curbing on the outside shoulder, or without curbing but in cut, should be a minimum of 0.35 percent and desirably, 0.50 percent.

d. Combination of Horizontal and Vertical Alignment

1) The beginning of a horizontal curve should never be so located that it is hidden by a vertical curve.

2) The minimum sag vertical curve length at the end of a long tangent (greater than 400 m) should be 300 m.

e. Typical Section

1) Minimum median width	-	4.0 m for four-lane and six-lane sections
	-	5.0 m for eight-lane section. (to provide wider inside shoulders)
2) Lane width	-	3.75 m
3) Right of way	-	Minimum 40 m for four-lane
	-	Minimum 48 m for six-lane
	-	Minimum 56 m for eight-lane

For other details, see Exhibit VII-11

f. Bridges

1) Vertical Clearance (at Ultimate Width)

a) Highway over railway	5.4 m - clearance
b) Railway over highway	4.9 m - clearance
c) Highway over freeway	4.9 m - clearance
d) Freeway over highway	4.6 m - clearance

e) Freeway over waterway--Minimum clearance between high water level of design frequency and bottom of superstructure should be 1.50 meters.

2) Horizontal Clearance

a) Freeway crossings over local roads should allow for the ultimate road width.

b) Freeway crossings over railways should be long enough to allow for planned additional tracks in the future.

3) Basic Design Code

a) American Association of State Highway Officials' (AASHO) Specification for Highway Bridges, 1969 edition, is recommended as basic design specifications.

b) The design live load should be based on the AASHO system of live load designation HS20-44 and the alternate Interstate special loading of two 10.9 metric ton (24 kips) axles spaced at 1.22 meters (4 feet) on center.

c) Winds and earthquakes are two major considerations for freeway structure design in Taiwan. Wind force should be assessed on the basis of 160 km/hr winds. A minimum of 10 percent of the dead load of the structure should be designed as an earthquake force, applied horizontally at the center of gravity of the structure.

g. Drainage

1) Design Storm Frequency

Type of Drainage Structure	Design Frequency (Years)
Storm sewers, culvert pipes	15
Box culverts, short span bridges	25
Large bridges	50
Very large and costly bridges	100

2) Height of Fill

The design height of roadway embankment should be established as indicated in the following table which shows the minimum clearance between profile grade and highest recorded water level:

	Meters
8-land highway	1.20
6-lane highway	1.20
4-lane highway	1.10

CAPACITY

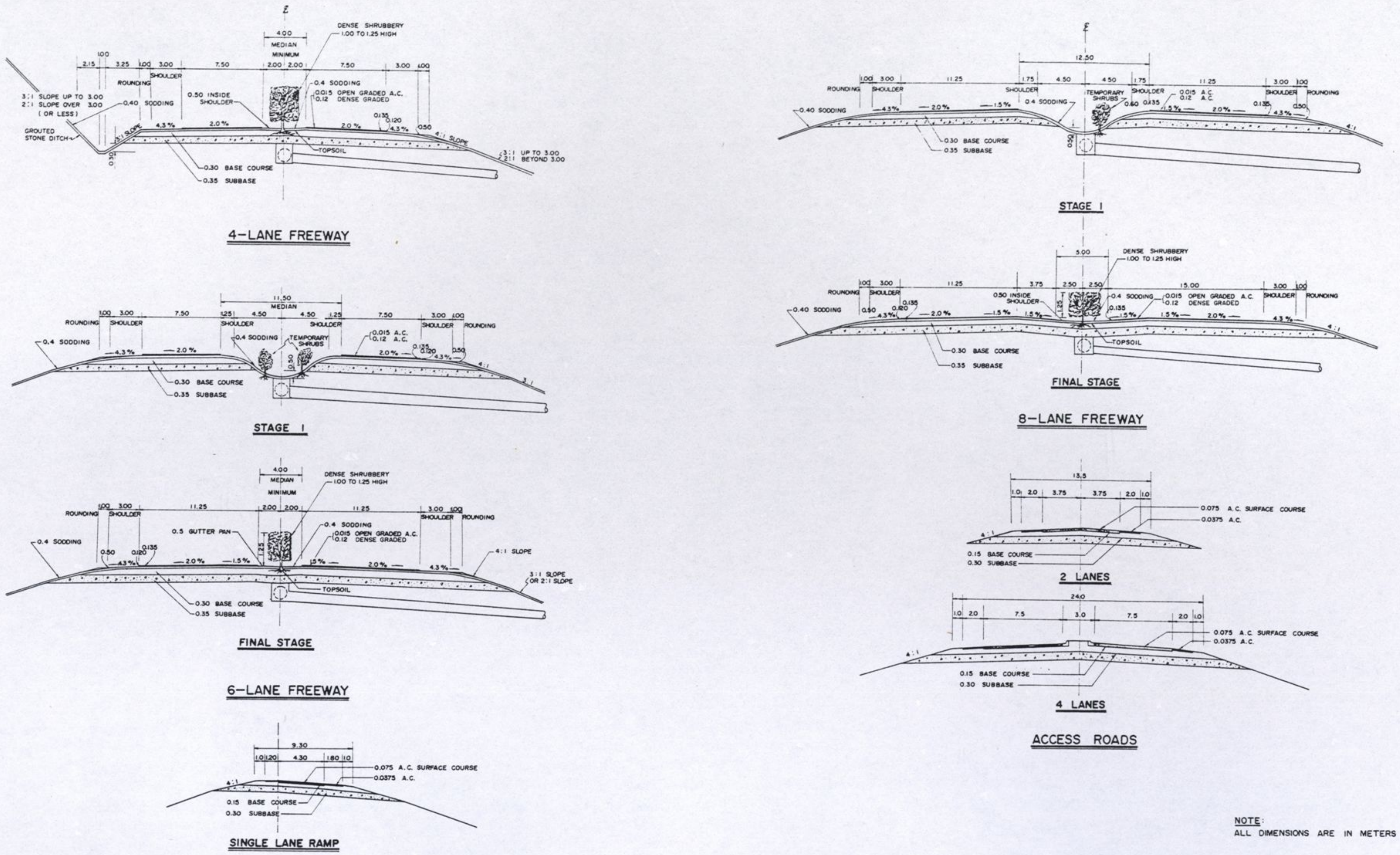
The number of vehicles which can travel on a highway depends on the prevailing roadway conditions and on the traffic characteristics, such as vehicle mix and speeds. The maximum number is called the "capacity" of the highway, and it is related to low speeds.

The procedures for capacity calculations are described in the 1965 "Highway Capacity Manual" and "A Policy on Geometric Design of Rural Highways". For practical application, the statistics and charts were simplified and modified in regard to the special traffic composition in Taiwan. The adequacy of this modified procedure was checked by application to existing conditions as observed at the 37 survey stations.

Four specific problems of capacity calculation were first resolved.

1. The forecast of traffic by expansion method is only as complete as the surveyed traffic. It is not complete at locations between O-D stations, where short trips within a sector are not known. Capacity, therefore, was calculated only near the screenlines. Highway improvements between these checkpoints were interpolated along the corridor axis. Many conditions of local traffic congestion--especially near and within cities and on transversal roads--are not reflected in the simulated traffic volumes.

2. Traffic composition or "mix" will change considerably between 1969 and 1990. Future traffic will include a larger proportion of autos. By



TYPICAL FREEWAY CROSS SECTIONS

(NOT TO SCALE)

1990, large vehicles are expected to represent about 30 percent of all traffic instead of the present 50 percent.

In order to use a set of capacity figures independent of the traffic mixture, passenger car equivalents are used to represent both capacity and traffic volumes. After testing the existing conditions, the following passenger car equivalents (PCE) were chosen:

Terrain	Auto	Light Truck	Heavy Truck	Bus
Level	1.0	1.0	2.0	2.0
Rolling	1.0	2.0	3.0	3.0
Mountainous	1.0	4.0	6.0	6.0

3. It is shown in Chapter V that, with the exception of motorcycles, all other types of slow-moving vehicles and traffic have been declining and are forecast to decline further in the future. Motorcycle registration is estimated to grow almost 5.5 times between 1969 and 1990, but it is estimated that motorcycle traffic on highways will grow at lower rates as people in the future will prefer improved and more comfortable passenger car, taxi, bus, and railway services. It is forecast that motorcycle traffic will grow approximately four times on highways in Taiwan between 1969 and 1990.

In estimating the freeway corridor capacity requirements, motorcycles were treated as creating a zero distance side clearance condition. Any other method, such as assigning a passenger car equivalency to motorcycles, has not proved to be workable. The latter assumption produced conflicting results when compared with existing conditions in Taiwan, since it indicated that present traffic volumes are impossible. It was observed that, in high volume conditions approaching maximum capacities of highways, the motorcycles occupy the spaces between the vehicles, share single lanes with small cars, and use the shoulders. The latter practice should not be permitted on the proposed freeway, however.

Most motorcycle trips are short, and are concentrated on the sections of highways in the vicinity of urban areas. As numbers of other slow-moving vehicles decline and some portion of motorcycle trips is diverted to freeway buses, it will be possible to accommodate the remaining motorcycle traffic.

In estimating number of freeway lanes and highway widening requirements, the capacities of the existing highways in the North-South direction were considered to be fully utilized. With the adopted capacity procedure of assuming zero lateral clearance for motorcycle traffic on these highways, the widening requirements and dates for opening freeway sections were estimated on the basis of the forecast traffic growth. If congestion developed on existing highways because of the motorcycle traffic before the estimated dates, the adjustments which would have to be made in scheduled new construction would be minor since the total increase of motorcycle traffic (in passenger car equivalents) would be less than even one year's increase of faster-moving traffic. Thus, at the most, motorcycle traffic would require that widening of the freeway be advanced by some period less than one year. Even without considering motorcycle traffic, some adjustments in the construction schedule might still have to be made.

For example, it is estimated that, in Study Section 2 between Taipei and Taoyuan, another highway improvement, possibly a freeway, will be needed by 1982. Volume change in that year for the six-lane section, based on a 1981 traffic volume of 90,000 PCE and ten percent growth, might be in the vicinity of 9,000 PCE. The motorcycle traffic on this section was 4,000 per day during the 1969 survey. If it doubled by 1982 (i.e., to a level of 8,000), the additional number of motorcycles to be accommodated by the existing highways would be only 4,000 per day, which is lower than the increase in the corridor main traffic and considerably lower when converted to PCE's.

4. Accurate capacity calculations are usually based on hourly traffic. In order to use them for the forecast daily traffic, the relationship between hourly and daily traffic had to be used. In 1969, hourly traffic for both directions combined was found to vary between five percent and ten percent of total daily traffic.

Design hourly volume was estimated to be 10.0 percent of average daily traffic. In Taiwan, this K factor should be smaller than the corresponding 13.0 percent factor in the United States, due to the longer working hours, subtropical climate, night-driving, and congestion. Peak hour traffic in one direction here averages 60 percent of traffic in both directions. Average daily capacity, therefore, is obtained by multiplying peak hour capacity in one direction by 16.6.

These four decisions were tested by detailed capacity calculations at the 37 survey stations. Most of these stations had two lanes, and all the influences of lane width, side clearance, design speed, passing sight distances, grades, traffic peaking and composition were considered.

The level of service of a highway is determined by the prevailing traffic flow and speed. The levels, designated A to F, are described in the Highway Capacity Manual, with A being applicable to higher speeds and low traffic volumes, and F designating forced flow under continued traffic pressure. Average conditions during the entire day are better than during peak periods, especially if peak traffic lasts for only short periods. The lower off-peak volumes allow easy flow and higher speeds. In the study area, the sustained high traffic between 9:00 a.m. and 6:00 p.m. permitted only a small part of the daily traffic to exceed average speeds at any one moment. The daily average condition was only about one level of service better than during the peak hour, or in other words the average speed was only about 12 kilometers per hour higher than the average speed in peak periods. Between Taipei and Chungli, for example, existing traffic conditions were found to be at level E or F during peak period which means that level of service was D or E as a daily average.

Traffic Growth at Each Screenline

Anticipated traffic growth was plotted on a separate graph for each screenline. The 1969 vehicle counts and the 1990 forecast were calculated in passenger car equivalents, and the volumes for the intermediate years were based on the growth curves previously developed in Chapter V. These results are shown as Graphs VII-1 to 17.

The screenline was separated into West and East for Taichung-Changhua versus Taichung-Nantou, and an additional graph was made for Linkou-Taipei traffic. Only the latter and the Tamshui River graph required a different scale. The 1990 traffic assignment indicates traffic volume on each highway at each screenline, but the total screenline volume is more accurate because of the assignment techniques used.

Screenline Traffic Growth and Lane Requirements 1969-1990

Traffic growth between 1969 and 1990 with freeway would be composed of the normal increase together with the traffic diverted from the railway. Graphs VII-1 to 17 illustrating anticipated growth were derived by adding to the normal growth curve, the traffic diverted from rail as a black band.

The growth rate would accelerate sharply when the entire length of the freeway was opened around 1975. Thereafter, "rail truck" traffic would increase while "rail bus" traffic would be expected to decrease to zero about 1980. New traffic induced by the freeway was not specifically forecast. Some additional traffic could be absorbed by the capacity reserve on the freeway and other highways at lower levels of service and speed than indicated. If the induced traffic was higher than expected, the freeway might have to be widened sooner than predicted.

The following freeway capacities were chosen for levels C, D and E corresponding to various roadway widths, respectively:

	Level of Service		
Type of Freeway	C	D	E
4-lane	50,000	60,000	66,000
6-lane	75,000	90,000	100,000
8-lane	100,000	120,000	133,000

These volumes in passenger car equivalents on a normal day can be related to actual volumes by considering the traffic "mix". For an average mixture of 30 percent large vehicles in the Keelung-Chungli area, actual capacity would be 77 percent of above PCE figures, but on the balance of the freeway with approximately 50 percent large vehicles, the service volumes in vehicles would euqal only two-thirds of the above PCE volumes. On grades, where capacity is further reduced, additional climbing lanes for large slow-moving vehicles should be built to assure that capacity is adequate.

Successive improvements of highways and freeways are noted above the traffic curve on the graph for each screenline.

The various possibilities of capacity improvements by new freeway, by highway widening, and by freeway widening, and their relative sequence, were integrated to form a balanced network. Many alternatives were weighed to reach decisions on the major network in each section.

The proposed network is illustrated on a simplified plan showing the year of opening of each major portion. The timetable for improvement or construction of each section is shown in Table VII-29. The table summarizes proposals for the network with the freeway and comparable highway widenings without freeway.

PAVEMENT

The roadway pavement structure and the related earthwork and foundation standards were developed on the basis of methods and practices of AASHO, the State of California Division of Highways, the Asphalt Institute, and the Portland Cement Association. Pavement structures were developed by analyzing basement soils, traffic loads, and structural pavement components for both flexible and rigid designs. The earthwork and foundation standards were developed from existing AASHO standards and from an evaluation of current practices of the Taiwan Highway Bureau.

Basement Soils

The basement soils along the west side of Taiwan were previously classified as silty materials, with varying percentages of sand and clay. The strength properties of these soils were estimated to range from poor to good, with most of them described as fair. The Resistance Values (R values) of the soils had been measured by the Taiwan Highway Bureau by sampling and testing along existing highways. The method of measuring soil strengths developed by the California Division of Highways has been used extensively by the Taiwan Highway Bureau for evaluating basement soils, aggregate subbases, and aggregate bases.

In designing pavement structure, an R value of 20 was chosen to represent the soils throughout the freeway alignment. This was thought to be on the conservative side since many of the soils showed values in the 30's and 40's. Until design sampling has been completed, however, it should be assumed that soils with very low R values will control pavement design for both excavation and embankment.

Traffic Loads

The effect of traffic loads was determined from both wheel loads and vehicle repetitions for periods of 10 and 20 years. The existing two-lane highways were evaluated for 10 years, and the proposed freeway was evaluated for 20 years. The existing highways were considered to require an asphaltic concrete overlay at the end of the 10-year period.

In analyzing the destructive effects of traffic, automobiles and light trucks were omitted from the calculations. Their combined effect on pavement structure thickness requirements was found to be negligible when compared with the requirements imposed by heavy trucks and buses. Pavement structure was developed on the assumption of trucks and buses occupying two traffic lanes in each direction simultaneously.

The method of "Equivalent Wheel Loads" developed by the California Division of Highways was used to relate wheel loads and repetitions for various vehicle loads. Average daily truck and bus traffic on existing highways was estimated from traffic data at 1, 1?5 vehicles per lane. This daily figure provided an Equivalent Wheel Load of approximately 19 million and a Traffic Index of 9.4 on a 10-year design basis. The average daily truck and bus traffic for the freeway section from Erhchung to Chungli was estimated from traffic data at 3,425 vehicles per lane. This daily figure provided an Equivalent Wheel Load of approximately 150 million and a Traffic Index of 12.0 on a 20-year design basis.

The average daily truck and bus traffic was estimated from traffic data for all other sections of the freeway, and compared with the Erhchung-Chungli traffic. It was found that vehicles per lane were approximately the same for all sections, and the differences in volume did not warrant a separate pavement structure for each freeway section. The differences in traffic volumes should be accounted for during the design phases, when detailed changes in pavement structure could be more accurately developed.

Structural Components

The practices developed by the California Division of Highways were followed in evaluating the structural components of the pavement. For flexible pavements, Asphalt Institute recommendations were used to assign gravel equivalencies to the component materials. For rigid pavement, Portland Cement Association recommendations were used to assign load safety factors to the concrete pavement.

Pavement Structure for Freeway

The pavement structure for the freeway was developed for both flexible and rigid designs. The flexible analysis was developed for the combination of an open-graded asphaltic concrete wearing surface over dense-graded asphaltic concrete, crushed aggregate base, and uncrushed aggregate subbase. In addition, aggregate bases with cement and bitumen were considered as alternates. The rigid analysis was developed for the combination of Portland cement concrete over a treated crushed aggregate base and uncrushed aggregate subbase.

Due to anticipated wearing of the surface course for the flexible design, a thin asphaltic concrete overlay of four centimeters thickness was considered as necessary after 14 years.

A pavement structure for the frontage roads was developed for the combination of an open-graded asphaltic concrete wearing surface over a dense-graded asphaltic concrete on top of a crushed aggregate base. The structural thicknesses were determined by assigning an R value of 20 to the basement soil and estimating the Traffic Index at approximately 7.5 for a design period of ten years.

Flexible Versus Rigid Pavement

In evaluating the two alternative types of pavement structures, an economic comparison was made for an estimated pavement life of 25 years. This evaluation considered construction and maintenance for both pavement structures and resurfacing for the asphalt. Although a slight cost advantage in favor of rigid design was estimated, the overall costs were so close that final selection at this time would not be prudent. The factors of stage construction, material and equipment availability, and adverse weather conditions are significant in the analysis. These factors cannot be estimated accurately until design plans and a construction schedule have been developed.

In regard to material availability, the production capability of the cement industry of Taiwan is expanding rapidly. A drop in export demand would probably reduce prices to the local construction industry. This one factor might place rigid design in a favored position from the standpoint of cost.

The required thickness of the two types of pavement structures is shown below:

<u>Flexible Pavement</u>	
Open-graded Asphalt Concrete	1.5 cm
Dense-graded Asphalt Concrete	12.0 cm
Crushed Aggregate Base	30.0 cm
Uncrushed Aggregate Subbase	35.0 cm
Total Thickness	56.0 cm
<u>Rigid Pavement</u>	
Portland Cement Concrete	21.0 cm
Cement or Bituminous Base	12.0 cm
Uncrushed Aggregate Subbase	23.0 cm
Total Thickness	78.5 cm

The flexible pavement structure, developed originally as the standard section, was used to represent the typical section for the entire freeway length. However, the alternates of treated bases and Portland cement, should be completely evaluated when design plans are prepared for the Erhchung-Chungli freeway section.

BRIDGES

The freeway project would include approximately 370 bridges. These can be classified into three major groups:

- River crossings;
- Grade separations; and
- Elevated structures.

Eight major river bridges would cross Tamshui, Touchien, Hou Lung, Ta An, Ta Chia, Tatu, Choshui, and Tseng Wen rivers with lengths ranging from 600 to 2,000 meters. The cost of these major bridges would represent 35 percent of total bridge cost. A total of 130 grade separation structures, including bridges for interchanges, railroad and road underpasses and overpasses, would be required. In order to overcome problems at certain of the poor sites, conditions such as flood plains and hillsides with frequent landslides, elevated structures are considered preferable. Several such viaducts would be required, especially between Keelung and Chungli. They would also be employed to act as flood relief structures, to cross deep valleys, and to minimize right of way requirements. In addition, 232 river bridges with span lengths of 600 meters and less would be required.

Typical Freeway Bridge Section

It is recommended that bridge widths from curb to curb be kept the same as the roadway widths from outside edge of shoulder to outside edge of shoulder, and that safety walks be omitted. These standards are in accordance with the latest recommendations of the AASHO Traffic Safety Committee. Sixty-centimeter-high safety curbs with a railing should be provided on each side of the bridges, and an 80-centimeter high concrete barrier would be built in the median.

Since most of the rivers are unsuitable for navigation, a clearance of 1.5 meters between the bottom of girder and the high water level would be sufficient for all rivers except the Tamshui River. With the planned development of a harbor at its entrance, this river could be developed as a navigable channel for barges in the future. If such a plan is adopted, the span length over the central channel should be at least 65 meters and vertical clearance above high water should be at least three meters.

