REPORT TO

TAIWAN HIGHWAY BUREAU
REPUBLIC OF CHINA

NORTH–SOUTH FREEWAY
KEELUNG TO KAOHSIUNG

AUGUST 1970

VOLUME I of 2

DE LEUW, CATHER INTERNATIONAL • Consulting Engineers • Chicago

REPORT TO

TAIWAN HIGHWAY BUREAU

REPUBLIC OF CHINA

NORTH–SOUTH FREEWAY

KEELUNG TO KAOHSIUNG

AUGUST 1970

VOLUME I of 2

DE LEUW, CATHER INTERNATIONAL • Consulting Engineers • Chicago

DE LEUW, CATHER INTERNATIONAL
INCORPORATED
CONSULTING ENGINEERS
165 WEST WACKER DRIVE · CHICAGO, ILLINOIS 60601
PHONE AREA CODE 312 346-0424 · CABLE DELCAC CHICAGO
TWX 910 221 5842

OUR REF. 5040-00

August 21, 1970

Mr. Hsi-Yu Lee, Director
Taiwan Highway Bureau
Taipei, Taiwan

Dear Director Lee:

You will find herewith the feasibility report on the North-South Freeway project prepared under the terms of a contract with the Taiwan Highway Bureau dated January 16, 1969.

The report incorporates the corrections and additions to the preliminary draft report which was distributed for review to various government agencies, including the Taiwan Highway Bureau, the Council for International Economic Cooperation and Development, and the Asian Development Bank. The comments and suggestions of the officers and staff members of these organizations were deeply appreciated. The Consultant, however, assumes full responsibility for the accuracy of the findings and the professional integrity of the recommendations contained herein.

Our engineering studies and economic analyses indicate that the proposed freeway from Keelung to Kaohsiung would be an economically feasible project. We recommend construction of the North-South Freeway, therefore, as scheduled in this report.

Our financial analyses indicate that this highway should be operated as a toll-free facility. Foreign exchange components would represent approximately 42 percent of construction costs, and would be almost fully covered by savings in foreign exchange.

The assistance and cooperation extended by Mr. M. H. Hu, Chief Engineer, and other members of the Taiwan Highway Bureau, throughout the course of this study is gratefully acknowledged. The officials and staff of this agency as well as of the many other government and private institutions contacted during the data compilation phase cooperated fully and furnished valuable assistance.

Specific contributions of the following men were also particularly helpful: Mr. A. L. Anderson of the CIECD Engineering Consulting Group, who made his extensive highway experience and knowledge of Taiwan's transportation problems available to the Consultant, and Mr. N. N. Baily, Advisor to the Taiwan Railway Administration, who helped in development of the "Railroad Model" used in the economic studies.

Thank you for the opportunity to serve you on this important project.

Sincerely,

DE LEUW, CATHER INTERNATIONAL

J. E. Linden,
President

TABLE OF CONTENTS

LIST OF EXHIBITS

LIST OF GRAPHS

APPENDIX

GLOSSARY OF TERMS

Chi - Creek

Chia - Strait or Gorge

Chung - Central

Ho - River

Hsien - Administrative District

Pei - North

Nan - South

Tung - East

Si - West

Shan - Mountain

Shih - Municipality

Shui - Stream

ABBREVIATIONS

AADT - Annual Average Daily Traffic

AASHO - American Association of State Highway Officials

ADB - Asian Development Bank

ADT - Average Daily Traffic

CAA - Civil Aeronautics Agency

CAL - China Airlines

CECG - CIECD Engineering Consulting Group

CIECD - Council for International Economic Cooperation and Development

CPC - Chinese Petroleum Corporation

CTC - Central Trust China

DHV - Design Hourly Volume

GNP - Gross National Product

IBRD - International Bank for Reconstruction and Development (World Bank)

O-D - Origin-Destination

THB - Taiwan Highway Bureau

TRA - Taiwan Railway Administration

UHDC - Urban and Housing Development Committee chapter I

INTRODUCTION

INTRODUCTION

HISTORICAL DEVELOPMENT OF THE FREEWAY PROJECT

A north-south freeway to serve the western coastal area of the Province of Taiwan was first considered by the Government of the Republic of China in 1965. The Government had previously studied a four-lane highway from Taipei to Taoyuan. In 1965, however, the Council for International Economic Cooperation and Development (CIECD) suggested that planning be initiated for a limited-access highway from Keelung on the northern coast to Kaohsiung on the southwestern coast--a distance of approximately 400 kilometers by existing roads. The proposed freeway would supplement or replace an existing arterial road, the North-South Highway, serving much of this corridor.