Site Conditions

In addition to shortness and steepness, the rivers of Taiwan are characterized by wide seasonal fluctuations in volume of their discharges, as previously discussed. The variations in water level will be an important consideration in construction of river pier foundations. If possible, all substructure work should be scheduled for periods of low water.

Foundations

Foundation soils supporting bridge structures typically would be the fine-grained silty materials comprising most of the west side of the Island; however, there are granular materials existing to great depths in some of the rivers and streams.

The silty materials would generally require driven or drilled piling substructures to carry the loads to lower-lying materials of greater strength. The area near Taipei is typical of this type of foundation condition, and piling has been found necessary for most existing structures. In the central part of western Taiwan, the granular soils in the rivers and streams contain a large percentage of rocks and boulders which make the use of piles extremely difficult. Where these conditions exist, spread footings or caissons would be required. The area near Taichung is typical of this foundation condition.

Construction Materials

The materials necessary for producing good quality reinforced concrete and prestressed concrete are available in Taiwan. Portland cement is produced in several major cities and has been one of the major export items in the past decade. There would be sufficient cement manufacturing capacity to supply the freeway project without creating a shortage. Mild steel reinforcing bars of good quality, up to 36 mm size, have also been produced. The only high tensile steel mill is located in a Taipei suburb. It has a present capacity of 3,000 tons per year for all sizes of wires from 2.0 mm to 12.8 mm. It is understood that the capacity of this factory could be increased to a maximum of 12,000 tons annually which would be adequate for freeway bridge construction. Several prestressed concrete plants producing many kinds of precast members for buildings could easily be converted to manufacturing bridge members.

Comparison of Bridge Types

Selection of the most suitable type of bridge in each case is governed by various requirements such as cost, traffic, site and foundation conditions, and appearance. Bridges, for the proposed freeway, as previously noted, were classified into three categories for comparative purposes: (1) Grade Separations; (2) Elevated Structures; and (3) Major River Bridges. See Exhibits VII-12, 13, and 14.

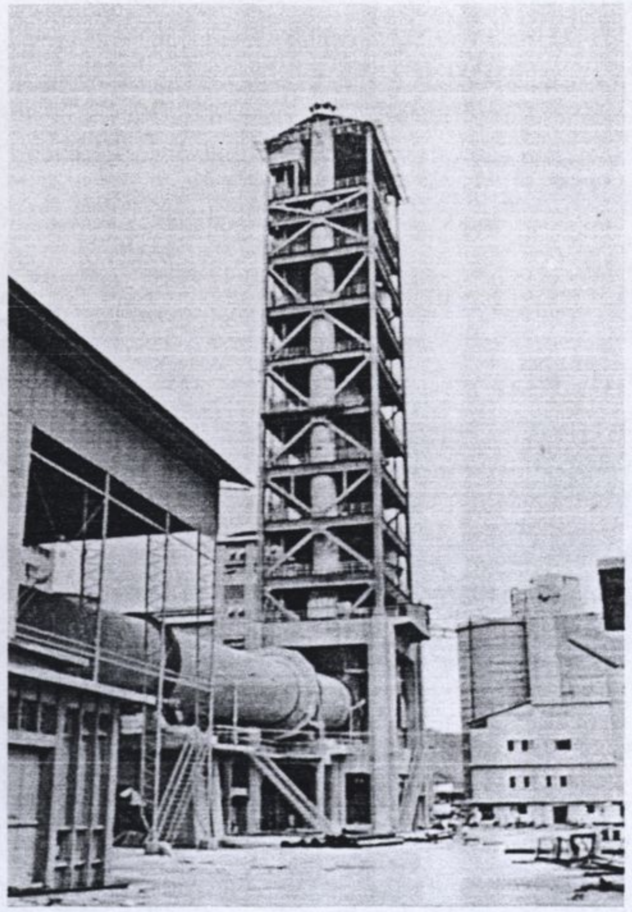
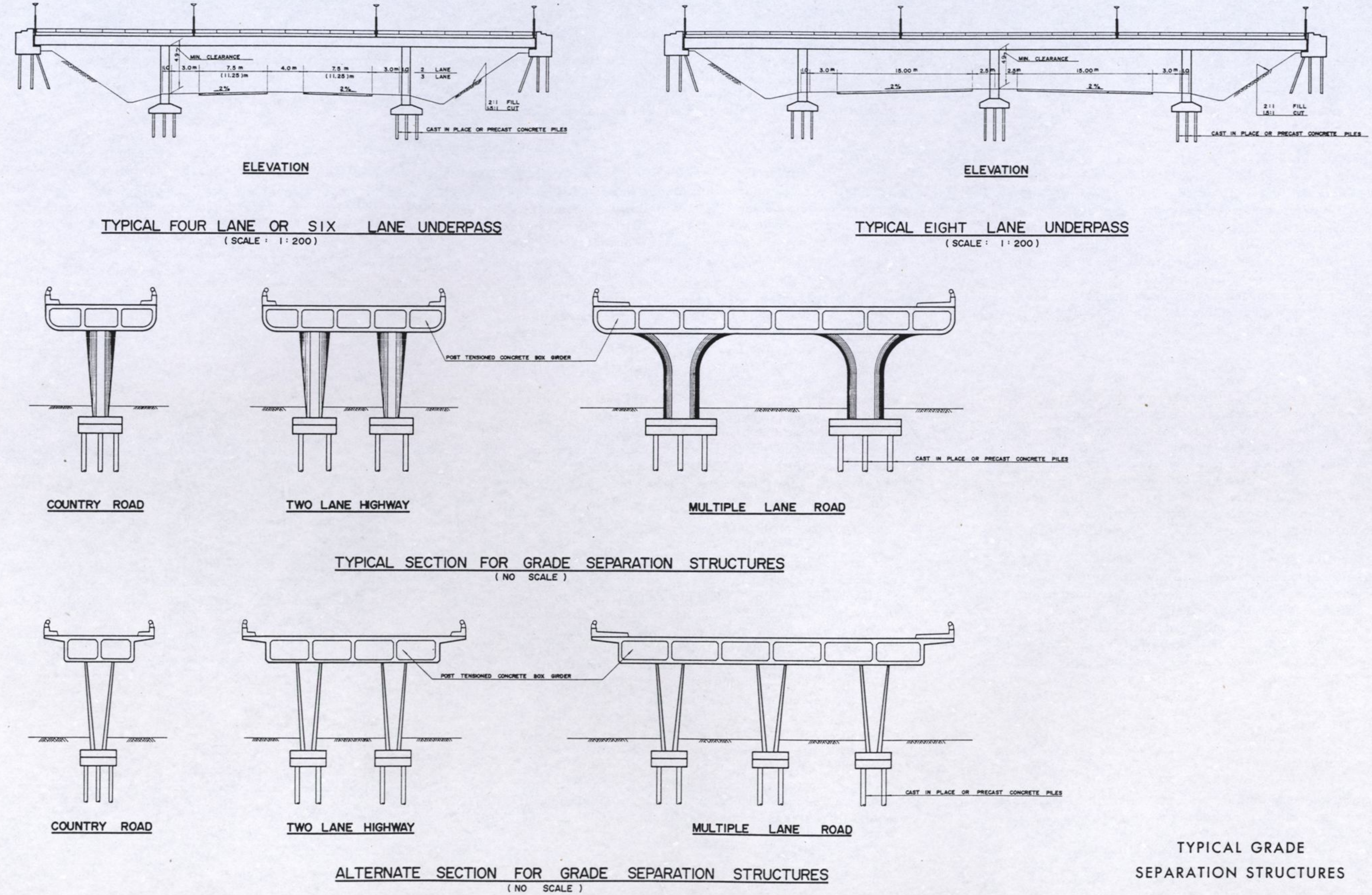
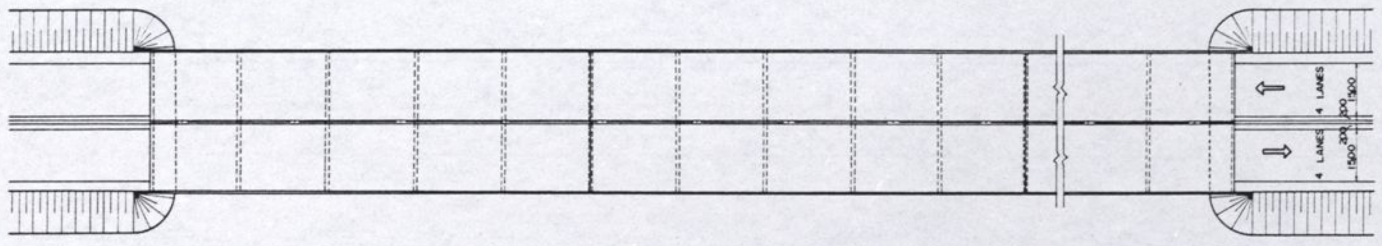


Exhibit VII-12

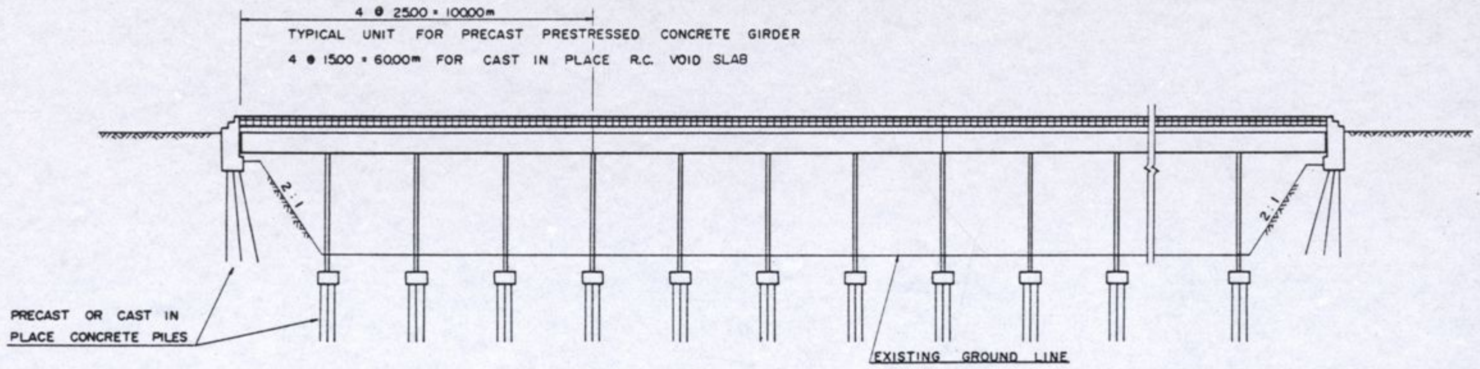


TYPICAL GRADE SEPARATION STRUCTURES



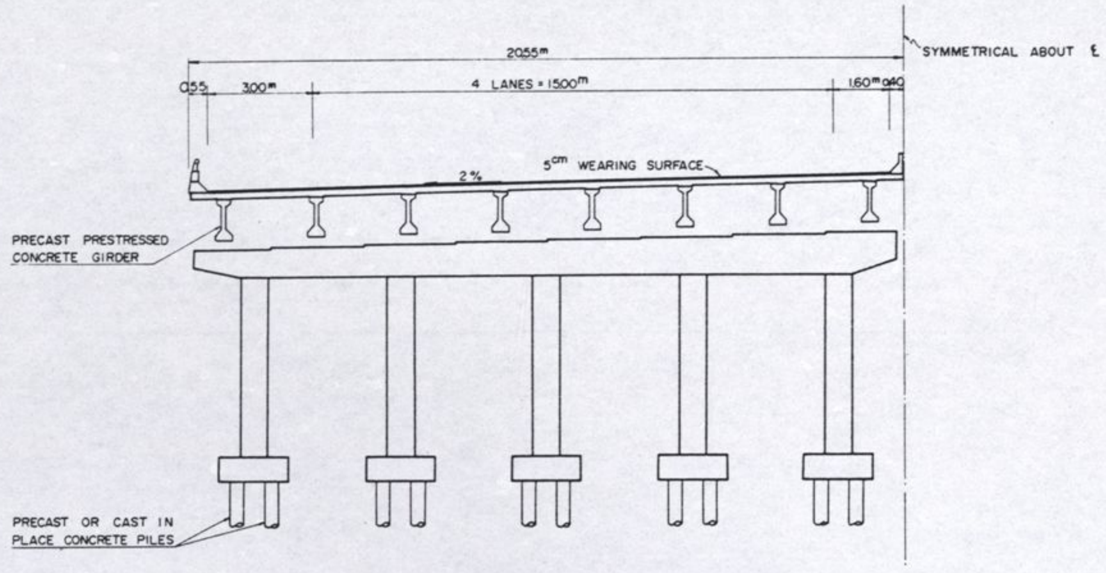
PLAN

(SCALE 1:1,000)



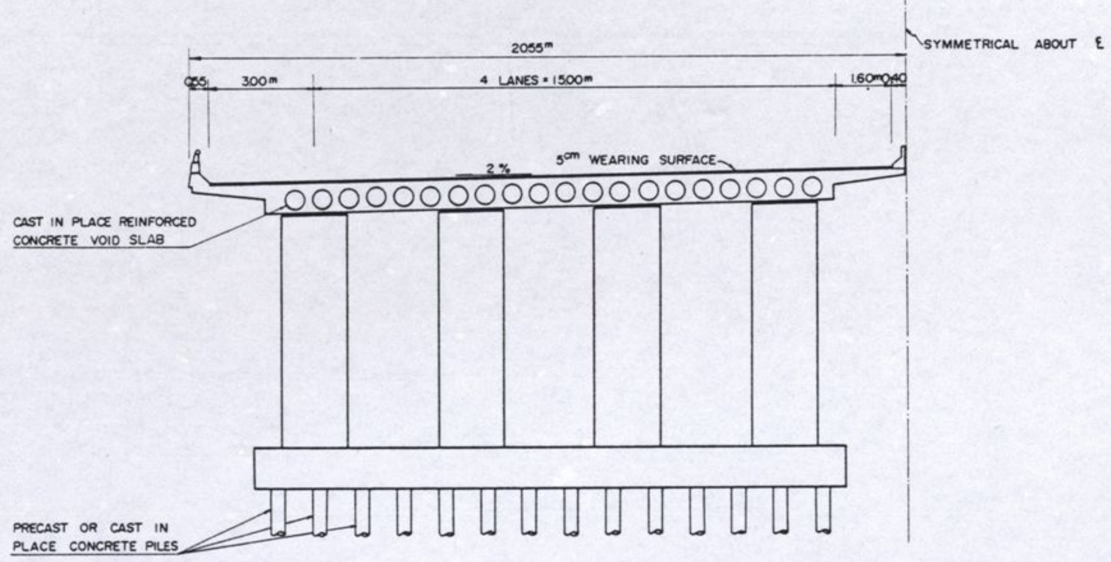
ELEVATION

SCALE: HORIZ. 1:1,000
VERT. 1:200



TYPICAL HALF SECTION—PRECAST P.C. GIRDER

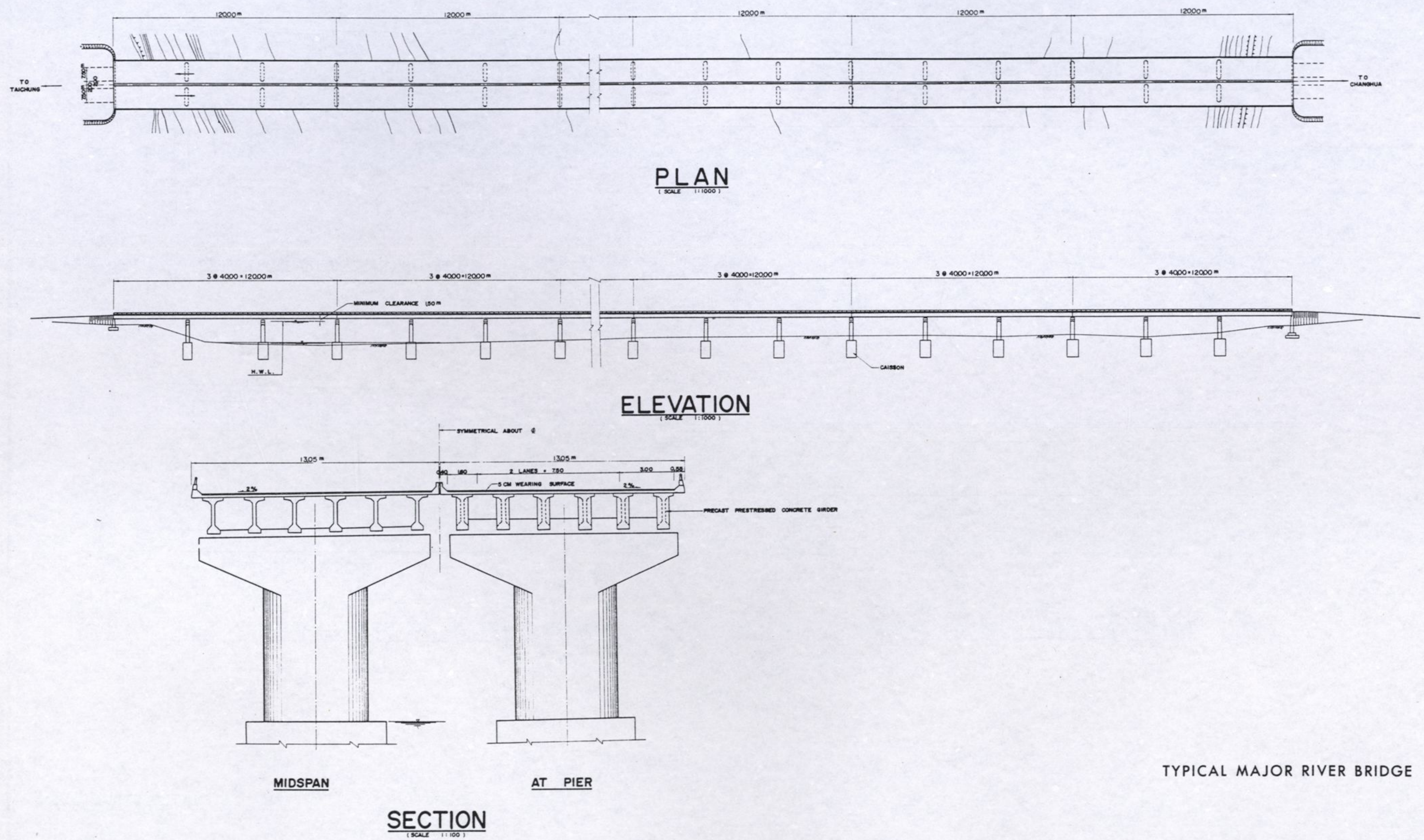
(SCALE 1:100)



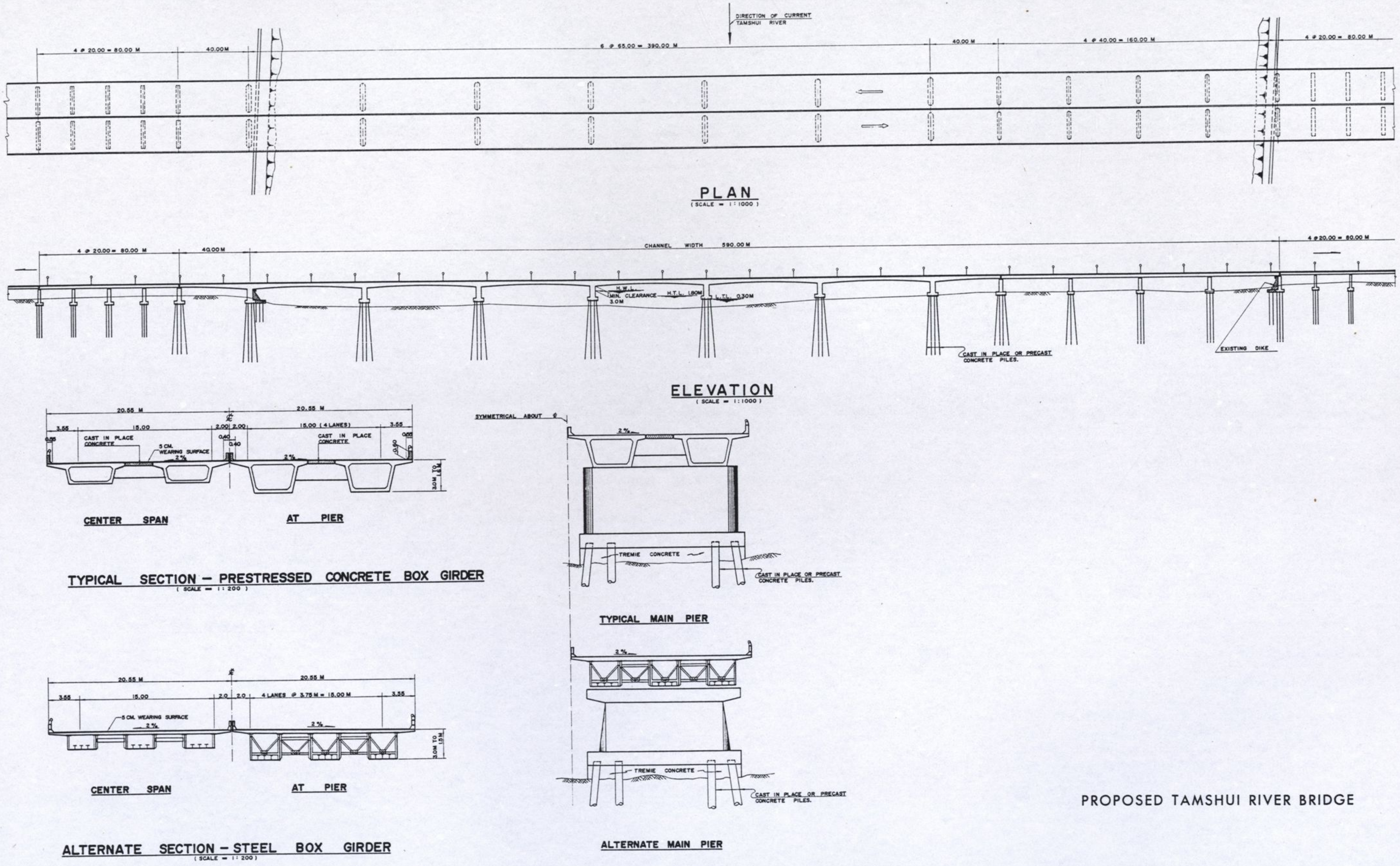
ALTERNATIVE HALF SECTION—CAST IN PLACE R.C. VOID SLAB

(SCALE 1:100)

TYPICAL ELEVATED STRUCTURE



TYPICAL MAJOR RIVER BRIDGE



PROPOSED TAMSHUI RIVER BRIDGE

For grade separation structures, the following six bridge types were studied:

a. Reinforced concrete box girder

b. Post-tensioned concrete box girder

c. Prestressed concrete girder

d. Cast-in-place concrete void slab

e. Post-tensioned concrete slab

f. Welded steel plate girder

A preliminary cost analysis indicates that these types could be grouped under three cost ranges: Types a and c would be the lowest; b, d and e, five percent costlier, and Type f would be twenty percent more expensive. It is recommended that the curved multiple cell post-tensioned concrete box girder be adopted because of its graceful lines as well as its reasonable cost. It has other advantages such as high torsional stiffness and relatively shallow superstructure depth. A tapered or rectangular box, instead of a curved box, might be used as an alternative because of its simple formwork. Pier type should be selected to match the type of superstructure selected.

For elevated structures, the following five types were studied:

a. Precast prestressed concrete girder

b. Cast-in-place reinforced concrete void slab

c. Precast prestressed void slab

d. Post-tensioned concrete slab

e. Composite wide flange beam

The precast-prestressed concrete I-girder with span lengths of 25 meters or less is recommended since it would cost less than the other four types. It has good appearance and riding qualities, and can be constructed quickly. A cast-in-place void slab could be considered as an alternative on firm ground.

For major river crossings, the bridges were considered as either (1) long-span; or (2) medium-span. The former would be used over navigable rivers and would apply to the Tamshui River in the north, since it may be made navigable in the future. See Exhibit VII-15. Medium-span river bridges were considered appropriate for the other rivers which have wide and flat beds, and are dry except in rainy seasons.

For the long-span river structures, the following four bridge types were studied:

a. Post-tensioned concrete box girder (by cantilever method)

b. Steel box girder

c. Steel plate girder

d. Orthotropic type

The post-tensioned concrete box girder is recommended since it would be less expensive than any type of steel bridge. Its other advantages are lower maintenance cost, good appearance and durability. The cantilever construction method is suggested, and could be used for both precast and cast-in-place types. Central span lengths of 65 meters and approach span lengths of 35 meters or less are suggested. If fast construction were required, however, a steel box girder might be used as an alternative.

For the medium-span river structures, the following three bridge types were studied:

a. Precast prestressed I-girder

b. Post-tensioned concrete box girder

c. Steel plate girder

Precast prestressed I-girders with span lengths of 45 meters or less are recommended since this type would cost less than the other two. The I-girders could be built quickly in a casting yard adjacent to the bridge site.

The foregoing studies were made to establish preliminary bridge types for estimating purposes. Final selection of bridge types should be made in the preliminary design stage, at which time cost estimates would be based on detailed knowledge of site and foundation conditions.

FREEWAY FEATURES

Alignment

The length of the North-South Freeway would be 373.81 kilometers. The general route and corridor Key Plan and Route Plans 1 to 27, showing the plan and profile of the recommended alignment, are contained in the back of this volume.

The proposed North-South Freeway, in comparison with the existing arterial highway network and the MacArthur Thruway, represents a travel distance savings of 25 kilometers from Keelung to Kaohsiung. A time savings of approximately 50 percent would be realized.

The point of origin of stationing was taken to be the intersection of the proposed line through the city of Taipei with the centerline of the Chung Ching North Road or its extension. Stationing extends to the north to terminate at Keelung and south to terminate at Kaohsiung. This procedure for stationing was requested by the Taiwan Highway Bureau to conform with existing methods.

The North-South Freeway, if it followed the recommended alignment, would occupy 23.4 million square meters of land. Of this amount, about 14 percent is urban and 86 percent is rural. Of the rural portion, about 20 percent is in hilly or forested areas and about 80 percent would be in rice paddy areas. The breakdown is as shown below:

Land Area in Square Meters

Land Area	Square Meters
Urban	3,235,000
Rural	
Hilly or forested areas	3,894,000
Rice paddy or other agricultural areas	16,257,000
Total	23,386,000

The proposed North-South Freeway corridor passes through the western side of the Island relatively near the coast line. The closest point to the sea is 2.4 kilometers just north of Kaohsiung, while the farthest point is 30 kilometers just north of Chiayi.

The vertical alignment is characterized by long, relatively flat grades.

A total of 12.8 kilometers would have a profile grade steeper than three percent. These sections would be in Study Sections 1, 2, and 4, and would be 1.6 kilometers, 7.7 kilometers, and 3.5 kilometers long, respectively. In all other locations, the gradient would be three percent or less.

The two highest points on the freeway would be in Study Section 2 at station 16k + 500, with an elevation of 262 meters, and in Study Section 4 at station 123k + 000, with an elevation of 360 meters above sea level. These locations are the summits approached by gradients in excess of three percent for Study Sections 2 and 4 as mentioned above. This condition is partly fixed in Study Section 1 because of the intent to use existing alignment for the sake of economy.

The recommended route of the North-South Freeway is in valleys and isolated plains in mountainous areas north of Changhua and on large expansive plains south of Changhua. Due to the heavy rainfall and the high mountain range running north and south for the full length of the Island, water runoff is intensive. This results in swollen rivers and serious flood conditions at times in certain areas along the proposed freeway corridor. Many large rivers flow from the mountain ranges to the west coast, and all of these rivers would be crossed by the North-South Freeway. The important rivers requiring very long crossings were studied to establish shortest spans and shortest pier lengths practicable in combination with minimal earthwork on the approaches. The total length of freeway in areas subject to floods would be 70 kilometers, or about 19 percent of the total length. The profile grade line in these areas should be such that the subgrade would be above the high water level. Critical areas where the freeway would be elevated on fill occurred in all of the seven study sections.

Service to Adjoining Areas

The North-South Freeway would pass through densely populated areas in the western part of Taiwan. It would serve a population of about 10.5 million people (1969)--about 75 percent of the entire population of Taiwan who would be within 25 kilometers of the freeway. Fifty-seven interchanges with an average spacing of 6.5 kilometers would be provided to serve the area.

To capitalize on the benefits of the freeway, the adjacent roads would also have to be improved, especially those highways that would have interchanges with the freeway. The total length of proposed access roads would be 83 kilometers of which 34 kilometers would be improved two-lane highway and 49 kilometers would be four-lane highway.

During floods caused by typhoons, existing highways are either congested or are too heavily flooded to be usable. A freeway could supplement the railway during such emergencies, continuing the flow of goods and bringing relief to flood-stricken areas.

Effect on Adjoining Lands

The North-South Freeway would encourage industrial growth and development along the route, especially near large cities, by assuring a constant supply of raw materials and expediting distribution of finished products. Residential subdivisions would develop in the outlying suburbs on land made more attractive by the freeway for easy commuting to city centers.

The freeway alignment through the cities of Taipei and Kaohsiung could be expected to offer them more rapid and efficient transportation services. More important, considerable traffic along streets paralleling the freeway route would be diverted to the freeway, thus relieving overburdened arteries.

The North-South Freeway would occupy about 0.07 percent of total land in Taiwan and about 0.10 percent of the land now under cultivation. The loss of productive land should be more than offset by the increase in land values adjacent to the freeway and the better access to markets for the more distant farms. It is recommended that the necessary rights of way be acquired by the Taiwan Highway Bureau or officially designated as land to be expropriated in advance of actual construction to avoid inflation of prices.

Stage Construction

A planned schedule of construction is proposed to assure maximum benefits from the freeway. Exhibit VII-11 shows details of typical sections. Length, number of lanes required, opening date, and widening date are shown in Exhibit VII-18.

Aesthetic Considerations

Curvilinear alignment with appropriate spiral curves or long, flat curves coordinated with the vertical curvature of the profile is recommended. This would result in a symmetrical, third dimension effect, heighten driver anticipation, and produce a relaxing, relatively accident-free facility. The median would be of variable widths and independent profiles would be used for the northbound and southbound roadways whereever topographical and property controls would permit to stimulate driver interest and to decrease boredom and fatigue. This design would also improve drainage of the median, lessen driver tension by increasing distance to opposing traffic, and enlarge the areas available for landscaping.

The many river crossings would enhance interest and open up vistas for motorists. This feature could be maximized by using long, graceful curves on the approaches to the river bridges and by keeping bridge parapets and rails below eye level.

The sections where the freeway would be close to the sea near Kaohsiung and Chunan should be designed so that freeway users could enjoy a view of the ocean.

Where feasible, extra land should be obtained adjacent to the freeway for park lands and public gardens. The exotic flowers, shrubs and trees in Taiwan and the proficiency of the Chinese in landscaping could be used to good advantage to enhance the beauty of the North-South Freeway.

The sources of borrow for fill should be given careful thought. In some countries, hills and valleys have been scarred by thoughtless road-building operations. It is good practice to reseed such areas, make them into small lakes, or otherwise preclude unsightliness. Where practicable, borrow materials should be obtained by cutting back the bottom of mountain slopes at their base or by leveling barren and hilly knolls. In this way, additional land may be obtained for cultivation. Similarly, excavated material to be disposed of should be used to fill steep, mountain draws now unsuitable for cultivation, thus adding to arable lands. All cut slopes should be seeded where vegetation will grow, and berms should be constructed at regular intervals along cut slopes for landscaping to improve appearance, decrease maintenance costs, and protect against rock and earth slides.

FREEWAY AUXILIARIES

Interchanges

Three basic types of interchanges are recommended for the North-South Freeway, as indicated by symbols on the Route Plans. They are the Trumpet, the Diamond, and the Parclo.

1. The trumpet is normally used at a three-way connection, where access to the freeway is provided in one direction only. There are no at-grade crossings with the freeway. If a trumpet interchange connects with a crossroad, however, an at-grade intersection is permissible.

2. The diamond interchange serves a four-way connection with access to and from the freeway in both directions. It is simple and inexpensive both in construction and in property requirements. Signing is easy and direct. It requires four left turn movements at grade crossings with the crossroad, however.

3. The parclo (partial cloverleaf) has two loops, one in each of two opposite quadrants. The parclo with loop arrangements as shown is desirable for simple, direct signing. It allows more capacity on the crossroad than the diamond because it requires only two left turn movements at grade crossings.

Rest Areas

Rest areas should be provided at approximately 40-kilometer intervals along the North-South Freeway. They are a safety feature in that they encourage tired drivers to stop, rest and consult maps. They should be located in scenic areas with good views, and should be landscaped as desirable to enhance natural beauty.

Service Areas

Service areas are designated sites for service stations, restaurants, and gift shops. They are usually operated as government concessions.

Bus Stops

Bus stops could be permitted along the North-South Freeway. Care should be taken in design to preclude interference with other traffic. Bus stops could be incorporated in the design of interchanges, thus removing the stopping places a considerable distance from the freeway. The hazards to persons waiting for or leaving buses would thus be minimized. Only one stopping place with adequate waiting facilities such as shelters or buildings would have to be constructed and maintained. In addition, transfers from expressway buses to local buses would be facilitated by this design.

Truck Weigh Stations

Truck weigh stations should be installed to monitor the gross weight of large trucks. Truck weighing for this purpose is already practiced in Taiwan. Facilities should be so designed that trucks would pass the scale building on the driver's side to permit easy communication between the truck driver and the station operator. Sufficient storage space should be provided for detained trucks or trucks required to wait. The scales should be operable in all kinds of weather.

Patrol Stations

In addition to truck weigh stations, facilities should be provided for police patrol cars. These facilities might be incorporated in the truck weigh station complex. Police patrols would be necessary to enforce laws concerning overweight trucks, to enforce traffic laws, to check vehicles, and to direct traffic during emergencies.

For additional mobility, U-turn openings through the median, restricted to use by police and maintenance vehicles, should be provided between interchanges more than eight kilometers apart. Telephones should also be installed along the freeway for use by both the police and the public.

Maintenance Stations

Allowance should be made for the storage of maintenance equipment and materials. These maintenance yards should be built near the freeway, but screens of shrubs or trees should shield freeway users from views of equipment, service buildings and construction materials. Maintenance yards could be adjacent to weigh stations to minimize property takings, at the foot of high fill slopes and thus hidden from the freeway, or near or within interchanges to minimize access problems.

Emergency Aircraft Landing Strip

A portion of the freeway near Chungli would be constructed so that it could be used as an emergency landing strip for aircraft. Freeway traffic could be diverted on occasion from this portion, via the directional trumpet interchange, to an adjacent parallel highway through Chungli.

THE STUDY SECTIONS

The proposed freeway would be 373.81 kilometers long, and would be a multi-lane freeway from Keelung to Fengshan. It has been divided into seven sections for study purposes as follows:

Section	1	Keelung-Erhchung	28.75 km.
Section	2	Erhchung-Yangmei	41.00 km.
Section	3	Yangmei-Hsinchu	21.58 km.

Section 4	Hsinchu-Taichung	85.92 km.
Section 5	Taichung-Tounan	64.40 km.
Section 6	Tounan-Tainan	77.30 km.
Section 7	Tainan-Fengshan	54.86 km.
Total	Keelung-Fengshan	373.81 km.

The project is a refinement of and further extension of the original scheme established by the Taiwan Highway Bureau as follows:

Keelung to Erhchung	35 km.
Erhchung to Chungli	34 km.
Chungli to Hsinshih	260 km.
Hsinshih to Fengshan	70 km.
Total - Keelung to Fengshan	399 km.

The original THB distances were based on the existing distances along Highway No. 1. The current scheme was divided into seven sections to consider similar traffic and topographic conditions, and for comparison of alternative alignments.

STUDY SECTION 1 - KEELUNG TO ERHCHUNG

Study Section 1 comprises Subsection 1A - Neihu to Keelung - Station 10k + 250 to 26k + 250; and Subsection 1B - Erhchung to Neihu - Station 2k + 500 to 0k + 000 to 10k + 250.

Subsection 1A - Neihu to Keelung

The existing facility, the MacArthur Thruway, is an access-controlled, two-lane toll facility extending throughout the entire length of this section. Its only points of access and egress are at the toll stations at the beginning and end of the facility. Designed for 80 kilometers per hour, it was constructed in 1964.

The following three alternatives were compared:

Scheme 1 - Improve MacArthur Thruway to 100 kilometers/hour standards, and add another set of lanes for the opposing direction immediately adjacent to the improved facility. See Route Plan 26.

Scheme 2 - Improve MacArthur Thruway to 100 kilometers/hour standards, and construct a new set of lanes in the opposing direction on a new, separated and shorter alignment, as indicated in Route Plan 27 for the critical lengths from Sta. 12k + 000 to Sta. 16k + 000 and from Sta. 17k + 000 to Sta 19k + 000. The remainder of the alignment would be improved in a manner similar to Scheme 1.

Scheme 3 - Both northbound and southbound lanes would be relocated along a straighter and shorter alignment, as indicated in Route Plan 27 from Sta. 12k + 000 to Sta. 16k + 000 and from Sta. 17k + 000 to Sta. 19k + 000. The remainder of the alignment would be similar to Schemes 1 and 2.

Alignment

Scheme 1

The alignment would extend from Sta. 10k + 250 to Sta. 26k + 250, a distance of 16 kilometers. Because of the existence of a high standard, two-lane highway, it was logical to incorporate this facility into the proposed North-South Freeway to the extent possible. See Route Plan 26.

The new alignment would be curvilinear, but within design standards, as it would be influenced by the natural contours of the terrain between the foothills and the Keelung River. The southbound lanes would parallel the improved northbound lanes and, with a standard width of median, would require additional earthwork. The heaviest construction costs would be incurred where rock cut was encountered.

Scheme 2

The existing alignment would be improved and utilized either as southbound or northbound lanes, as in Route Plan 27. The alignment would correspond exactly with the northbound lanes of Scheme 1 from Sta. 12k + 000 to Sta. 16k + 000 and from Sta. 17k + 000 to Sta. 19k + 000.

The new alignment would be used for the northbound lanes, Route Plan 27. This alignment would extend from Sta. 10k + 250 to Sta. 25k + 250--a distance of 15.5 kilometers. The travel distance would then be 0.5 kilometers shorter from Taipei to Keelung than from Keelung to Taipei. The new alignment would require four additional drainage structures. The profile would be flatter and less rock cut would be required, but additional earthwork would be needed in order to keep the straightened portions above the flood level of the Keelung River.

Scheme 3

Both northbound and southbound lanes would be located on the straighter, shortened alignment similar to the northbound lanes of Scheme 2 from Sta. 12k + 000 to Sta. 16k + 000 and from Sta. 17k + 000 to Sta. 19k + 000. This scheme would require the most relocation of existing hydro power transmission lines of all three schemes.

Service to Adjoining Areas

The interchange near Sta. 15k + 000 would be placed in a slightly different location in each of the three alignments, See Route Plans 26 and 27. The other interchange would remain in the same location for all three schemes at Sta. 22k + 750 to Sta. 22k + 250. All conditions would affect adjoining areas similarly.

At least two interchanges appeared to be justified for this 16-kilometer portion to afford access to the area between Neihu and Keelung now served by Highway No. 5. If no interchanges were constructed, the situation would be similar to the one that exists now on MacArthur Thruway in that no use could be made of the new facility by vehicles traveling between Neihu and Keelung.

Stage Construction

Scheme 1

Four lanes would be required by 1974 with expansion to six lanes by 1984. Scheme 1 would require alignment and earthwork to be done for the ultimate six lanes during Stage 1 in 1974. See previous discussion on lane demand. Bridges and pavement would be constructed to four lanes only for Stage 1. Bridges and pavements would be widened on the median side in Stage 2.

Scheme 2

The existing two-lane alignment could remain exactly as it is for Stage 1 and be used for the southbound lanes from Sta. 12k + 000 to Sta. 16k + 000 and from Sta. 17k + 000 to Sta. 19k + 000. The northbound lanes in these two critical sections would require earthwork for an ultimate three lanes, but would have bridges and surfacing for two lanes for Stage 1. The remaining portions of the freeway would be constructed in stages as in Scheme 1.

Scheme 3

The entire alignment would require earthwork for six lanes with bridges and pavement for four lanes during Stage 1 and then widened to six lanes in Stage 2.

All three schemes would cause a certain amount of disruption to existing traffic during construction. Scheme 3 would result in the least disruption to existing traffic; Scheme 2 would cause intermediate disruption, and Scheme 1 would cause the most.

Aesthetics

Scenic values under all three schemes would be similar to those on the existing MacArthur Thruway. Scheme 1, in particular, would be practically the same as the existing MacArthur Thruway in this respect.

Scheme 2, with separated lanes at the two critical sections, would present a more varied and interesting alignment.

Scheme 3 would be the least interesting in that the alignment would be straight for the entire length. It would lack the variety of Scheme 2, and would appear unimaginative in comparison with the curvilinear alignment blending with the river and hillside as in Scheme 1. The areas between the separated roadways in the critical sections of Scheme 2 could be used as farm lands or rest areas.

Estimated Costs

Estimated costs of the three schemes are shown below.

(Cost in thousand NT$)

Item	Scheme 1	Scheme 2	Scheme 3
Stage 1			
Construction	595,865	665,680	763,360
Right of Way	208,240	262,280	289,280
Sub-Total	804,105	927,960	1,052,640
Stage 2			
Construction	167,095	148,120	132,680
Right of Way	-	-	-
Sub-Total	167,095	148,120	132,680
Total	971,200	1,076,080	1,185,320

The cost estimates indicate that Scheme 1 would be the least costly to build due to partial use of the existing highway. Scheme 3 would be the most expensive due to the earthwork along with additional structural and right of way costs of the two new sections. Details of cost estimates are shown in Table VII-8.

Comparison and Summary

All three schemes would be acceptable operationally. Scheme 2 would be most pleasing to the eye, followed by Scheme 1. Scheme 3 would probably cause less disturbance to existing traffic on the MacArthur Thruway, followed by Scheme 1. Service to adjoining areas would be comparable under all three schemes.

The cost of Scheme 1 would be less than that of Scheme 2, which in turn would be less than for Scheme 3. This, then, should determine the order of preference. It is recommended, therefore, that Scheme 1, utilizing existing and improved alignment, be constructed.

Subsection 1B - Erhchung to Neihu

Three alignments were studied through Taipei and one bypassing the city. They are denoted on Route Plans 23 and 25 as Alternatives A, B, C, and D.

Alignment

Alternative A would be 12.75 kilometers long, and would lie, for the most part, just south of the Keelung River, but still within the boundaries of the city of Taipei. It would run east and west for its entire length so that it would have the slight disadvantage that drivers would face the sun during early morning and late evening hours. It would be adjacent to and north of the Sungshan Airport. To a large extent, it would be in government park land and open areas, which would have the advantage of assuring reasonable right of way cost. Alternative A would be shorter than Alternatives C and D, and would also be shorter than Alternative B when joined to Alternative A in Study Section 2.