In August 1966, the Government assigned priority status to the planning of two sections of the freeway--from Taipei to Hsinchu, and from Tainan to Kaohsiung--and authorized the collection of data on traffic in the freeway corridor. By November 1966, it had been agreed by all Government agencies involved that the freeway should be an all-new facility, physically and financially independent of the existing North-South Highway.

The feasibility of the project was reviewed by various Government departments and funding agencies in April 1967. Preliminary terms of reference were prepared for discussion with consultants. In May 1968, the Asian Development Bank (ADB) sent a team to Taiwan to discuss a comprehensive feasibility study for the freeway project. New terms of reference and a general agreement on loan conditions for consulting engineering services were finalized in August 1968. A Technical Assistance Agreement between the Taiwan Highway Bureau (THB) and the Asian Development Bank was signed on November 30, 1968. On January 16, 1969, the THB retained De Leuw, Cather International Inc., Consulting Engineers, to conduct a feasibility study of the entire proposed North-South Freeway, and to prepare preliminary designs and cost estimates for Section II, the Erhchung-Chungli portion. Mobilization of the Consultant's project staff began immediately, and the initial group arrived in Taipei on March 3, 1969.

SCOPE OF THE STUDY

The Terms of Reference for the North-South Freeway Project stipulated that De Leuw, Cather International Inc. was to prepare a feasibility study of a proposed freeway through the western plain of Taiwan, between Keelung Harbor in the north and Kaohsiung Harbor in the south. The terms specifically defined a western study corridor made up of sections as follows:

Section 1	Keelung to Erhchung	35 km.
Section 2	Erhchung to Chungli	34 km.
Section 3	Chungli to Hsinshih	260 km.
Section 4	Hsinshih to Fengshan	70 km.

Under the terms of reference, De Leuw, Cather International was to perform the following services:

1. Transportation Economics and Traffic Studies

   Review all relevant existing data and statistics and make any additional traffic counts and origin-destination studies required to determine the nature of traffic and present volume of freight and passenger movements.

   Analyze traffic flows on the railway lines serving the same area as the freeway, and on coastal shipping along the west coast.

   Determine the economic cost, per ton-kilometer, for the various commodities or groups of commodities and per passenger-kilometer on each of the three modes of transport, to help in estimating the most appropriate division of traffic between the various modes of transport. This part of the study was to be carried out in close collaboration with the Taiwan Railway Administration which had made similar studies.

   Identify and describe existing and potential traffic generating sources for both the existing North-South Arterial Highway and the proposed freeway, and estimate future traffic resulting from:

   a. Population growth and changes in rural and urban population distribution;

   b. National and regional economic growth resulting from development of agriculture, forestry, mineral resources and industry;

   c. Anticipated foreign and domestic trade in principal commodities;

   d. Expansion of tourism; and

   e. Other considerations, including users' preference.

   Examine alternative routes of the freeway, with a view to maximizing benefits and service to the area traversed. Approximate locations of interchanges were to be determined, and principal design features of the freeway were to be defined.

   Determine at what date various sections of an improved North-South Arterial Highway would likely become congested, recommend the most economic way of meeting traffic needs, and determine if the freeway should be built.

2. Economic Analyses and Engineering Studies of the Freeway

   Analyze present vehicle operating costs, with and without taxes, for representative types of motor vehicles on existing roads, and estimate future costs of vehicle operation:

   a. On roads to be relieved by the new facility; and

   b. On the proposed freeway.

   For the entire project and also for each section, prepare an economic analysis of the proposed investment including:

   a. Estimated reduction in vehicle operating costs (excluding taxes) that would result from the proposed improvements, for specific types of vehicles;

   b. Estimated value of other time savings including that of bus and automobile passengers;

   c. Estimated future highway maintenance costs;

   d. Estimated effect of the freeway on tax receipts from road users; and

   e. Evaluation of quantifiable economic benefits and costs, based on the anticipated economic life of the freeway, and determination of the rate of return on the investment, calculated by discounting future costs and benefits to present value.