Alternative A would be constructed on about five meters of fill to assure adequate freeboard above flood waters. The raised freeway would constitute a levee in sections near the Keelung River.

The alignment of Alternative B would use the right of way of the Tsung-Kuan Railway. Since the railway is planning to construct a viaduct passing over existing city streets, the freeway could be built as a viaduct over the railway and about 14 meters above the ground, or as a viaduct adjacent to the railway which would place it about six meters above the ground.

Alternative C would bypass the city of Taipei, and would be 15.45 kilometers long. It would pass along the foothills of the Chi Nan mountains north of the Keelung River with a 1,000-meter long tunnel just east of the Waishuang Chi. There would be considerable earthwork in cuts, but much of the material could be used for fill. The alignment would pass through a portion of the property of Suchow University. Alternative C, being located in a relatively open area, would cause greater severance damage than the other alternatives.

Alternative D would lie along the southern city limits of Taipei, adjacent to such topographical restraints as the Hsintien Chi and the Fu-chow mountains. It would be a rather lengthy and winding alignment, cutting through the property of the Agricultural Research Institute, and through an area now being rapidly built up with new apartment complexes.

Service to the City of Taipei

All alignments would have interchanges with major streets and roads. Interchange locations are shown for Alternative A only.

Alternative A could be expected to serve the city of Taipei effectively. Interchanges would be built at Chung Ching North Road, Chunshan North Road, Hsin Sheng North Road, Ping-Chiang Road, and Teng Hua Road extended, thus providing fairly direct service to the central business district. A major advantage of this alignment would be the excellent service to Sungshan Airport.

Alternative B would bisect the city of Taipei, passing through the central business district. This route would offer the most direct service to the city of all the four possibilities. The major disadvantage would be the construction of interchanges if the freeway were to be 15 meters above the ground. Excessively long ramps would be required with increased weaving difficulties. The ramp intersections with the streets, as well as the streets themselves, would require considerable widening to meet the capacity requirements, thus causing considerable property damage.

Only Alternatives A and B could accommodate the intercity traffic in the city of Taipei, thus offering a high-speed urban freeway to the city and relieving east-west city arterials.

Alternative C would bypass the city of Taipei and, as such, would provide the poorest service to the city of all the alignments. It would serve such suburbs as Shihlin and Tienmou very well, but traffic destined for the city would have to travel over long, circuitous routes and heavily traveled arterial streets.

Alternative D would adequately serve the southern areas, but the central business district would be almost as distant from this alignment as it would be from Alternative C. Poor service to the major activity areas of the city would be a serious shortcoming of Alternative D.

Stage Construction

To meet traffic demands, a six-lane freeway would be required through the city of Taipei by 1974, with widening to eight lanes by 1979. See Table VII-3. In addition, to obtain maximum benefits of the Erhchung to Chungli Section, the extension through Taipei should be constructed as soon as possible.

Alternatives A, C and D might possibly meet the Stage 1 - 1974 schedule, but this would depend on the availability of rights of way.

Alternative B would depend on construction of the overhead railway on a viaduct; consequently the question of attainability of Alternative B is questionable.

Attainability

The type and amount of property that would have to be acquired becomes a critical factor in the attainability of the proposed urban freeway. Type of construction, which would be another factor in public acceptance, would also have a direct bearing.

Construction of Alternative B would be contingent on timely approval of the TRA to build the Tsung-Kuan (West Line) Railway on its proposed alignment. With the building of the freeway to be integrated with construction of the railway, there would be administrative as well as design and construction problems. Alternative B, therefore, is deemed to be the least attainable of all four schemes.

Of the three remaining alignments, Alternatives A and C would be the most attainable in that properties should be easier to acquire than for Alternative D. Alternative A would be located largely on government lands, including parks and open lands. It is presumed that these lands could be purchased quickly at a reasonable price since they are under government control.

Aesthetics

Alternative B would probably be least desirable in appearance since it would be alongside or over the railway. Its alignment, too, would depend on the railway. Much would depend on the care given aesthetic treatment in the design of the freeway and railway viaducts.

Alternative A would have several aesthetic advantages. It would have curvilinear alignment, and would be adjacent to the Keelung River, so that a pleasant view along the river would be assured. In addition, the government park lands and potential for park lands between the freeway and the Keelung River would offer opportunities for enhancement of the environment.

Alternatives C and D would also present potentials for aesthetic benefits, due to their locations near rivers and mountains.

Cost Comparison

Preliminary cost estimates were prepared for Alternatives A, B and C. Construction costs would be greatest for Alternative B because of the expensive viaduct construction. Alternative C would be next highest in cost because of its length, which would be 2.70 kilometers longer than Alternative A, and because of the tunnel required.

Similarly, Alternative D could be expected to have higher construction and property costs than Alternative A because of its additional length. Property costs for Alternative D would be high, because it would pass through about 14.4 kilometers of the city, whereas Alternative A would pass through only 6.8 kilometers of the city. The cost estimate for Alternative A is shown in Table VII-26.

Summary

Alternative A would have the shortest alignment, which would tend to keep construction costs low. Its relative short length would also result in the greatest user benefits.

Alternative A would be only slightly inferior to Alternative B in providing service to the city of Taipei, and would be considerably better in this respect than Alternative C or D. Alternatives A and B also could be used to serve intracity traffic in Taipei, and thus double as an urban freeway. Alternative A would provide the best service to the Sungshan Airport.

Attainability of Alternatives A and C would be greater than that of the other two alignments because of their lower property costs.

The high potential for aesthetic treatment along with minimum property severance due to its proximity to the Keelung Chi, would be another important factor in favor of Alternative A.

Because of the relatively low construction cost, its excellent service to the city of Taipei, the high attainability factor, and the aesthetic benefits, it is recommended that Alternative A be adopted.

STUDY SECTION 2 - ERHCHUNG TO YANGMEI

Four routes were studied. They are identified as Alternatives A, B, C and D on Route Plans 20 to 25.

Alignment

Alternative A would begin just west of the Tamshui River at Sta. 2k + 500, and would be 41 kilometers in length. The horizontal alignment would cross the low valley floor to Taishan and enter the Tako-ken Chi Valley to ascend to the Linkou Terrace and bisect the area proposed for the Linkou Community. The selected alignment across the Linkou Terrace would also pass through the site of the existing U.S. Air Force communications facility. It would then descend to the lower Taoyuan Terrace, passing 5.5 kilometers to the north of Taoyuan and about 1.5 kilometers north of Chungli, and continue to Yangmei to terminate at Sta. 43k + 500.

The vertical alignment would be the most critical feature of this alternative. An ascending grade at 4.5 percent for a length of 4.5 kilometers, and a six-kilometer climbing lane, would be required on the northern approaches to the Linkou Terrace from the Taipei side. This would constitute a rise from elevation of 10.0 meters at the valley floor to an elevation of 262 meters, a rise of 252 meters over a length of 9.5 kilometers. This would be the most difficult profile of the entire North-South Freeway alignment.

The freeway would ascend on a 5.0 percent grade along the southern approach from Chungli. The 5.0 percent grade would extend for 2.5 kilometers and require a 5.5-kilometer climbing lane. The ascent from elevation 70 meters on the Taoyuan Terrace to elevation 262 meters on the Linkou Terrace, for a rise of 192 meters in 7.25 kilometers, would be considerably less significant than the grade on the northern approach.

Another mountainous section would be met near Sta. 41k + 000 just north of Yangmei, where grades would be 2.8 percent and 3.0 percent to the north and south, respectively.

Alternative B would be 38.9 kilometers long and would begin at Erhchung. It would pass along the valley floor adjacent to and north of Highway No. 1, entering the Tamshui River Valley about 7.0 kilometers to the west. It would cross Highway No. 1 at that point and continue parallel to and immediately south of that highway. It would pass through the southern part of the city of Taoyuan about 1.5 kilometers from its center and about 2.5 kilometers south of Chungli, thence continue to Yangmei.

The profile of Alternative B would require it to cross a summit elevation of 150 meters. This would result in a rise of 140 meters over a length of 4.25 kilometers from the north approach (Taipei side) and a rise of 40 meters for a length of 3.0 kilometers from the south approach (Chungli side). The gradient on the north approach would be 5.0 percent for 1.0 kilometer, requiring 3.5 kilometers of climbing lane. The gradient from the southern approach would be 2.0 percent for 2.0 kilometers, requiring a 3.0-kilometer-long climbing lane.

Alternative B in the area just north of Yangmei would avoid the high plateau, which Alternative A would cross from Sta. 39k + 000 to 42k + 000. It would have a much better grade line, therefore, and less earthwork than Alternative A.

Alternative C would be 39.5 kilometers in length, and would approximate the location of Alternative B in that it would be within the Highway No. 1 corridor. It would begin at the same point as Alternative A, west of the Tamshui Chi. Its main variation from Alternative B would be at the summit of the pass through the nearby creek. Alternative C would leave Alternative B at that point by diverging to the south through a tunnel, and descending along a small river valley. This alignment would then bypass Taoyuan through open fields at a maximum distance of 2.0 kilometers south and east of Alternative B, and converge into the alignment of Alternative B just east of Chungli.

A 1,000-meter tunnel would allow Alternative C to go under the pass instead of over it as was required for Alternative B. This would result in lowering the summit to an elevation of 115 meters. By reducing the vertical distance by 35 meters, maximum gradients would be 3.5 percent on the northern approach and 2.6 percent for the southern approach. Climbing lanes would not be required with Alternative C.

Alternative D would begin at the same point as the alternatives west of the Tamshui River. It would then follow the corridor of the West Line Railway north of Taoyuan, converging into the alignments of Alternatives B and C at Chungli.

The difficult condition between Erhchung and Taoyuan would be surmounted by using an alignment on the floor of the Tamshui River basin and with earthwork placed immediately next to the Tsung Kuan Railway embankment. Slope protection would be required along the river side of the embankment.

Alternative D would be 44 kilometers long, or 3.0 kilometers longer than Alternative A. It would be the longest of all four schemes.

The profile of Alternative D would be almost level. Consequently, it would be superior to the other three plans. The excellent grade line of Alternative D would decrease truck operating costs, but savings would be offset somewhat by greater distance as compared with the other three alignments.

One advantage of Alternative D would be that very good borrow material would be readily available for fill from the Tamshui River bed.

Service to Adjoining Areas

Alternative A would derive its main advantage over other alignments in that it would serve the proposed Linkou Community and the proposed Taoyuan International Airport. If any of the other alignments were chosen, a four-lane access road would have to be constructed to these two important traffic generators to provide equivalent service. This would increase construction cost as well as travel distance. Construction of Alternative A would also stimulate earlier construction of these two developments.

Removed from existing built up areas, and occupying virtually virgin lands, property costs would be low, and attractive land areas for future residential and commercial developments in addition to the Linkou Terrace would be available. Nine interchanges would serve such areas.

Alternatives B and C would have the advantage over Alternative A of being located close to existing Highway No. 1 and Taoyuan. Consequently, a freeway on either of those alignments would induce more traffic from existing development--at least for the next few years--than Alternative A. However, development of the valley occupied by Highway No. 1 and north of Taoyuan would be limited to a very narrow strip along the valley floor. The area available for future development would be reduced still further by the freeway, which would occupy a considerable portion of it.

Alternative D would have even less opportunity to serve an area with future growth potential north and east of Taoyuan. The railway and existing Highway No. 114 already occupy most of the flat land between the foothills of the Kueishan Mountain and the Tamshui River.

Attainability

All alignments would have some problems in this regard. Alternative A would involve difficult construction along the Takuokung Chi Valley--the northern approach to the Linkou Terrace. The U.S. Air Force is scheduled to move its communications facilities in about ten years but earlier removal would be needed to permit Alternative A to proceed. Construction of Alternative A in an undeveloped area would disturb Highway No. 1 less than construction of Alternatives B or C.

Alternative B would encounter right of way problems through Taoyuan and north of this city along Highway No. 1.

Alternative C would be the most attainable of all four plans. The major right of way problem of Alternative B would be avoided by staying farther away from Highway No. 1 and by passing through the outskirts of Taoyuan. The main problem would be construction of the tunnel.

Alternative D would have to be protected against floods in the Tamshui River basin adjacent to the railway north of Taoyuan. Considerable fill and heavy riprap slope protection would be required, similar to that along the existing railway embankment.

Because of its close proximity to the West Line Railway, military authorities might find this scheme less desirable than other plans.

Stage Construction

Traffic demands are heavy, so that a multi-lane freeway is needed urgently. See Table VII-3. The following discussion refers to the proposed alignment, Alternative A, but would also apply to the other alignments in Study Section 2.

Six lanes will be required by 1972 from Erhchung to Linkou, and four lanes from Linkou to Yangmei. Widening to eight lanes will be needed by 1978 from Erhchung to Linkou, and to six lanes from Linkou to Taoyuan.

The first portion of the North-South Freeway, scheduled for completion by 1971 will be a 31-kilometer section from Erhchung to Chungli. Consequently, consideration has been given to the methods of stage construction.

The first portion of the North-South Freeway to be constructed would begin at the east end at Sta. 2k + 500. A partial trumpet interchange would connect the freeway with Sanho Road (Highway No. 103) in Sanchung, which would be widened to four lanes to the Taipei Bridge. Widening of the Taipei Bridge to four lanes was scheduled for completion by November 1969. The North-South Freeway would temporarily change from six lanes to four lanes just west of this interchange, which would consist only of temporary two-lane ramps connecting with the freeway to the west. See Route Plan 23. The remaining ramps and structure would be built when the freeway was continued across the Tamshui River to Taipei.

The freeway through Taipei should be constructed as soon as possible after the Erhchung to Chungli section was completed. The temporary connection with the Taipei Bridge would result in some congestion, which would be acceptable temporarily. Private property along the proposed freeway route in Taipei should be purchased as soon as possible to avoid inflated prices.

Either of two alternatives would be practical for staged construction of the west end of the proposed freeway:

Method 1 Terminate the freeway at Sta. 31k + 500 and construct a trumpet interchange connecting with Highway No. 45 in a manner similar to that described for the east end connection with Sanho Road (Highway No. 103) in Sanchung. See Route Plan 21.

Method 2 Continue the freeway to the crossing of Highway No. 1 at Sta. 43k + 500, north of Yangmei (end of Study Section 2) and make a temporary connection with Highway No. 1. See Route Plan 20.

Method 2 would be preferable from the operating standpoint. The biggest disadvantage of Method 1 would be that through traffic destined to the south of Chungli would be forced to travel through the city streets of Chungli. In addition to causing congestion in Chungli, the sudden change from high to slow speeds would tend to raise the accident rate. Method 2, however, would require an additional outlay of approximately NT $560 million.

Aesthetics

Alternative A would produce the best scenic views. The valleys on the approach to Linkou would provide beautiful scenery for the motorist. The proposed alignment straddling the Takokeng Chi approaching Linkou from Taipei would be especially attractive.

Alternatives B and C would present few opportunities for scenic views. Alternative B would not be as scenic as existing Highway No. 1 because it would be in the bottom of the valley floor from Sta. 13k + 000 to Sta. 17k + 000. Alternative C, on leaving the tunnel, would present some scenic areas along the small river valley to the south.

Travelers along Alternative D would see the West Line Railway and the two railway towns of Shulin and Yinko, negating any scenery on the west. However, the Tamshui River and vistas across the river would be attractive.

Cost Comparisons

Cost estimates were made for Alternatives A and B. See Tables VII-10 and 11. Cost of Alternatives A or B would be almost identical. Alternative A would have higher roadway, earthwork, and structural costs, due to more difficult terrain, while Alternative B would have greater right of way costs because it would traverse heavily built-up areas. With the required multi-lane access roads to the Taoyuan Airport and Linkou Community, however, Alternative B would be more expensive.

Alternative C, disregarding the cost of the access road, would be considerably more expensive than either Alternative A or B because of the tunnel. The tunnel would also increase future maintenance expenses.

An economic comparison was made between Alternatives A and B as discussed in Chapter VIII under the economic analysis of alternative solutions.

Summary

In comparing the various alignments, Alternative D was eliminated because its location would provide little benefit to the existing or proposed densely populated areas between Taoyuan and Erhchung. Assuming that Alternative A would be acceptable through the city of Taipei, Alternative D would be circuitous in connecting with Section 1B of Alternative A. This would make Alternative D three kilometers longer than Alternative A between Yangmei and Erhchung.

Alternative C would have these advantages over Alternative B: lesser property required through Taoyuan; an alignment farther from Highway No. 1 just north of Taoyuan; and flatter grades with no climbing lanes required over the summit. These advantages would be outweighed, however, by the high cost and future maintenance expenses of the tunnel.

Alternatives A and B had comparable advantages and disadvantages making a choice difficult.

Alternative A would encourage early development of new areas, especially proposed Linkou Community and the Taoyuan International Airport. Alternative A would also have greater aesthetic potential. Alternative A would not require construction of access roads to these developments. It would be preferred by military authorities. One disadvantage of Alternative A would be that it would necessitate relocation of the U.S. Air Force installations earlier than is now contemplated.

The principal advantages of Alternative B over Alternative A would be shorter alignment, flatter grades, and lower summit. All would result in lower road user costs. Initially, at least, it would also serve a larger population. These advantages are reflected in higher economic benefits.

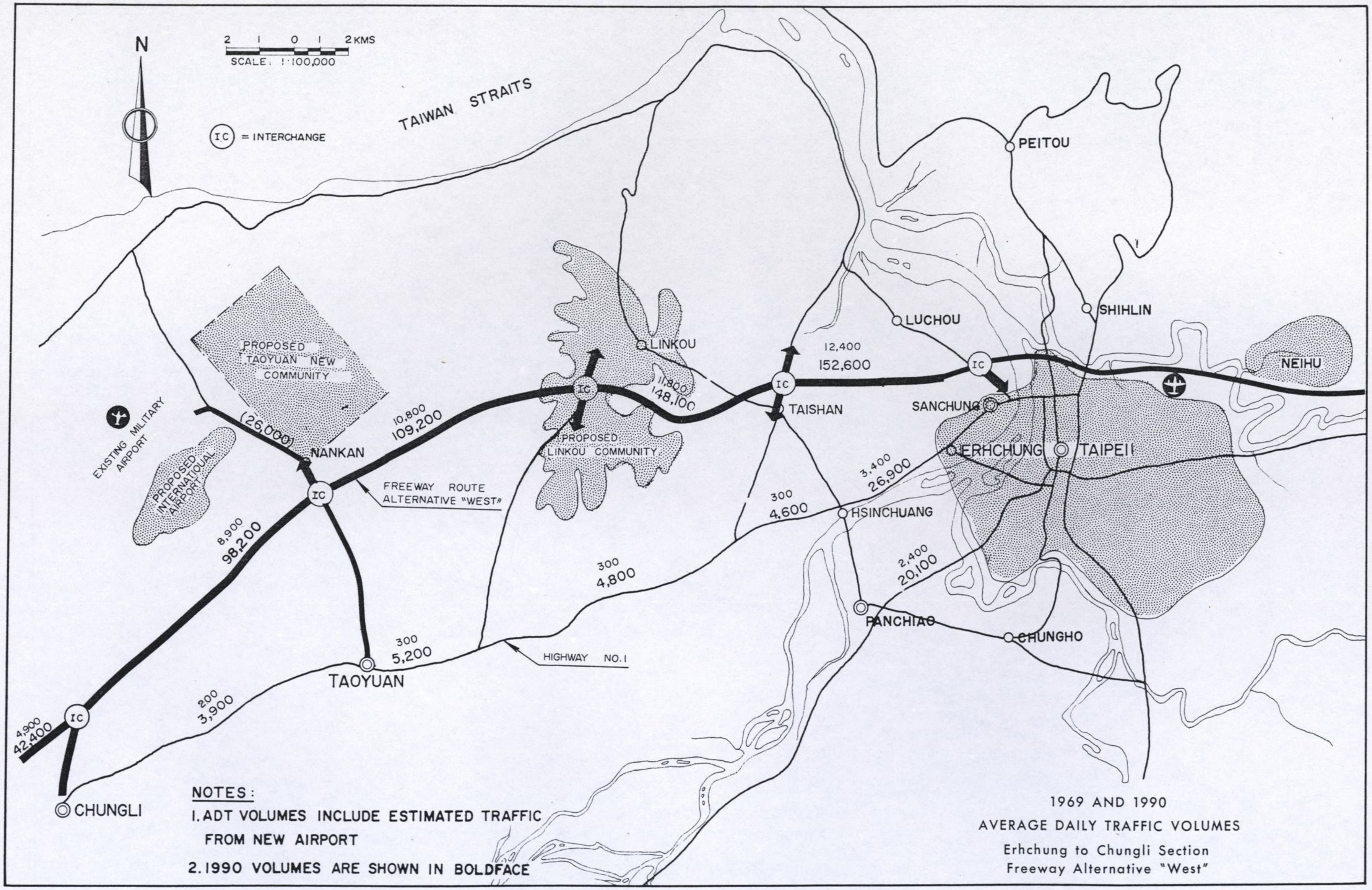
Great weight was placed on the desirability of serving the two new developments. These factors, together with the possibility of opening up still more areas for future development, favor Alternative A. This plan would also have aesthetic advantages.

Improvement of Highway No. 1

Exhibit VII-16 shows 1969 and 1990 average daily traffic volumes assigned to "Freeway West" and existing Highway No. 1. Average daily traffic on the existing highway in 1990 would be approximately 5,000 vehicles. The ADT volume in 1982 is estimated to be less than 2,000 vehicles. Both figures are less than the capacity of this two-lane highway. Widening of Highway No. 1 would not be necessary, therefore, if the freeway were constructed.

Only the section of Highway No. 1 within the urban limits between Tan-Feng and Erhchung would have to be widened by 1982, and this would be required to accommodate local traffic. This widening would also be necessary with "Freeway East", as indicated by the assigned traffic volumes on Exhibit VII-17.

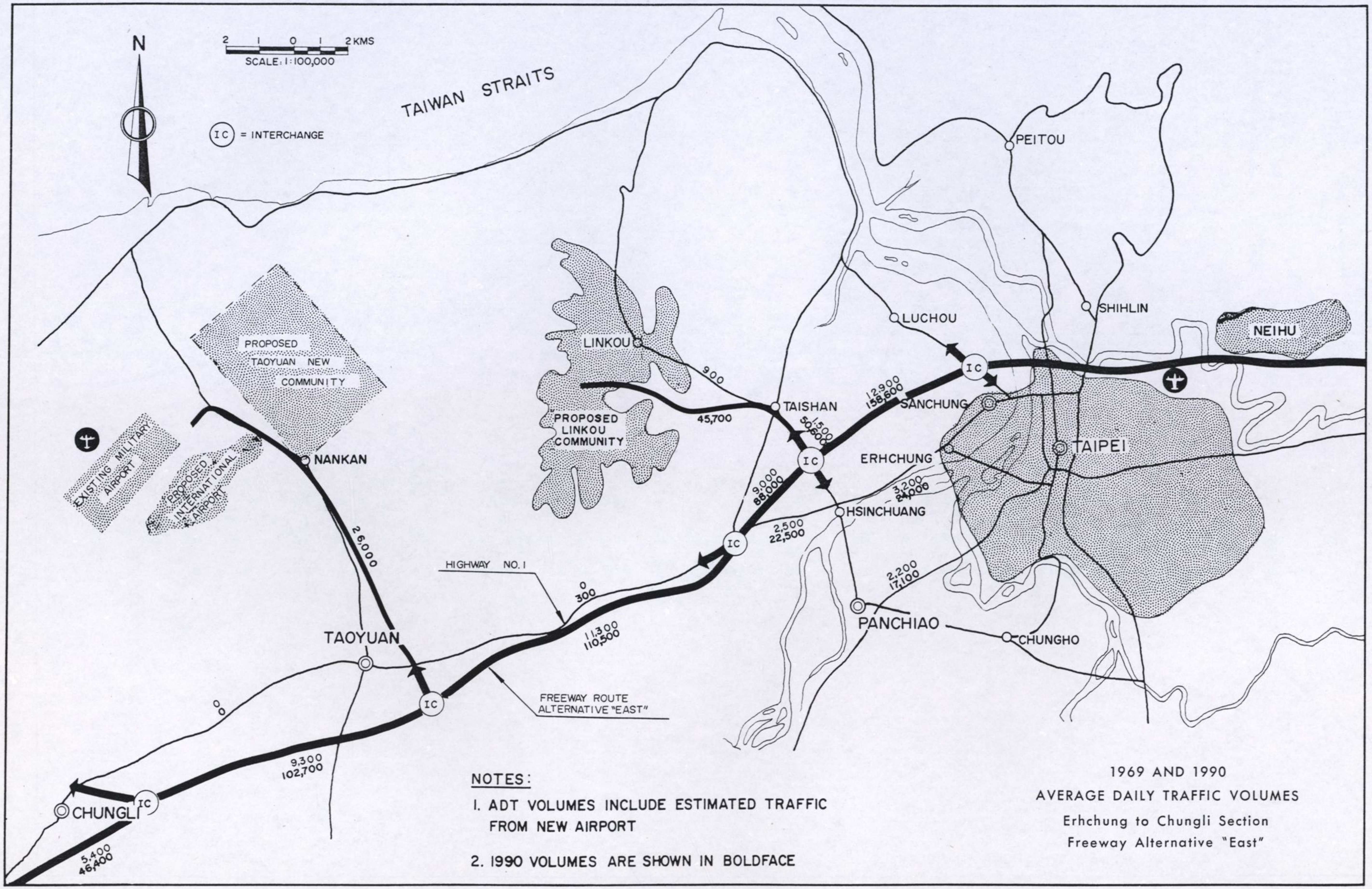
Similar urban conditions will be encountered throughout the length of the freeway corridor from Keelung to Kaohsiung. Widening of sections of existing north-south highways within urban limits should be considered separately from the freeway project. Since they serve local urban traffic, they are considered parts of city street systems in this feasibility study. The cost of widening these streets, therefore, is not included in the cost of highway improvements needed, either "with" or "without" freeway conditions.



NOTES:

1. ADT VOLUMES INCLUDE ESTIMATED TRAFFIC FROM NEW AIRPORT
2. 1990 VOLUMES ARE SHOWN IN BOLDFACE

1969 AND 1990
AVERAGE DAILY TRAFFIC VOLUMES
Erhchung to Chungli Section
Freeway Alternative "West"



NOTES:

1. ADT VOLUMES INCLUDE ESTIMATED TRAFFIC FROM NEW AIRPORT

2. 1990 VOLUMES ARE SHOWN IN BOLDFACE

1969 AND 1990
AVERAGE DAILY TRAFFIC VOLUMES
Erhchung to Chungli Section
Freeway Alternative "East"

To indicate the magnitude of the work to be done, cost estimates were prepared for widening a 7.2-kilometer section of Highway No. 1 between Tan-feng and Erhchung. The widened section was assumed to consist of four traffic lanes, each 3.5 meters wide, and two slow-moving vehicle lanes, each 3.0 meters wide. Sidewalks on each side at least 2.0 meters wide were assumed. A concrete median divider was provided. Total cost was estimated to be NT $284 million; NT $212 million of this amount would be for right of way acquisition.

STUDY SECTION 3 - YANGMEI-HSINCHU

This section, the shortest of all sections, would extend from Yangmei to Hsinchu. See Route Plans 19 and 20. Freeway West would extend from Sta. 43k + 500 to Sta. 65k + 080, and would be 21.56 kilometers long. Freeway East would extend from Sta. 43k + 500 to Sta. 63k + 600, and would be 20.1 kilometers long. The absence of population along both alignments would make their economic benefits almost identical.

Horizontal Alignment

Freeway West would parallel Highway No. 1, lying east of it from Yangmei to Ssu Chiao Ting and west of it from Ssu Chiao Ting to Sta. 55k + 800. It would then be parallel to and west of rural Highway No. 9 to Sta. 59k + 000, and subsequently curve to the east and slightly north along the mountainous north face of the Fengshan Chi. It would cross the Fengshan Chi on a 300-meter bridge in the vicinity of Sta. 62k + 000. The section would terminate just north and east of Hsinchu at Sta. 65k + 080.

The alignment would be located westerly in the vicinity of Sta. 58k + 000 to Sta. 60k + 000 to:

> go through a minimum number of small "lakes"; displace as few buildings as possible; and make feasible a long, flat curve to the north bank of the Fengshan Chi.

The alignment of Freeway East would follow the corridor of rural Highway No. 115. The north half of Freeway East would require relocation of the Hsiaoli Chi from Sta. 48k + 300 to Sta. 52k + 500 and relocation of rural Highway No. 115 from Sta. 49k + 900 to Sta. 52k + 500. It would be parallel to and east and south of rural Highway No. 118 for the southern half of this section.

Profile

The west line would begin at an elevation of 183 meters (above sea level) at Yangmei, climb slightly to elevation 190 meters in the first three kilometers to the south, then continue on a gradually descending grade of less than 2.5 percent to the Fengshan Chi with a bridge at elevation 30 meters. Continuing, it would climb to elevation 40 and terminate at Sta. 65k + 080.

The steepest grade would be 2.5 percent, for a length of 1.5 kilometers, at the north approaches to the Fengshan Chi. The relative flatness of the profile of the west line would keep operating costs for trucks and buses relatively low.

The profile of the east line, beginning at Yangmei, would approach the summit of elevation 250 meters at Sta. 47k + 300 on a 3.5 percent grade and then drop rather sharply on a 4.3 percent grade to elevation 150 meters at Sta. 50k + 000. It would then continue on a gradual descent to elevation 40 meters at Sta. 63k + 600.

Earthwork would be heavy and climbing lanes would be required for both approaches to the summit. Traffic would climb 60 meters more than on the West Line.

Service to Adjoining Areas

Service to adjoining areas would be relatively unimportant, as there are few population centers between Hsinchu and Yangmei. Economic benefits would be about the same for each alignment. Only one interchange in 10.8 kilometers, other than the ones at each end of Study Section 3, would be required. Study Section 3 would be basically a "through" freeway so that the choice of location should be determined by costs, grades, length of route, and aesthetics.

Stage Construction

Stage construction would call for four lanes by 1974 with widening to six lanes by 1986. See Table VII-3.

Aesthetics

Aesthetic achievement would be nominal for Freeway West. The highway designer could exploit the potential along the northern approach of the Fengshan Chi. The gradual descent, with a side hill cut along the steep river bank constructed with separated roadways, would permit several good views along the Fengshan Chi, across the river, and of the bridge itself.

Aesthetic possibilities would exist for Freeway West through the mountainous terrain in the northern portion. The valley floor between the Wen Shui Keng and Lu Ming Keng mountain ranges would be of interest as would the crossing of the Fengshan Chi and the section along the Fengshan Chi from Sta. 59k + 000 to Sta. 61k + 000. However, no location on the east alignment could compare with the northern approaches to the Fengshan bridge along the west route, which would be the most attractive feature of either alignment.

Cost Comparison

The figures in Tables VII-12 and 13 show that the two alignments would cost about the same. The extra right of way costs of Freeway West would probably be balanced by the costs of additional earthwork for the east line. Construction and right of way cost of NT $54 million per kilometer would be slightly less than the average of NT $60 million per kilometer.

Summary

Because there are very few populated areas along the route, an economic comparison was not considered critical. In comparing operational characteristics, the flatter grades of the west line would be offset by its additional length of 1.53 kilometers over the east line. However, more detailed study might result in shortening Freeway West.

Both alignments would displace rice-growing land, and costs of the two alignments would be practically the same.

The extensive river and rural road relocation that would be involved on the east line would be unfavorable factors.

Further studies during the design stage might also indicate hidden difficulties in the construction of the east line, such as extensive rock cuts, increased earthwork, and additional river relocation, which might further increase costs.

Although the two alignments would be similar in advantages and disadvantages, the easier construction of the west line through a relatively flat area, the flatter grades, and the future possibility of shortening the alignment in the detailed design stage, makes the Freeway West alignment preferable.

STUDY SECTION 4 - HSINCHU-TAICHUNG

In this study section, only one corridor was studied. The corridor along existing Highway No. 117 and Highway No. 3 appeared to be the only one that would serve such major population centers as Taichung, Fengyuan, and Miaoli. The proposed port of Wuchi would be beyond the immediate periphery of the freeway but would still be benefited by it. Extending from Sta. 65k + 080 to Sta. 151k + 000, this section would be 85.9 kilometers long--the longest of the seven Study Sections. Except for a length of 15 kilometers just north of Taichung, the entire section would be in mountainous terrain. The freeway would be carried by 6.6 kilometers of structures, the remaining 79.3 kilometers consisting of conventional roadways.

Horizontal Alignment

The alignment would begin north and east of Hsinchu at Sta. 65k + 080 and would pass through the eastern outskirts of Hsinchu. It would enter mountainous terrain at Sta. 70k + 000 and, except for seven kilometers from Sta. 76k + 000 to Sta. 83k + 000, the line would be close to the existing power line.

Various minor variations from Sta. 70k + 000 to Sta. 85k + 000 and Sta. 88k + 000 were studied, as shown on Route Plans 11 to 19. It was found, however, that grades were flatter and earthwork requirements were the least on the recommended line. The alignment for this portion would bypass Toufen on the west side. The possibility of bypassing Toufen on the east was studied, but was found to involve more expensive right of way as well as flood control problems. Furthermore, the west bypass alignment would be straighter and shorter than the east bypass. A possible advantage of the alternative east of Toufen would be that it might serve as a levee to protect Toufen from floods.

Several routes through the mountainous terrain from Sta. 90k + 000 to Sta 99k + 000 were studied as indicated in Route Plans 17 and 18. The rather circuitous route of the recommended alignment was one kilometer longer than the most direct route, but grades would be easiest and earthwork the least of all the alternatives.

Two alternatives to bypass Miaoli were studied between Stations 97k + 000 and 108k + 000. The most easterly route was chosen because it would cross the Hou-lung Chi once, whereas the westerly route would cross it twice; and right of way would cost less on the easterly route because it would be farther from Miaoli and also because it would be on the opposite side of the river.

The westerly location would have two advantages in that service to Miaoli would be closer and more direct, and it would reduce the costs of improving two access roads and widening their structures over the Hou-lung Chi to Miaoli.

The proposed route would make a 60-degree crossing of the Hou-lung Chi via a 1.2 kilometer bridge. It would then curve to the east and enter the Ssuhu Chi valley. In addition to the river, the valley corridor would be shared with the West Line Railroad, Highway No. 117, and a power transmission line. Relocation of Highway No. 117 would be required from Sta. 112k + 800 to Sta. 116k + 700 in order that Highway No. 117 could continue to serve properties on the eastern slopes of the Ssuchu Chi valley. The freeway would be adjacent to and on the east side of the West Line Railroad. Stream relocations would be required at Stations 117k + 000 and 118k + 800.

The preferred route would cross the Ssuhu Chi just north of Sanyi. The freeway would be as high up on the foothills as required to miss major properties and at the same time keep earthwork costs reasonable. This concept would continue to Sta. 128k + 500 where a 1.4-kilometer bridge would cross the Ta An Chi.

From Sta. 129k + 000 to Sta. 151k + 000--at the end of this section--the alignment would pass through intensively developed farm and paddy lands. The line would cross the Ta Chia Chi at its narrowest point and displace a minimum number of buildings.

Profile

From the beginning of Study Section 4 at Sta. 65k + 080 to Sta. 136k + 000, various horizontal alignments were investigated to obtain the flattest possible grades. The maximum gradient would be 5.0 percent from Sta. 126k + 500 to Sta. 127k + 500 (1,000 meters). At that point it would join a 3.8 percent grade of 2,000 meters long to the summit at Sta. 123k + 000. A 4.0-kilometer climbing lane would be required. The longest and steepest sustained gradient for the North-South Freeway would be from Sta. 103k + 000 to the summit at Sta. 123k + 000, where it would rise from elevation 55 meters to 360 meters--a rise of 305 meters in 20 kilometers. The summit at Sta. 123k + 000 would be the highest point on the entire North-South Freeway. The freeway would then drop rather steeply on 3.8 percent and 5.0 percent gradients for 6.0 kilometers to reach the most economical height at elevation 185 meters for the construction of the 1400-meter bridge over the Ta An Chi.

The median should be widened and separate roadways provided wherever possible throughout this mountainous section when located along the sides of steep mountain slopes between Sta. 112k + 000 and Sta. 127k + 500. This would assist in keeping earthwork costs to a minimum.

Considerable fill will be required to support the freeway at the south approaches to the Ta An Chi bridge as well as some masonry slope protection on the upstream face to confine the river to the channels under the proposed bridge.

South of the Ta An Chi, the profile would rise to a nearly flat plateau of rice paddies and farmland, and the Ta Chia Chi would be crossed again. The gradient would then continue to Sta. 140k + 600 and then gradually descend at 2.0 percent to the outskirts of Taichung.

The most critical earthwork portion for the entire North-South Freeway would be through the summit between Sta.

119k + 800 and Sta. 127k ∓ 500, where nearly the entire section would be through an average depth of cut of about 20 meters.

The freeway would be on fill for the southern section from Ta Chia Chi Bridge to the end of Study Section 4 at Sta. 151k + 000. This would be to ensure that the freeway would be above flood levels of the Ta Chia Chi and other rivers near Taichung.

Service to Adjoining Areas

The freeway would serve Hsinchu, Toufen, Miaoli, Tunglo, Sanyi, Neipou, Fengyuan and Taichung. It would be about 2.5 kilometers from the central business district of Hsinchu and two kilometers from the center of Taichung, the major cities. A total population of about 826,000 (1969) would be within five kilometers of the proposed route.

The important military air base at Taichung would be about eight kilometers from the closest freeway interchange. Wuchi harbor, the site of a large port planned for the future would be accessible to the freeway via a 20 kilometer drive over Highway No. 134. Another point of access from Wuchi to the freeway would be along Highway No. 1 for 18 kilometers to connect with the freeway at the interchange just north of the proposed North-South Freeway bridge of the Tatu Chi in Study Section 5.

Stage Construction

Traffic volumes are anticipated to warrant a four-lane freeway in Study Section 4 by 1975. This Study Section would be one of the last to be built. See Table VII-3. In 1985, the short section of 5.20 kilometers from Taichung to Tantzu would have to be widened from four lanes to six lanes.

Aesthetics

The motorist would be presented with an ever-changing scene by the mountainous terrian from Hsinchu to Miaoli, the broad, expansive plain along the Houlung Chi near Miaoli, the crossing of the Houlung Chi, the drive through the Ssuhu Chi valley with its gradually ascending grade to the summit pass followed by the descent to and crossing of the Ta An Chi, and the gradual descent to Taichung flanked by the Tatu Shan plateau to the west and the Pa-Kua Shan range to the east.

Advantage should be taken of the proposed location within 3.3 kilometers of the sea near Chunan to design the freeway so that a view of the sea would be obtained for the longest possible time. The proposed differences in profile for northbound and southbound lanes north of the Ta An Chi, as mentioned above, would add further to driver interest.

Rest Areas

Rest areas, picnic sites, and service areas could be placed to advantage at any of the scenic locations listed above. Service and rest areas should be on level or downhill freeway gradients to minimize problems of trucks in accelerating after stops.

Costs

Cost estimates for Study Section 4 are shown in Table VII-14. Construction and right of way costs of NT $46 million per kilometer would be significantly less than the average costs of NT $60 million per kilometer for the entire freeway (Table VII-6). While about 80 percent of this section would be in mountainous terrain, earthwork costs would be low because of the availability of fill material and short hauling distances. In addition, 90 percent of the section would require only four lanes up to 1990.

Summary

The chosen corridor would serve all important population, military, and industrial centers, with the exception of Wuchi, and would have the further attribute of low cost.

STUDY SECTION 5 - TAICHUNG-TOUNAN

Study Section 5 would extend from Taichung to Tounan. Two alignments were studied in plan and profile. See Route Plans 8 through 14. Cost estimates are shown in Tables 15 and 16.

The west line (Study Section 5A) would be along the corridor of existing Highway No. 1, bypassing Changhua and other population centers. It would extend from Sta. 151k + 000 to Sta. 215k + 400.

The east line (Section 5B) would follow in general the corridor in the vicinity of existing Highways No. 12 and No. 3. It would bypass but adequately serve Wufeng, which houses the provincial assembly, Chung-Hsing New Village, the new provincial capital, and Nantou. It would extend from Sta. 151k + 000 in the north to Sta. 219k + 600 to the south.

Alignment

The more westerly alignment would be 64.4 kilometers in length. Of this, 7.13 kilometers would be on structure and 57.27 would consist of conventional roadway. About 70 percent of the 7.13-kilometer structure length would be comprised of drainage structures.

The line would begin at Highway No. 134 west of the city of Taichung. It would be west and north of Highway No. 12 and lie along the foothills north of existing Tatu Bridge between Sta. 159k + 000 and Sta. 164k + 000. The median would vary in width and separate roadways would be constructed along the hillsides. The freeway would then cross Highway No. 1 and the Tatu Chi, on a long, flat curve and continue south to bypass Changhua through open fields west of the city. It would be characterized by many curves to avoid buildings, populated areas, and cross drainage areas. Open areas would be selected for interchanges. Most of the area consists of low, flat rice land, marked with many irrigation ditches, canals, lakes and other watercourses near the alignment. The proposed line would intersect the power transmission line at eight points, a large water main at three, and an oil pipeline at two.

Two large rivers would be crossed--the Tatu Chi between Sta. 164k + 600 and Sta. 165k + 550, and the Choshui Chi Bridge from Sta. 199k + 500 to Sta. 201k + 700. The bridge over the Choshui Chi, 2200 meters long, would be the longest bridge on the entire freeway.

The west line would run in a north-south direction except for five kilometers between Changhua and Taichung, where it would run east and west.

The proposed profile would require considerable earth fill to elevate the freeway above flood waters. There would also be many road and railway crossings. The longest length of freeway subject to serious flooding would be in the vicinity of the Tatu Chi, extending for 11.6 kilometers from Sta. 163 + 700 to Sta. 175 + 300. Another flood area associated with the Choshui Chi would extend for 500 meters from Sta. 190 + 400 to Sta. 190 + 900. In addition, the freeway would cross 19 local highways and 11 railways. Of the railways, one is a main line which would require maximum clearance but the others are sugar cane branch railroads.

The profile would undulate with a maximum grade of 1.5 percent and a minimum of 0.35 percent.

The east line would serve the provincial assembly at Wufeng and the provincial capital of Taiwan--Chung-Hsing New Village. The east line would be 68.6 kilometers long.