   Make an engineering study and develop cost estimates:

   a. In line with THB standards, assign suitable design standards for the freeway (including access and service roads) such as design speeds, roadway and pavement widths, pavement types, horizontal and vertical alignments, sight distances, design loads, and structure clearances;

   b. Prepare preliminary estimates of construction cost based on estimated quantities of principal work items (within 20 percent and with approximate foreign exchange component) and applicable current unit prices; and

   c. Estimate the cost of land to be acquired for the freeway and access roads.

3. Investigation of Toll or Non-Toll Facility

   Based on analyses of traffic forecasts, probable diversion of traffic, route studies, spacing of interchanges, preliminary cost estimates, and other relevant factors, recommend whether the proposed freeway or any section should be operated as a toll facility. The effects on distribution of traffic between the freeway and existing roads, the benefits to road users, and maintenance costs for both the existing North-South Highway and the freeway were to be clearly indicated for each alternative.

   If toll operation were recommended, cost of toll collection facilities was to be included in the estimated cost of the project. Estimates were also to be prepared of revenues and expenses, return on net fixed assets, and other relevant financial information. Revenues were to be estimated on the basis of toll rates recommended by the Consultant.

   In case a toll-free facility was recommended, the Consultant was to assess the effect present or revised road user charges, rail tariff structure, and coastal shipping rates would have on the distribution of traffic between the various transport modes.

The THB provided necessary staff to carry out all traffic surveys, transportation analyses, and economic analyses. It also made available all existing economic and engineering data relevant to the study.

PROCEDURES AND METHODS

Reference statistics compiled by the THB in preparation for the feasibility study were furnished to the Consultant's staff upon arrival. In addition to these data, other information was obtained through interviews with Bureau personnel. This included operating and financial statistics of the Bureau, THB bus operating cost and revenue data, historic records, and information concerning regulatory and pricing policies affecting buses and long-distance truck services. Vehicle operating cost data, in addition to that provided by THB, were obtained by interviewing the truck, bus, and taxi companies. Economic statistics on national affairs such as exports, imports, finance, production, employment, and population were undertaken with other government agencies and with the rail, harbor, and air service administrators.