The alignment of Study Section 5B would begin west of the city of Taichung at the same location as the west line. It would swing immediately to the south, crossing the Ta-Li Chi, via a 0.25-kilometer bridge, and enter the Wu Chi valley. It would continue south with a series of long curves connected by short tangents just to the west of Tsaotun, Chung-Hsing New Village, and Nantou. It would cross the Ping-Lin Chi bridge at Sta. 176k + 000. Just south of Ming-Chien at Sta. 188k + 600, the alignment would leave the Wu Chi valley and curve sharply to the west along the north side of the Choshui Chi. Minimum costs with maximum protection could be achieved by placing the freeway fill immediately next to the existing railway embankment with a slope protection wall of heavy masonry or concrete along its south face from Sta. 189k + 000 to Sta. 197k + 000. The freeway would then cross the Choshui Chi bridge, which would be 2.2 kilometers long, and traverse irrigated plains and rice paddy fields to Tounan.

The profile would begin at elevation 95.0 meters, dropping to a low point of elevation 42.5 meters at Sta. 159k + 600, then rising to a high point of elevation 115 meters at Sta. 187k + 600. It would continue to descent gradually to elevation 32.5 meters at Tounan.

This alignment would require 26 grade separation structures over local roads and railways. Of the 68.6 kilometers of freeway, 4.6 kilometers would be on structures while 64.0 kilometers would be of conventional design. Of the 4.6 kilometers of structure, about 90 percent would be drainage structures.

Service to Adjoining Areas

Service to important areas can be gauged by examining traffic figures. Average daily traffic in 1990 would be 68,667. A 1969 population of about 1,135,000 would also be served directly by the freeway with ten interchanges on the west alignment (Study Section 5A).

This alignment would pass through 18.7 kilometers of urban area--11.6 kilometers in Taichung and 7.1 kilometers in Changhua. In addition, it would serve 19 communities of over 25,000 population within five kilometers.

Service to important adjoining areas by the east and west alignments was compared as shown in the table below. About 710,000 persons would have direct service via ten interchanges with the proposed east alignment (Study Section 5B). This line would traverse 6.5 kilometers of urban area, serving 12 communities of over 25,000 people.

	Service to Adjoining Areas	
	(West line) Study Section 5A	(East line) Study Section 5B
1990 population within 5 kilometers	1,135,000	710,000
Average ADT (1990)	68,667	60,000
Distance through Taichung City	11.6 km	6.5 km
Distance through Changhua City	7.1 km	-

The west line would carry more traffic and serve more people than the east line. This was borne out by later economic studies which indicated a higher benefit-cost ratio for the west alignment.

Stage Construction

Staging requirements are indicated in Table VII-3. A four-lane freeway would be required in 1975. Ultimate widening of the section from four to six lanes from Taichung through Changhua would be required in 1986 for the west alignment (Study Section 5A).

The section from Taichung to Chung-Hsing New Village would be widened to six lanes in 1986 for the east alignment (Study Section 5B).

Aesthetics

By varying the profile of the southbound and northbound roadways, the attractiveness of Study Section 5A would be enhanced. A view across the Tatu Chi could also be assured by this technique. Rest areas with scenic park land would be advantageous in this section.

Widening the median from four meters to eight or ten meters between Changhua and Tounan where right of way costs would be low is suggested to widen the distance between opposing traffic; relieve driver boredom; and create a larger area for attractive landscaping.

Aesthetic possibilities would be considerable along the eastern alignment. The motorist would be confronted with an ever-changing panorama, beginning with the crossing of the Ta-Li Chi. The view would change from the rice paddies to the Wu Chi valley flanked by the low Pa-Kua Shan range on the west and the higher Tatu Shan range on the east. After crossing the Ping-Lin Chi the motorist would continue south and west of Ming Chien, towards the Choshui Chi with long vistas across that river and the plains area to the south. There would be many opportunities for variable median widths and different profiles for northbound and southbound roadways.

Cost Comparison

Tables VII-15 and 16 show that the east line (Study Section 5B) would cost NT $746 million, or 20 percent, more than the west line (Study Section 5A).

Because the west line would be shorter (4.2 kilometers) than the east line and would serve a larger population, the economic benefits would be greater. The west line (Study Section 5A), along with highway improvements to Highways No. 12 and No. 3, would accommodate the same traffic as the east line (Study Section 5B) with the highway improvements to Highway No. 12, construction of a bypass around Changhua, and another Tatu Bridge. An economic comparison between the western and eastern alignments, both with necessary highway improvements, is presented in Chapter VIII.

Summary

Shorter by 4.2 kilometers, the west line would have an important advantage over the eastern alignment. Construction costs of the west line would be reduced by 20 percent, and benefits for through-traffic enhanced. These advantages, along with the important fact that the west line (Study Section 5A) would serve a larger population, would give it higher economic benefits than could be claimed by the east line (Study Section 5B). However, the east line would serve the provincial assembly and the provincial capitals of Wufeng and Chung-Hsing New Village.

Aesthetic possibilities would be better with the east line, but aesthetics would be relatively unimportant in this area in contrast to number of people served together with political, economic, and technical considerations. Based on its engineering and economic advantages, the west line (Study Section 5A) is recommended for the future freeway in Study Section 5.

STUDY SECTION 6 - TOUNAN-TAINAN

This 77.3-kilometer section would extend from Tounan to Tainan, Sta. 215k + 400 to Sta. 292k + 700. See Route Plans 4 through 8.

Alignment

Study Section 6 would combine many curves with tangents of varying lengths. It would be in expansive rice paddy fields within one to 14 kilometers of Highway No. 1, and west of it.

Its alignment would keep it in open areas away from populated areas with minimum right of way costs.

Study Section 6 is second longest of the sections in the feasibility study. It would cross many drainage areas and irrigation ditches used to water the rice paddies. The only long river crossing would be at the Tseng Wen Chi from Sta. 282k + 350 to Sta. 283k + 150, a length of 800 meters. Study Section 6 would terminate at Highway No. 1, just east of Tainan.

The profile would be generally flat, rising and falling gently over the many grade separations.

It would cross 14 local roads and 18 sugar cane railways but no main line railways. Utility relocation would involve power transmission lines at seven locations, sugar cane railways at eleven, and water mains at five.

Fill costs would be high, due to the 11,225,000 cubic meters required, and the 20-kilometer average haul, longest of all the study sections. The large amount of fill would be required to keep the freeway above the water level, which is high due to irrigation of the rice paddies and also the susceptibility of this area to flooding. A serious flood area would exist from Sta. 235k + 000 to Sta. 235k + 500, a length of 500 meters, near Chiayi.

Service to Adjoining Areas

Adjoining areas would be served by nine interchanges. Population centers over 25,000 would include Tounan, Talin, Min Hsuing, Pekang, Chiayi, Potze, Shui Shang, Houpi, Hsinying, Yenshi, and Matou. A 1969 population of about 700,000 would be served, and average traffic would be about 56,000 ADT by 1990.

Stage Construction

Staging plans considered future traffic data. Four lanes were estimated to be sufficient up to 1990. The studies revealed that benefits would be maximized by building the section Tainan to Chiayi first, in 1973, followed by the portion from Chiayi to Tounan in 1977. See Tables VII-3 and 29.

Aesthetics

The length of Study Section 6--77 kilometers--through the same type of countryside as Study Sections 5 and 7 would be monotonous for the motorist. For this reason, and because right of way would be inexpensive, a median varying in width from 10 to 15 meters should be considered. The median should be landscaped with interesting shrubs and flowers.

Rest Areas

There should be two or more rest areas in Study Section 6. One possible location would be near the Tseng Wen Chi crossing.

Costs

At NT $45 million per kilometer, construction cost would be the same as the average for the entire freeway. See Tables VII-6 and 17. Earthwork costs per kilometer would be the highest of all study sections, due to the need for flood protection and the many grade separations.

Right of way cost of NT $3.3 million per kilometer would be the lowest of all study sections and well below the average of NT $15 million for the project. See Table VII-6.

STUDY SECTION 7 - TAINAN-FENGSHAN

This Study Section starts at its point of crossing Highway No. 1 north and east of Tainan and extends south to Fengshan.

Two alignments were studied throughout the section. The west line would lie between the sea and Highway No. 1 from Sta. 292k + 700 to Sta. 347k + 550, a distance of 54.85 kilometers. The east line would be east of Highway No.1 from Sta. 292k + 700 to Sta. 348k + 550, a distance of 55.85 kilometers. Both lines are shown on Route Plans 1 to 4.

Alignment

The east line would be longer than the west line by 1.00 kilometer.

The west line would be largely straight, with a few long flat curves. It would begin at Highway No. 1 and pass through an open area through Tainan. It would continue through rice lands and skirt two airports, a naval base, and some industrial developments near Kaohsiung. It would be in a built-up area between Stations 331k + 000 and 334k + 000, and just west of a prominent hill. A branch of the freeway would serve the Kaohsiung central business district at Chung Hwa Road near the railway station while the main alignment would take advantage of large open areas in the city such as that just west of Ho Ping Street between Chung Cheng and San Tuo Streets. The freeway would continue to curve south and east to a terminus at Highway No. 183. It would end at a point from which it could be extended southerly through a low mountain pass in the future to cross the Kao Ping Chi and continue on to Pingtung.

The freeway would be on fill above flood levels, but with gentle undulations over grade separations at eight railways and sixteen highways.

The east and west lines would have the same alignment from Highway No. 1 to Sta. 311k + 000. From there, the east line would swing easterly, rejoining the west line at Sta. 340k + 000. The east line would be generally to the east of Highway No. 1. It would differ from the west line in that it would be in open farmlands rather than in populated and built-up areas. A possible continuation of the east line is shown as "east line extension", Route Plan 1. The east line extension would traverse the outer perimeter of Kaohsiung about 700 meters north of and parallel to Highway No. 1, terminating at Fengshan at Highway No. 183. If the freeway were continued south of Fengshan in the future, it could be parallel and adjacent to Highway No. 1. Until this continuation is effected, a connection could be made with Highway No. 1 for traffic destined for Pingtung and other points south. However, the bridge across the Kao Ping Chi, in its present condition, would not be adequate for heavy traffic leaving the freeway. It would probably not be wide enough, moreover, to accommodate future volumes that would be generated by a freeway terminating on Highway No. 1.

The profiles of the east and west lines would be similar in that extensive fill would be required to ensure that the freeway would be above flood waters. Both would also require numerous highway and railway grade separations.

Service to Adjoining Areas

In passing as it would through populated centers, next to three airports, and near naval installations, the west line would offer excellent service to adjoining areas. Access roads to these traffic generators would be relatively short. Ten interchanges, averaging one every 5.5 kilometers along the route, would provide access to these areas.

Of particular interest would be the alignment through the city of Kaohsiung, with a length of 16.70 kilometers. The availability of open land, for 8.50 kilometers, or 51 percent of the length through Kaohsiung, would minimize right of way problems. The freeway would also serve as an intraurban facility for citizens of Kaohsiung. It would probably attract considerable commercial and industrial development due to its proximity to the central business district. In addition, the important harbor works could be adequately served with the assistance of a network of arterial streets now being constructed or being planned by the city.

Since the east line would be farther from populated areas than the west line, service to adjoining areas would not be as direct. Longer access roads would be required to such important areas as Kaohsiung central business district, Kan Shan airports, and the naval base. In most cases where the alignment would differ from that of the west line, traffic would also have to cross Highway No. 1, causing inconvenience to traffic from the freeway as well as to that on Highway No. 1. One exception would be service to the recreational and scenic area at Cheng Ching Lake. The eastern alignment would serve this area better than the western alignment.

Both alignments would have the same number of interchanges. The main disadvantage of the east line extension would be the relatively poor service to the city of Kaohsiung.

Stage Construction

Stage development is indicated in Table VII-3. Four lanes would be required by 1973, with expansion to six lanes by 1984.

Aesthetics

Scenic values were considered in planning the freeway. The flatness of the terrain and the elevation of the freeway on fill would accord motorists a view of the entire countryside until the area adjacent to the freeway was landscaped or developed. A view of the sea could be had at Sta. 333k + 000, just north of Kaohsiung, as this point would be only about 2.4 kilometers from the coast. Other sections, however, would permit pleasant views of the sea as well as the harbor works at Kaohsiung. One such spot would be near Sta. 333k + 000, where the freeway would be west of a knoll.

Aesthetics were also considered in connection with the eastern line. As with the west alignment, a wide view of the surrounding area would be possible due to the high elevation of the freeway. One distracting feature would be the prominent oil tanks opposite Sta. 333k + 000 which would be hidden from view on the west alignment.

Cost Comparison

Cost estimates were made for the east and west lines. The east line would cost NT $3,781 million, or about six percent more than the west line. The economic comparison, which favors the west line, is presented in Chapter VIII. Cost estimates are shown in Tables VII-18 and 19.

Summary

The east line extension was eliminated from serious consideration because of the poor service rendered Kaohsiung. Another disadvantage of the east line extension would be the temporary connection with Highway No. 1 and the poor condition of the existing Kao Ping Chi bridge.

The location of the west line between Highway No. 1 and the coastline would give much better service to military installations, airports, and the naval harbor works than would the east line. Also, because of its location through the city of Kaohsiung, the west line would provide excellent service to the city, and expedite movement of traffic within Kaohsiung. Construction of the freeway on the west line could be expected to stimulate growth of developments along it within the city.

The most important advantages of the west line over the east line would be that both construction and right of way costs would be about six percent less and economic benefits would be greater. A freeway through a corridor in the vicinity of the west line, therefore, is recommended.

ESTIMATES OF COST

Total costs for the proposed North-South Freeway route are shown in Table VII-6. The total construction and right of way costs, excluding access roads, would be about NT $22.3 billion.

Right of Way

Basic requirements for right of way were established from typical sections as shown in Exhibit VII-11, and as previously described under design criteria of this chapter. Appropriate allowances were made for additional property required in sectors of heavy cut and fill.

Cost of demolition of buildings and property damage were also included. Buildings were counted as accurately as possible on the available maps. Expenses related to moving residents and relocating factory equipment and personnel were included as property damages.

Property costs were estimated after reviewing government records of land assessment and present market price as indicated by recent sales.

Total right of way costs for the freeway would be NT $5.6 billion. See Tables VII-6 and VII-8.

Construction Costs

A unit cost table was developed for the various construction items from available data on highway projects in Taiwan. See Table VII-4. Certain items were not costed separately, but were included with other items so that a new unit cost was prepared on the basis of material, equipment, and labor. For items on which experience in Taiwan was too limited to determine unit costs, they were estimated from experience in countries with conditions similar to those in Taiwan. All costs were based on the year 1969. Individual items were estimated as follows:

Clearing and Grubbing - New unit costs were developed because this item had not been included in any previous Taiwan Highway Bureau projects. Land areas were separated into the following categories:

Urban
Rural - Rice paddies
- Forested

Roadway Surfacing - Cost data for previous projects were obtained and updated for 1969 for asphalt, concrete, base, and subbase courses. Costs were then calculated for a lineal meter of roadway for four-, six-, and eight-lane freeways.

Guard Rail - Based on import costs and known costs for guard rail on other projects.

Fencing - Based on the import, freight, and shipping costs for chain link fencing.

Earthwork - Cost data from previous jobs were applied to this item for compaction, excavation, and haul. Locations of known borrow pits were used. The shrinkage factor was taken at 25 percent.

Utility Relocation - Utility relocation information for power transmission lines, oil pipe lines, water mains, gas mains, and telephone lines was taken from available topographic mapping. In addition, a check was made with appropriate utility agencies. Current unit prices were obtained from these agencies and applied to each utility relocation.

Drainage - The main drainage items for the proposed freeway were box culverts, culvert pipes, and stream relocation. Size of culverts needed was estimated from a study of existing drainage structures at locations upstream and downstream, stream flow conditions, and size of catchment area. Culvert lengths were based on both height of fill and typical section. Culverts were summarized for each section of freeway and for each alternative alignment; and costs estimated. The possibility of stream relocation was studied to minimize number of crossings. Other drainage items consisted of the following: curb inlets; storm drains; underdrains; ditch paving; slope protection; and check dams.

Stage Construction - Total cost of the project was first estimated for all items. Stage 1 costs were then obtained by reducing roadway surfacing and bridges by two lanes and by proportionately reducing the amount for items dependent on roadway surfacing such as signing, lighting, landscaping, and miscellaneous. The ultimate cost of right of way and earthwork was included in Stage 1.

Signing - Cost estimates for signing were compared with known costs on freeways in other countries. A factor of 2.6 percent of roadway surfacing cost was found consistently and was used to simplify costing.

Lighting - On previous projects in Taiwan, this factor had been 4.0 percent of roadway surfacing cost. This factor was used to simplify costing.

Landscaping - An approximate cost was developed, based on materials, labor, and equipment, for planting grass and shrubs along the median and side slopes of the freeway. A factor of 2.0 percent of roadway surfacing cost agreed closely with this calculation.

Interchanges - Roadway and earthwork costs were determined from typical designs for trumpet, diamond, and parclo type interchanges for both the "Freeway over" and "crossroad over" condition. Grade separation costs related to roadway and earthwork for the "crossroad over" condition only were included in this item.

Frontage Roads - Costs for subbase, base, and asphalt surfacing were determined for a standard high-type roadway currently used by the THB. Costs were calculated on a lineal meter basis for a two-lane roadway.

Miscellaneous - A factor of 10.0 percent of roadway surfacing cost was used to account for the total cost for such items as rest areas, service areas, a truck weighing station, an emergency landing strip, and other auxiliary items.

Bridges - Structures were categorized into three groups for making cost estimates:

Grade separations and viaducts;

Short and medium-length river crossings (less than 300 meters long); and

Large river crossings.

Tunnels - Based on recent Japanese standards for freeway tunnel construction and costed on a per lineal meter basis.

Retaining Walls - Based on current THB standards for cantilever and gravity type walls, and costed on a lineal meter basis according to height.

Contingencies and Engineering

Twenty percent of all construction costs was added for this item. Contingencies would include contractors' administrative expenses such as establishment of field offices, administrative personnel, taxes, and licenses and fees. Engineering would include preparation of plans and specifications, and engineering supervision and inspection during construction.

Maintenance Expenses

Annual maintenance expenses were estimated on a kilometer basis for two-lane highways from maintenance costs of existing highways. Past maintenance records were reviewed for pavement, signing, lighting, drainage, landscaping, slope protection repairs necessitated by storm damage, and administrative costs. Maintenance costs for structures and fencing were developed separately.

An allowance was made for one asphalt overlay during the study period of 20 years. Proportionate increases were made from two-lane costs to estimate costs for four-lane and six-lane highways. Estimated maintenance costs are shown in Table VII-5.

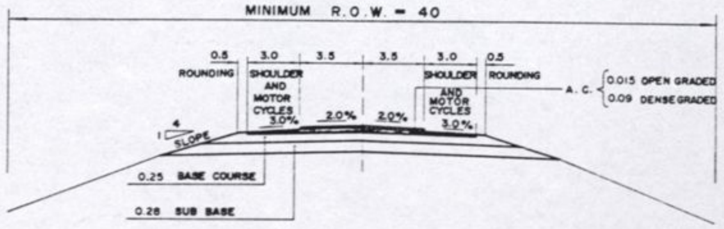
IMPROVEMENTS TO HIGHWAY SYSTEM WITH FREEWAY

Design Criteria

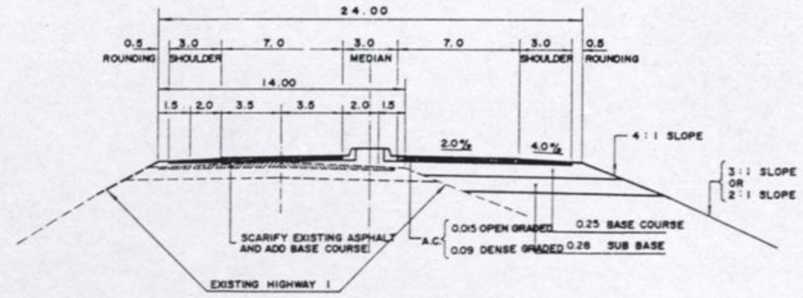
Design criteria for highway improvements with or without freeways should be the same. The section on "Highway System Without Freeway" lists criteria pertaining to alignment and typical sections.

Improvements Required

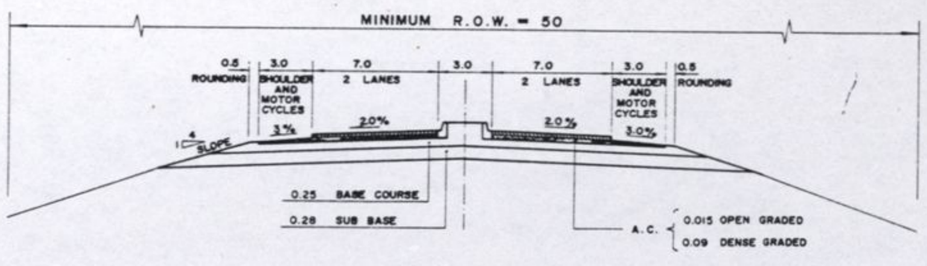
Improvements to designated highways parallel to the freeway should supplement the North-South Freeway to assure adequate accommodation of projected traffic volumes in the study corridor. Completion dates, with number of lanes requires, are shown in Table VII-29 and Exhibit VII-18. Capacity requirements indicate that Study Sections 3, 4 and 7 would require one highway to be improved in addition to the Freeway, while Study Sections 5 and 6 would require two highways to



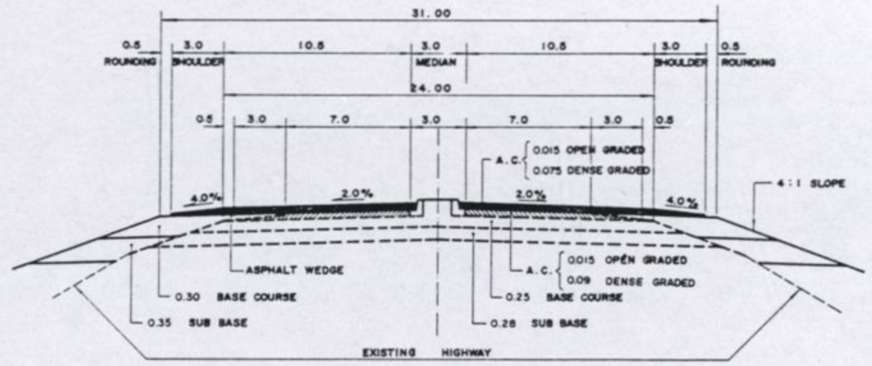
2 LANES



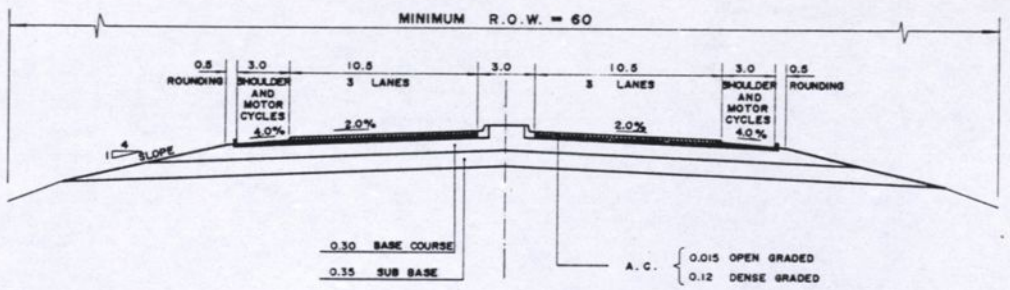
EXISTING HIGHWAY I WIDENING 2-LANES TO 4-LANES



4 LANES



EXISTING HIGHWAY WIDENING 4-LANES TO 6-LANES



6 LANES

TYPICAL HIGHWAY
IMPROVEMENT CROSS SECTIONS

(NOT TO SCALE)

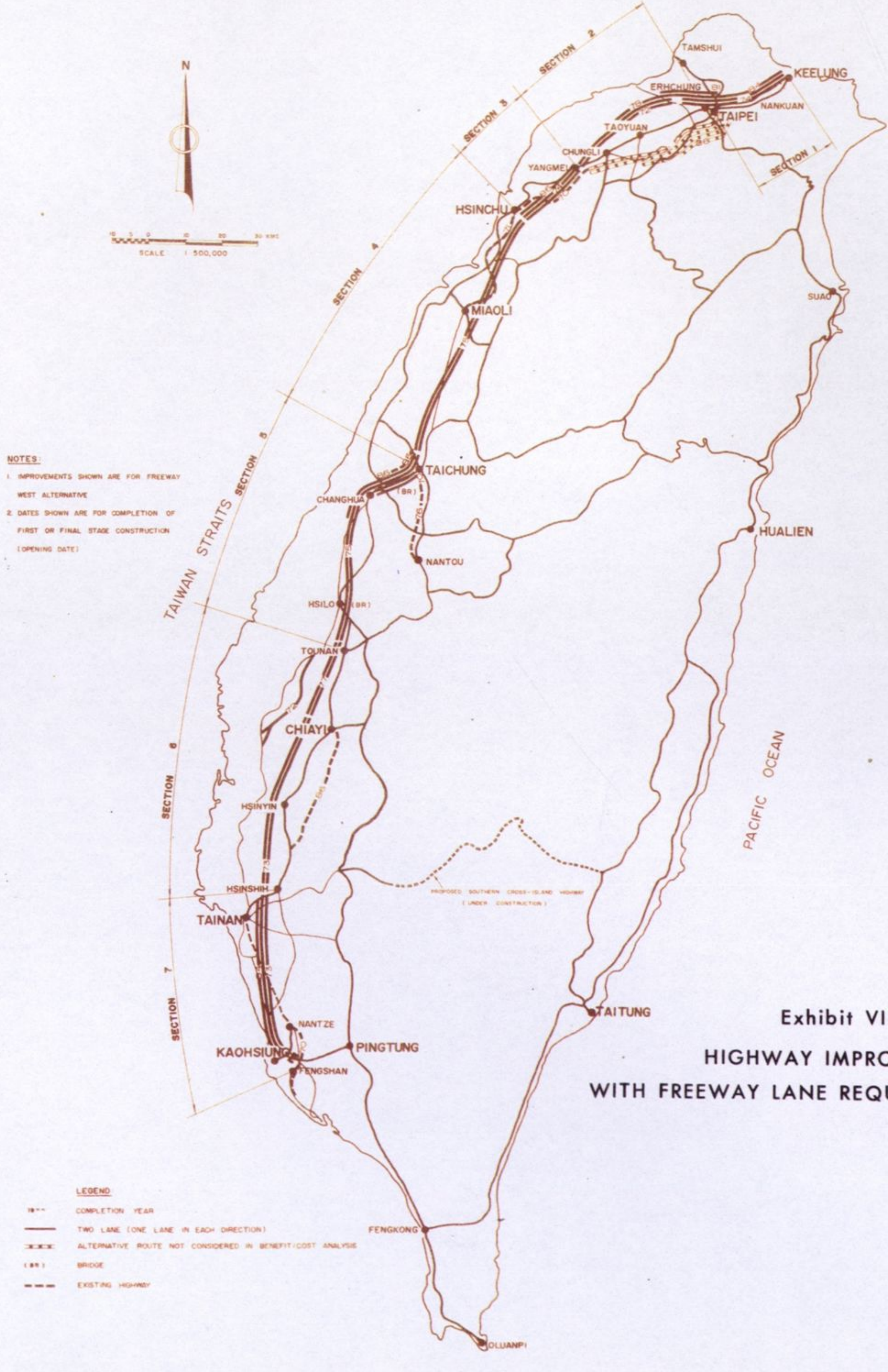


Exhibit VII-19

HIGHWAY IMPROVEMENTS WITH FREEWAY LANE REQUIREMENTS TO 1990

be improved to supplement the freeway. No highway improvements would be required in Sections 1 and 2 with the Freeway, but a second freeway would be required in these sections by 1982.

Estimates of Cost

The costs for all highway improvements with freeway are summarized in Table VII-30. The total cost of highway improvements only, for all study sections, would be NT $3.6 billion. Detailed costs for these highway improvements for Study Sections 3 through 7 are shown in Tables VII-31 through VII-36. The method of estimating costs of Construction, Property, and Maintenance for highway improvements with freeway was basically the same as for highway improvements without freeway.

HIGHWAY SYSTEM WITHOUT FREEWAY

This discussion summarizes the criteria used to develop the cost estimates for the improvements to the existing highways for the "without freeway" condition.

DESIGN CRITERIA

a. Type of Facility

Highways without control of access and having at-grade crossings with other highways and railways ranging from two to eight lanes wide.

b. Horizontal Alignment

	Type of Terrain		
	Flat	Rolling	Mountainous
Design speed (km/hr)	80	70	60
Maximum roadway super-elevation (m/m)	0.08	0.08	0.08
Minimum radius--meters	230	170	120

c. Vertical Alignment

	Type of Terrain		
	Flat	Rolling	Mountainous
Maximum grade--percent	4	6	7
Critical length of grade in meters	350	190	160

d. Typical Section

1) Typical sections for local highway improvements are shown in Exhibit VII-19. Improvements considered are:

   Widening existing two-lane roads to higher standard two-lane highways;

   Widening from two to four lanes;

   Widening from four to six lanes;

   Widening from six to eight lanes.

2) Shoulders--3.0 m (also used as motorcycle lanes)

3) Rounding--0.5 m

4) Minimum fill and cut slope:

   3:1 to 3 meters height of fill
   2:1 above 3 meters height of fill

5) Minimum right of way:

	Width in Meters		
	2-lane	4-lane	6-lane
Rural	30	40	50
Urban		As required	

IMPROVEMENTS REQUIRED

Highway improvements were considered for each of the seven study sections based on capacity requirements and the timing of the improvements. Improvements, with their locations, times of construction, and types of construction, are indicated for all study sections in Table VII-20 and Exhibit VII-20.

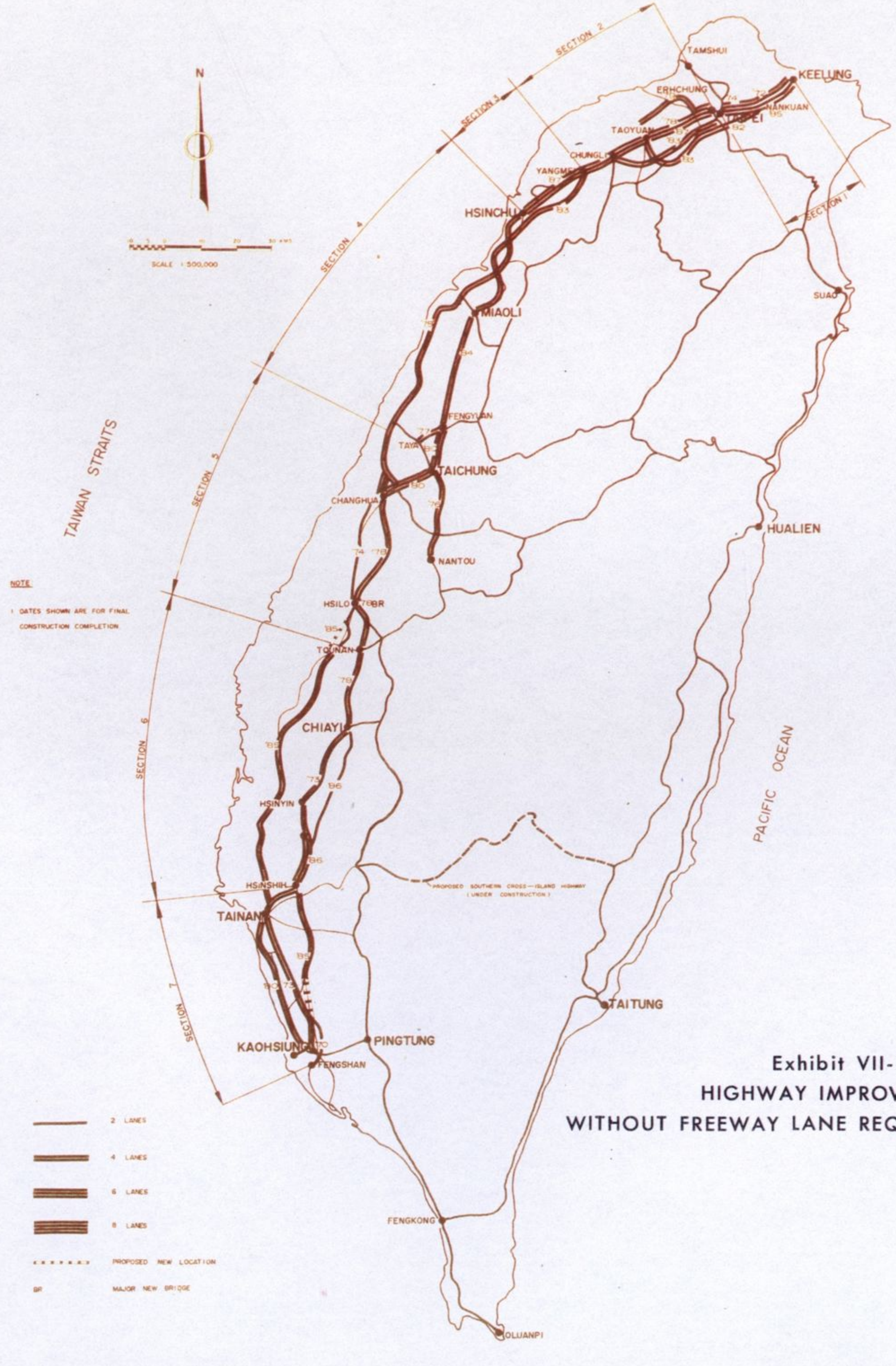


Exhibit VII-20
HIGHWAY IMPROVEMENTS
WITHOUT FREEWAY LANE REQUIREMENTS TO 1990

Only existing major north-south highways within the study corridor were chosen for improvement. In some cases, new sections of highway would be needed to connect discontinuous sections, for example Highways No. 175, No. 181, No. 177, and No. 183 in Study Section 7.

The total length of improved highways needed by 1990 would be 915.63 kilometers. Lengths, in kilometers, by width of highway, would be:

Two-lane	87.02
Four-lane	705.93
Six-lane	109.68
Eight-lane	13.00

CAPACITY

Highways were recommended for improvement on the assumption that capacity would be provided as needed, but that present speeds would remain unchanged, consistent with the simulated operating costs. The effect of increased speed, if any, is discussed in Chapter VIII under economic justification.

The following capacities, corresponding to level of service were used for the highway improvements since current average speeds correspond to this service level. They are expressed in passenger car equivalents per day:

Two-lane highway	8,000 to 14,000 PCE per day
Four-lane highway	40,000 to 45,000 PCE per day
Six-lane highway	65,000 to 75,000 PCE per day

These service volumes were compared with future traffic to determine lane demand. The lower part of each graph (Graphs VII-1 to 17) pertains to highway improvements without freeway. The upper part concerning freeways was discussed earlier in this chapter. Each graph shows the corresponding highway number, lane width, level of service, and capacity. When the horizontal line crosses the traffic growth curve, an improvement indicated above the line should be opened to traffic. The highway as thus improved would then serve until its capacity was reached.

The relatively simple Screenline 1, halfway between Taipei and Keelung may be taken as an example. The combined capacities of Highway No. 5 and MacArthur Thruway would be adequate until about 1974. Widening of MacArthur Thruway to four lanes carrying 60,000 PCE per day at level D would suffice until about 1985. A mid-point interchange connecting with Hsinchi should be added, however, for flexibility. Additional capacity would then be needed. This could be attained by widening Highway No. 5 to four lanes, to carry traffic at level of service E with capacity for 40,000 PCE per day through towns. The highway would then be adequate until around 1991.

The 17 graphs are not explained in detail since they are self-explanatory. Resulting lane requirements were summarized for each of the seven study sections. The plan illustrates the theoretical lane demand of highways without freeway until 1990. The accompanying list indicates the theoretically required improvements of highways that would have to be made by 1990 if no freeway were built.

PAVEMENT STRUCTURE FOR EXISTING HIGHWAYS

Existing two-lane highways were analyzed for structural capacity and found substantially deficient. An asphaltic concrete overlay was designed, therefore, that would increase the strength sufficiently to carry anticipated loads.

In analyzing existing highways to be widened, structural thicknesses were estimated by using a Resistance Value of 20 for the basement soil; by taking a Traffic Index of 9.4 for traffic loads; and by assuming the pavement structure to be composed of asphaltic concrete, crushed aggregate base, and uncrushed aggregate subbase.

To compare the cost of pavement for existing highways with the cost of pavement for the freeway, an overlay for existing highways was designed and its cost calculated. The overlay would be applied at the end of ten years and could be considered capable of carrying the increased traffic loads for the succeeding ten years.

BRIDGES

Current design load data were assembled from THB records for structures on highways for which improvements were considered. Bridges designed for loads below acceptable standards were considered unusable, and it was assumed that new structures would be built. Structures that met design standards would be widened to meet capacity requirements.

RIGHT OF WAY

Right of way requirements were developed from the typical sections as shown in design criteria and typical sections on Exhibits VII-11 and VII-19.

These widths agree with right of way standards currently used by the THB. Existing highways and rights of way were assumed to be retained where feasible. Where property costs would be high, such as through cities, bypass routes were used to the extent practicable.

It was assumed that widening would be symetrical on the centerline or all on one side, whichever was shown by detailed study to be the less expensive.

Right of way costs, including demolition of buildings and property damage, were obtained in the same manner as for the "with freeway" condition.

ESTIMATES OF COST

Cost estimates for highway improvements, including rights of way and construction, are shown for each of the seven study sections in Table VII-21. The total length of highway improvements for which cost estimates were made was 915.63 kilometers, and total cost was estimated at NT $24 billion. The average cost per kilometer of highway improved would be NT $26 million. See Table VII-20. Cost estimates for individual sections are shown in Tables VII-22 to 28.

CONSTRUCTION COSTS

Unit costs were developed for the following items from data on roads previously built by the THB.

Roadway Section New alignment	- New construction of a by-pass, connection between two existing highways, removal of sharp curves below design criteria, or replacement of existing low standard roadway surfacing.
	- Overlay pavement. Highway No. 1 was the only existing highway with surfacing, base and subbase which could be used without major upgrading.
Earthwork	- A nominal amount of earthwork was considered, such as two meters of fill in flat areas. Allowances for cut and fill were made in mountainous areas.
Utilities	- Based on property costs. Utilities for Highway No. 1 were estimated to be 10.0 percent of land costs. For other highways, 5.0 percent of land costs was used.
Miscellaneous	- Estimated at 10.0 percent of roadway surfacing costs. This would include signing, lighting, landscaping, and items too small to consider separately.
Drainage	- The major portion of the drainage costs in connection with highway improvements would be for lengthening existing structures. This would be required under the proposed new design standards. Most of the existing structures would remain except inadequate structures which should be replaced in any event. To arrive at required lengths, basic information about existing structures was compiled. Known data were listed on an overlay of a topographic map covering highways under study. Considering the height of existing embankment and new typical section at various stages of improvement, additional culvert lengths were determined and summarized for costing.
Structures	- Data on existing bridges were studied and they were planned to be widened or rebuilt, depending on design criteria used and present condition.
Engineering and Contingencies	- An allowance of 20 percent of all construction costs was made, as explained previously in discussing the cost of estimates for freeway.

MAINTENANCE COSTS

Annual maintenance expenses were developed on a per kilometer basis for two-lane highways from maintenance costs of existing highways. Structures were averaged out on a per kilometer basis.

An allowance was made for an asphalt overlay every ten years. Maintenance expenses in connection with highway improvements are shown on Table VII-5. Other details would be similar to those of maintenance costs for a freeway.

chapter VIII

BENEFIT–COST ANALYSIS

BENEFIT-COST ANALYSIS

Previous sections have indicated the probable effect of the proposed freeway on highway traffic patterns and on the distribution of passenger and freight traffic between railways and highways. The highway engineering section indicated what the freeway would cost, and estimated the cost of highway improvements which would have to be made if the freeway were not built. To determine the economic feasibility of the freeway project, it remains for this study to evaluate the benefits and compare them with the costs.

In making the evaluation, taxes were deducted from the estimated freeway and related highway costs to arrive at the actual cost to the country of the proposed construction. Measured against this cost were the benefits which would accrue to the country as a result of building the freeway, rather than investing only in the alternative highway improvements. These alternative improvements, themselves, would comprise one of the major benefits of the freeway, since, if it were constructed, the cost of the alternative program would not have to be borne.

Other benefits of the freeway would include highway user operating cost savings (including the value of passenger time savings), under the "with freeway" condition compared with costs of using the highways under the "without freeway" condition or of traveling or shipping by rail.

Taxes had to be deducted from the benefits as well as from the costs. While tax savings are real savings to users, they are not savings to the economy, and it is the costs and benefits to the economy that are of concern in evaluating a public investment.

After taxes had been deducted, both costs and benefits were discounted at various rates in order that they be measured against each other in terms of the value of money on the same basis. The net present values and benefit-cost ratios were determined at each discount rate, and the internal rate of return was derived as the discount rate at which discounted costs and benefits were equal. Such an evaluation was made, not only of the freeway as a whole, but also of each freeway section, including alternative alignments in each of three sections.

The first portion in this chapter discusses deduction of taxes from freeway costs and from the costs of related highway improvements. The without-tax alternative highway costs are discussed in the portion on deduction of taxes from benefits. The section on alternative solutions discusses the measurement of benefits against costs, indicates the results of the quantitative analysis, and draws conclusions therefrom.

The discussion on economic justification of the project shows the effects that varying costs and benefits would have on results of the analysis by using a sensitivity matrix developed for this purpose. Various other factors not considered in the quantitative analysis but nonetheless deserving of consideration are also evaluated.

DEDUCTION OF TAXES FROM COSTS

As explained in the preceding chapter, estimated freeway costs for each route section were itemized by property, surfacing, structures, and so forth, for a total of 20 main construction items. The costs were further broken down by stage of construction, and annual maintenance costs were estimated. Analytic tables were prepared to show taxes on each construction item: sales taxes on locally produced materials and equipment, income taxes on the labor component of each item, and import taxes on foreign-purchased materials and equipment. In order to find the distribution of taxes between local and foreign materials and equipment, percentage distributions of the costs of each item were estimated. These cost distributions permitted application of the relevant tax rate (sales, income or import), to the estimated cost in each category of expense. These taxes were then subtracted from the construction items and new total costs and cost schedules without taxes were found. These without-tax costs are shown in Tables VIII-1 through 8.

Taxes on Property Costs

The tax rates which apply to right of way costs, on sale of property, are of two kinds. The simplest is a seven percent sales tax on the market price of property sold. The second is a tax on profits from a sale at a price higher than the price set by government as the true value of the property. Price setting by government extends to land, improved property, and buildings. The total of these three valuations was stated as an average per square meter along each section of highway and freeway. Total fixed price was then calculated for small geographic areas along each highway and freeway route. These prices were then compared with a second set which reflected the estimated market prices at which the property might be acquired for highway and/or freeway construction.

The difference between the two prices was large in most cases as shown by Table VIII-9 which summarizes property taxes for each of the seven freeway sections. The sales profit tax is 20 percent for the first 100 percent of profit; 40 percent for the next 100 percent; and 60 percent for the third 100 percent profit. The tax rate varied from seven percent in Section 6 to a high of 27 percent in Section 3. The profit taxes were combined with the flat seven percent tax on market price to estimate total property taxes for each section as a percentage of total property costs. The tax levels ranged from 14 percent in Section 6 to 34 percent in Section 3.

Taxes on Construction Costs

Freeway construction and maintenance costs are subject to taxes in five categories. Engineering estimates of cost were prepared to show the materials, equipment and labor components of each construction item (surfacing, lighting, etc.). Local or foreign source was also differentiated. Table VIII-10 shows the percentage distribution of these weighted average total costs for the freeway system as a whole. This information was used as a basis for applying average total taxes to construction costs for each section of freeway. The table also shows, for 19 construction items, the average total tax applicable as a percentage of the costs of local materials and equipment and labor and a comparable figure for foreign materials and equipment. These average total tax rates are summarized below:

Tax Rate

Local Costs			Foreign Costs	
Materials	Equipment	Labor	Materials	Equipment
14%	17%	1.7%	18%	12%

The tax rates were derived by averaging the tax rates applying to various types of materials and equipment specified in the import tax and sales tax lists of the government taxing authorities. The method of calculating these taxes, therefore, incorporates a percentage distribution of costs between, for example, wheeled and stationary equipment (65 percent and 35 percent) for foreign imports. This distribution of foreign equipment costs was subjected to the average total tax on such equipment (11 percent and 15 percent), to find the average total tax for all such foreign equipment (12 percent). Each of the five categories was handled similarly. The relevant weighting factors are described in Table VIII-10.

The tax rates thus estimated were applied to the itemized construction costs for each of the 19 items, for seven freeway sections. These items, as shown in the summary table above, were separated into five categories of cost (local and foreign). For the income tax rate, found to be only 1.7 percent of labor costs, reference is made to Table VIII-11 which shows the general tax schedules of Taiwan. Labor costs on the freeway project were broken into the following three categories of workers:

1.	Workers with incomes of less than NT $30,000	- 80%
2.	Workers with incomes NT $30,000-$60,000	- 15%
3.	Workers with incomes NT $60,000-$100,000	- 5%
		100%

Taxes paid by the first category of workers would be relatively small, e.g. a family of five with income of NT $20,000 pays no tax. The highest group pays a tax of only 10.0 percent on taxable income. The total tax content of labor costs of the project was estimated to be 1.7 percent.

Taxes on Maintenance Costs

Taxes on maintenance costs were calculated at about 13 percent. Two calculations were made to confirm the average tax basis. First, roadway surfacing alone was selected as the basis; relevant average taxes (as a percentage) were multiplied by the average cost distribution (as a percentage). A tax rate of 13 percent was computed. However, maintenance also involves repairs, painting, replacement of signs, and many other types of work besides resurfacing. Therefore, a new tax base was selected: the average cost distributions of signing and lighting, and average total structural costs. Each was weighted at 50 percent of influence affecting final values, after multiplying by the relevant tax rates in Table VIII-10. Signing and lighting were found to represent a 7.7 percent tax rate, and structural maintenance 5.9 percent, or a total tax rate, again, of 13 percent. This tax rate was applied to the annual maintenance cost forecasts shown in the tables of cost schedules, and a new "without-tax" level of costs was determined.

ESTIMATE OF BENEFITS

The benefits considered in the quantitative evaluation of the freeway as an investment include only the alternative highway improvement costs, the highway user savings, the savings to traffic converted from the railway, and the value of cargo time savings. Only the alternative highway costs and the user savings are major benefits.

The alternative highway improvement costs represent benefits that would accrue to the economy as a result of constructing the freeway, since, with the freeway, these costs would not occur. These alternative costs were discussed in detail in the preceding chapter.

The estimated highway user savings, expressed as savings in the operating costs of road vehicles, would result mainly from time savings. These, in turn, would result from higher average speeds on the highways under the "with freeway" condition than "without freeway". In some sections, and over the freeway as a whole, there would also be distance savings, which would increase operating cost savings. See Exhibits VIII-1 and VIII-2 for comparison of average trip times from Taipei, with and without freeway.

Calculation of User Savings

Computer results, discussed in an earlier chapter, indicated 1969 and 1990 ADT kilometers, vehicle-hours of travel time, and operating costs for each of four vehicle types, for both the "with freeway" and "without freeway" alternatives, in each freeway section.

The 1969 and 1990 savings (or added cost, as was sometimes the case where travel distances were increased) of the freeway alternative, compared with the "without freeway" condition, were found by deducting the freeway alternative values from the "without freeway" values.

Thus, for example, the ADT operating costs of automobiles and taxis in Section 3, in 1969 (see Table VIII-12) were estimated at NT $119,400 under the "without freeway" condition, but would be only NT $88,100 under the "with freeway" condition; the difference would be NT $31,300, and this amount would represent the potential daily saving to auto users in Section 3, in 1969.

After the ADT savings were determined, they were converted to annual savings by using a factor of 365 for sedans (autos and taxis), light trucks, and buses, and by using a factor of 354 for heavy trucks. These factors were used because, as indicated in the earlier discussion of the road survey, auto, light truck, and bus traffic volumes are about the same on every day of the week, but heavy truck volumes fall off on weekends. Table

Exhibit VIII-1

PRESENT AVERAGE HIGHWAY TRAVEL TIMES FROM TAIPEI

VIII-12 indicates the annual savings for example discussed above, viz., Section 3, 1969.

To obtain interim year, i.e., 1970-1989, values for savings, the expansions from the respective 1969 and 1990 values were divided proportionately by using the vehicle registration growth curves developed in Chapter V. See Graphs V-11 through 15. The ratio of total increase in savings (i.e., the expansion factor less 1.00) to the growth of registrations between 1969 and 1990 was multiplied by the 1969 savings value to obtain a constant. This constant was then multiplied by the interim year registration growth expansion factors with 1969 as a base (i.e., the interim year expansion factors less 1.00) to obtain the savings growth values in kilometers, hours, or NT dollars. These values of savings growth in each year added to 1969 values gave total savings in each year.

Similar computations produced annual distance, time, and operating cost savings for each of the four vehicle types, for each freeway alternative, in each section. These values are shown in Tables VIII-13 through 27. Summaries of distance, time, and cost savings, respectively, for all freeway sections are shown in Tables VIII-28, 29 and 30.

Most of the values shown in these tables are explained by the preceding discussion; the complexity of Section 2, however, deserves special attention.

Forecast of User Savings in Section 2

Section 2 is more complex than other sections of the freeway, primarily because of the very high traffic volumes forecast. Traffic is expected to reach the capacity of the freeway at the design level of service by 1981. The proposed airport near Taoyuan, furthermore, would have a marked effect on the choice of a freeway route in the section.

Tables VIII-14 and 15 show the user savings expected with Freeway West (Alternative A) and Freeway East (Alternative B) in Section 2, respectively, if no airport were constructed near Taoyuan and neither route reached capacity before 1990. The values in these two tables were calculated by the above described procedure which was used for all other sections.

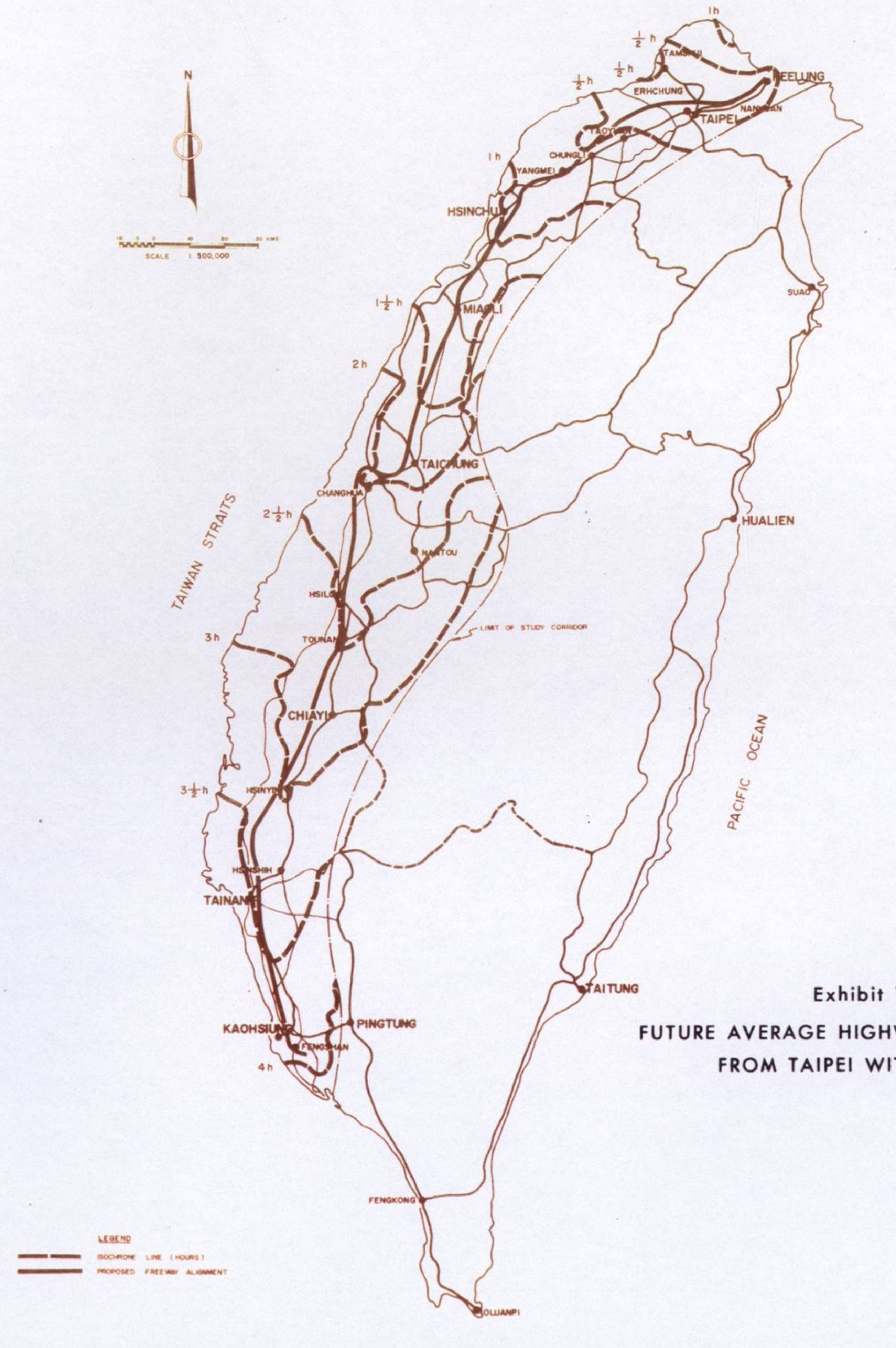


Exhibit VIII-2

FUTURE AVERAGE HIGHWAY TRAVEL TIMES FROM TAIPEI WITH FREEWAY

There was negligible traffic to and from the proposed airport site in 1969. Hence it was not possible to arrive at 1990 airport traffic volumes by expanding the road survey trip table. The pattern of airport traffic was projected separately, therefore, from the computer traffic projections. See Chapter VI for an explanation of the procedure used. Airport traffic user savings were calculated separately as shown in Tables VIII-16 and 17.

Total user savings for each of the two freeway alternatives in Section 2 were obtained for the years prior to 1982, by adding the potential savings indicated by the computer results (i.e., excluding airport traffic) to the savings of airport traffic. Traffic growth and capacity analyses indicate that by 1982, however, either freeway route would have reached its capacity, and benefits would not rise thereafter. User savings on either freeway route might be expected to remain at the levels of 1981, however, if other highways were improved at a rate sufficient to accommodate each year's growth.

This study estimated post-1981 user savings in Section 2 more conservatively, however. Instead of assuming gradual highway improvements in the section, over the 1981-1990 period, it was assumed that a second freeway would be opened in 1982. In that event, there would be excess freeway capacity for a few years, and the user savings resulting from the first freeway would show a sharp drop from 1981 to 1982.

Tables VIII-31 and 32 show the vehicle-hours on Freeway West and Freeway East in 1981, by vehicle type. It was then estimated that, were a freeway to open along the route of Freeway West in 1981, Freeway East having been built first, all of the airport vehicle-hours and Linkou vehicle-hours (the two estimated to be about equal in every year) would be diverted to the new freeway. In addition, Freeway East would lose about one-half of auto and light truck through-traffic and one-quarter of bus and heavy truck through-traffic. Less bus and heavy truck traffic would be lost since Freeway West, because of its greater gradient, would be less attractive to heavier vehicles. Since through-traffic was estimated to account for around two-thirds of vehicle-hours (excluding airport traffic) on Freeway East, it might lose one-third of its auto and light truck hours (i.e., one-half times two-thirds equals one-third), and one-sixth of the vehicle hours of the large vehicles (i.e., one-quarter times two-thirds equals one-sixth). Total vehicle-hours lost, according to these calculations, would be 3,502,000 if the other freeway were open in 1981. Remaining Freeway East vehicle-hours would number 5,283,000, or approximately 60.1 percent of the forecast 1981 total.

If both freeways were open in 1982, traffic would probably reach their combined capacity by 1990. Thus,it was forecast that the number of vehicle-hours would climb from a reduced amount, in 1982, to regain the 1981 level by 1990. The rate of increase used was the compound rate which would raise the hypothetical 1981 value to the forecast 1981 value by 1990. For Freeway East, this rate would be about 5.8 percent per annum.

The revised forecast of savings in vehicle operating cost was estimated by varying these savings with total vehicle-hours; that is, the reduced value for 1981 would be 60.1 percent of the forecast value, and values in subsequent years would increase at an annual rate of 5.8 percent. The assumption that vehicle operating cost savings would vary exactly with vehicle-hours tends to understate the benefits of the freeway route after 1981, even though vehicle-hours on one freeway route would be no higher in 1990 than in 1981. Composition of traffic would have altered so that the vehicles that would be deriving substantial savings would have increased as a percent of total; other vehicles that had been deriving only small savings from traveling on that route would have been diverted to the other freeway where their savings would be greater.

All airport and Linkou traffic was assumed to remain on Freeway West even after the opening of Freeway East. An estimated one-third of the balance would be local Freeway East traffic, and would all be diverted to that route. This would reduce vehicle-hours of other traffic by only about one-sixth, however, since the average travel distance on Freeway West would be less than half the distance traveled by through traffic. One-half of auto-taxi and light truck through-traffic would be elieliminated, and three-fourths of heavy truck and bus through-traffic would be diverted. The total reduction in vehicle-hours from the forecast 1981 value to a hypothetical value for 1981, would be 4,304,000. The number of vehicle-hours remaining to Freeway West would be 3,286,000, or only 43.3 percent of the forecast value. The rate of increase from the hypothetical 1981 value to the 1990 value, which would be same as the forecast 1981 value, would be 9.8 percent per annum.

Table VIII-18 shows the revised forecast of distance, time, and operating cost savings between 1982 and 1990 with either Freeway West or Freeway East in Section 2. Tables VIII-19 and 20 show the final forecasts of user savings for these alternatives in this section, during the entire 1969-1990 period. Airport traffic was eliminated in the latter two tables for years prior to 1975.

Although estimated user savings were substantially reduced by the procedure used, Tables VIII-29 and 30 indicate that Section 2 would produce the highest time and cost savings of any section of the freeway.

Other Benefits of the Freeway

Other benefits of the freeway considered in the quantitative analysis included savings to highway users (passengers and shippers) converted from railway use, and the value of cargo time savings. These benefits would be minor compared with the user savings and alternative highway costs. Table VIII-33 shows the totals of these benefits, referred to as "lesser benefits" of the freeway. These benefits were omitted from evaluations of individual sections of the freeway, but were included in the benefit-cost and rate of return analysis for the entire freeway.

Traffic Converted from the Railway

The shift of traffic from rail to highway was discussed in Chapter VI, and the effect of this diverted traffic on the pattern of highway traffic was discussed in Chapter VI. It remains only to translate this converted traffic into savings to the economy.

The traffic conversion analysis indicates that diversion of passenger traffic from rail to road would probably not continue after 1979. The hypothetical number of converted passengers in 1969 (100 percent of rail express passengers) was translated into bus vehicle-kilometers. These, in turn, were translated into cost savings, as explained in the footnote to Table VIII-34. The hypothetical 1969 value would be a sizeable NT $195 million, but the annual savings would decline rapidly to zero in 1980. The straight line method was used to obtain values for intermediate years between 1970 and 1979. In the first year that the entire freeway would be open (1975), the annual cost savings would be only NT $89 million (about US $2.25 million).

Cost savings of converted cargoes would also be minor. See Table VIII-35. Although there would be a substantial amount of cargo converted (translating to an additional 7,000 heavy truck trips per day in 1990), the cost saving per ton-kilometer would be only NT $0.10, after improvement of the rail system. The assumption of the post-rail improvement condition tends to understate the cost savings of converted cargos. There would be larger differentials before 1980 since the rail system would not have yet attained the ultimate efficiency forecast for it in this study..

As explained in the footnote to Table VIII-35, the cost savings values were obtained by using the product of the cost differential between rail and highway (viz., NT $0.10) and the average (1969) heavy truck size as a constant, expressing the savings in terms of per truck-kilometer. This constant (viz., NT $0.43 per truck-kilometer) was then multiplied by the number of truck-kilometers in every section in every year to estimate the savings shown in the table. The truck-kilometers in 1990 were given by the computer; earlier year values were derived by using the forecast rate of "without freeway" rail cargo growth.

Value of Cargo Time Savings

Cargo time savings not calculated elsewhere would be NT $270.4 million over the period 1974-1990. The value of cargo time was related to the economic and financial costs of business operation peculiar to the Taiwan economy. The hourly rate of money value was calculated as shown in Table VIII-36. This rate was multiplied by the average value of a heavy truck load to obtain the average money value of a loaded heavy truck-travel hour. This constant was then multiplied by the number of heavy truck travel hours saved to obtain the values of cargo time savings. See Table VIII-37.

These values are shown in Table VIII-38 for each route alternative in every freeway section.

The annual savings for the years 1975, 1980, 1985 and 1990 would be NT $9.5, 14.3, 18.3 and 23.9 million, respectively. As percentages of total annual user savings in those years, the amounts would be insignificant. A trend toward relative decline was also predicted. This would be partly due to the changing nature of traffic mix with an increasing number of autos relative to trucks, and a decline in number of heavy trucks as a percentage of total vehicle-kilometers (from 53.3 percent in 1975 to 41.3 percent in 1990). Cargo time savings would be only 0.50, 0.46, 0.42 and 0.38 percent of total user savings in 1975, 1980, 1985 and 1990, respectively.

DEDUCTION OF TAXES FROM BENEFITS

As with the costs of the freeway and related highways, it was necessary to eliminate taxes from all benefits before attempting to measure the value to the economy of the proposed freeway investment.

Taxes were calculated and eliminated from the alternative highway costs (discussed and scheduled in Chapter VII) in the manner described for deducting taxes from the freeway alternative costs. Table VIII-39 shows the without tax costs of the alternative highway improvements for every freeway section.

Elimination of Taxes from User Savings

User savings taxes on vehicle operations were applied separately to distance and time costs as initially shown by the road vehicle operating cost analysis. Calculation of vehicle and passenger savings without taxes required that both business taxes and vehicle taxes be estimated.

Table VIII-40 restates the vehicle operating cost basis, by type of vehicle, in a form which introduces the influence of the business gross revenue tax (1.5 percent) and the business profits tax (18.0 percent). These taxes were newly shown because taxes in road vehicle cost tables applied only to the road vehicles; business taxes apply to revenues and profits of operating a transport business, and affects the passenger who ultimately pays these taxes as part of his fare. The table applies these two tax rates to revenues and profits per passenger-kilometer. Such distance taxes were converted to time taxes (lower part of table) for ease of computing combined vehicle and passenger taxes. Taxes were made a function of time because passenger time values had been made an integral part of the time-and-distance value structure, and this was used by the computer in traffic assignments. Thus, the relevant passenger tax costs were shown to be 2.34 percent on express buses and 4.19 percent on taxi operations. These basic revenue and profit taxes were taken here as the relevant tax burden on passenger time values; business operating costs which are additional to the transport costs (the latter containing vehicle distance taxes) would be subject to many other taxes of various kinds, but they appear to apply with great irregularity. Business operating taxes, therefore, could not be calculated with confidence.

While the selected taxes on passenger time values may have been understated by omitting other levies (education, buildings, defense, etc.), the balance of taxes on transportation costs apart from business costs are thought to be fully recorded as vehicle distance and time costs. A restatement of these costs, including taxes, is shown in Table VIII-41.

Time values were estimated at NT $0.10 per bus passenger and NT $0.42 per taxi passenger. Total time values of these passengers, relative to the base alternative price paid for travel, was multiplied by the average number of passengers per bus or taxi; 35 and three respectively, or NT $3.50 per bus and NT $1.23 per taxi, on a per minute basis. The equivalent values per hour are shown, and to this was applied the tax on passenger time values per vehicle-hour, or NT $4.914 (bus) and NT $3.092 (taxi).

Passenger taxes were combined with vehicle taxes: on distance, as shown in section (1) and on time as shown in section (2) of Table VIII-41. Distance taxes ranged between 22 percent and 31 percent of total distance costs per kilometer; time taxes ranged between 8.0 percent