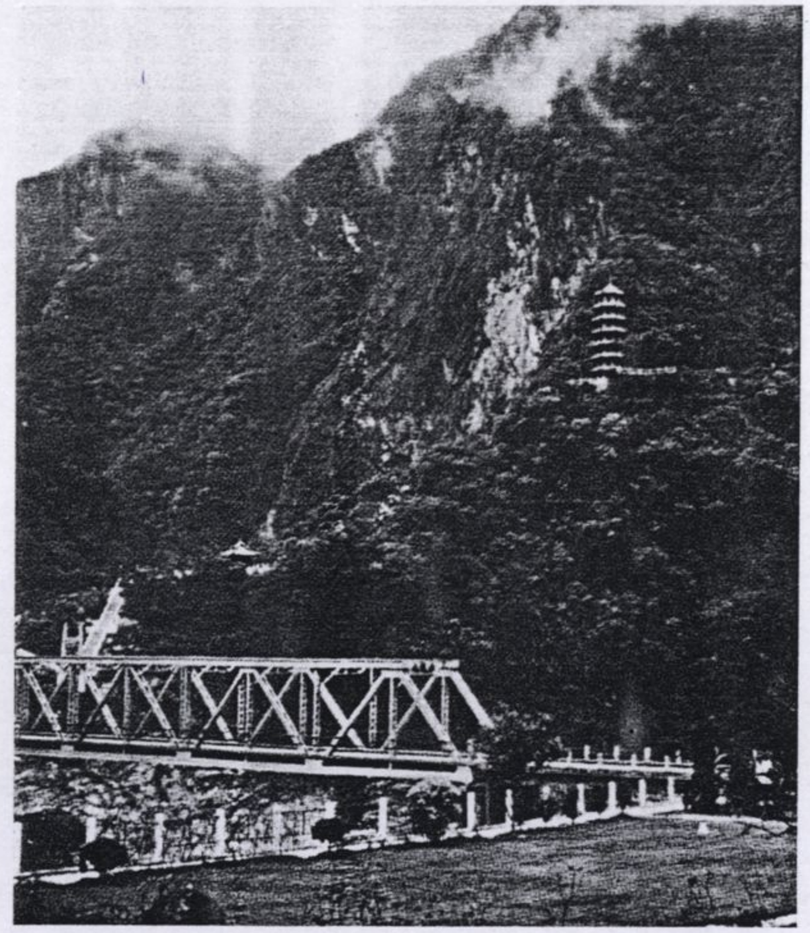
Methods

In general, analyses were made on the basis of conditions with and without the freeway as part of the future overall transportation network. Certain improvements to existing north-south highways were assumed under both alternatives in forecasting traffic volumes in the project corridor. The condition defined as "assumed highway improvements without freeway" postulated minimum improvements to accommodate future traffic volumes without upgrading operating conditions. Capacity used for this purpose corresponded to Level of Service E, as defined in the Highway Capacity Manual published by the Highway Research Board of the National Academy of Sciences-National Research Council (USA). Level of Service E, which is next to the lowest level classified in the Capacity Manual, represents operations with volumes at or near the capacity of the highway to which it refers. Speeds are typically in the neighborhood of 50 kilometers per hour. Flow is unstable, and there may be momentary stoppages.

Economic growth, future traffic volumes, and the value of the freeway to users were all estimated conservatively. Some anticipated benefits, although they might be substantial, were not evaluated since detailed statistical data for proper analysis were not available. One of these unquantified benefits was savings resulting from accident reduction. Freeway costs, however, were realistically estimated. When lack of data precluded reliable estimates, the least favorable condition was assumed. For example, pavement design was based on subgrade soils having very low bearing capacity.

The freeway was not compared with the existing railway. Instead, a model for a future railway which would be more efficient and provide passenger and freight service at lower cost was developed for comparative purposes. The amount of traffic drawn from the future railway to the freeway was estimated at the minimum as were the potential benefits. In preparing trip tables for diverted passenger and freight traffic, it was necessary to know total railway passenger and freight traffic. Since statistical data were incomplete, trip tables were developed partly from available data and partly by synthesis.

Future trips were estimated by expanding the 1969 trip tables by the Fratar method[1]. Traffic volumes were later checked with the Furness method which is described in Chapter VI.



---

[1] -In the Fratar method, the distribution of future vehicle trips from Zone i is proportional to present trip distribution from Zone i, modified by the growth factor of each zone to which the trips are attracted. The volume of trips from Zone i is determined by the growth factor of Zone i. This can be written as:

$$T_{i \to j} = t_{ij} \cdot F_i \cdot F_j \frac{\sum_{K=1}^{k=n} t_{ik}}{\sum_{K=1}^{k=n} (F_k : t_{ik})}$$

Where:

$T_{i \to j}$ = future vehicle trips from Zone i to Zone j

t_{ij} = present vehicle trips between Zone i and Zone j

F_i, F_j = growth factors of Zone i and Zone j

F_k = growth factor of Zone k

t_{ik} = present vehicle trips originating in Zone i and destined for Zone k (k = 1, 2, ... n)

The 1969 trip tables were expanded and various traffic assignments to existing and future networks were made on an IBM 1130-32K computer. Traffic assignments were made by the "all or nothing" technique by which all traffic between each pair of zones is assigned to the minimum cost path. The possibility of assigning traffic to the freeway beyond its capacity was considered during the corridor capacity analysis, but full utilization of parallel highways was assumed to reduce volumes assigned to the freeway.

Taxes were deducted from both costs and benefits to find the profitability of the investment to the national economy. The cash flow system of analysis was adopted as the basic method of organizing the economic information. Both "Net Present Value" and "Internal Rate of Return" analyses were used in comparing alternatives.

Passenger time values were computed by assuming zero time value for the least expensive mode (local bus) and by computing the cost differentials between various transportation means and local bus. Consequently, comfort and convenience values were automatically considered in passenger time values.

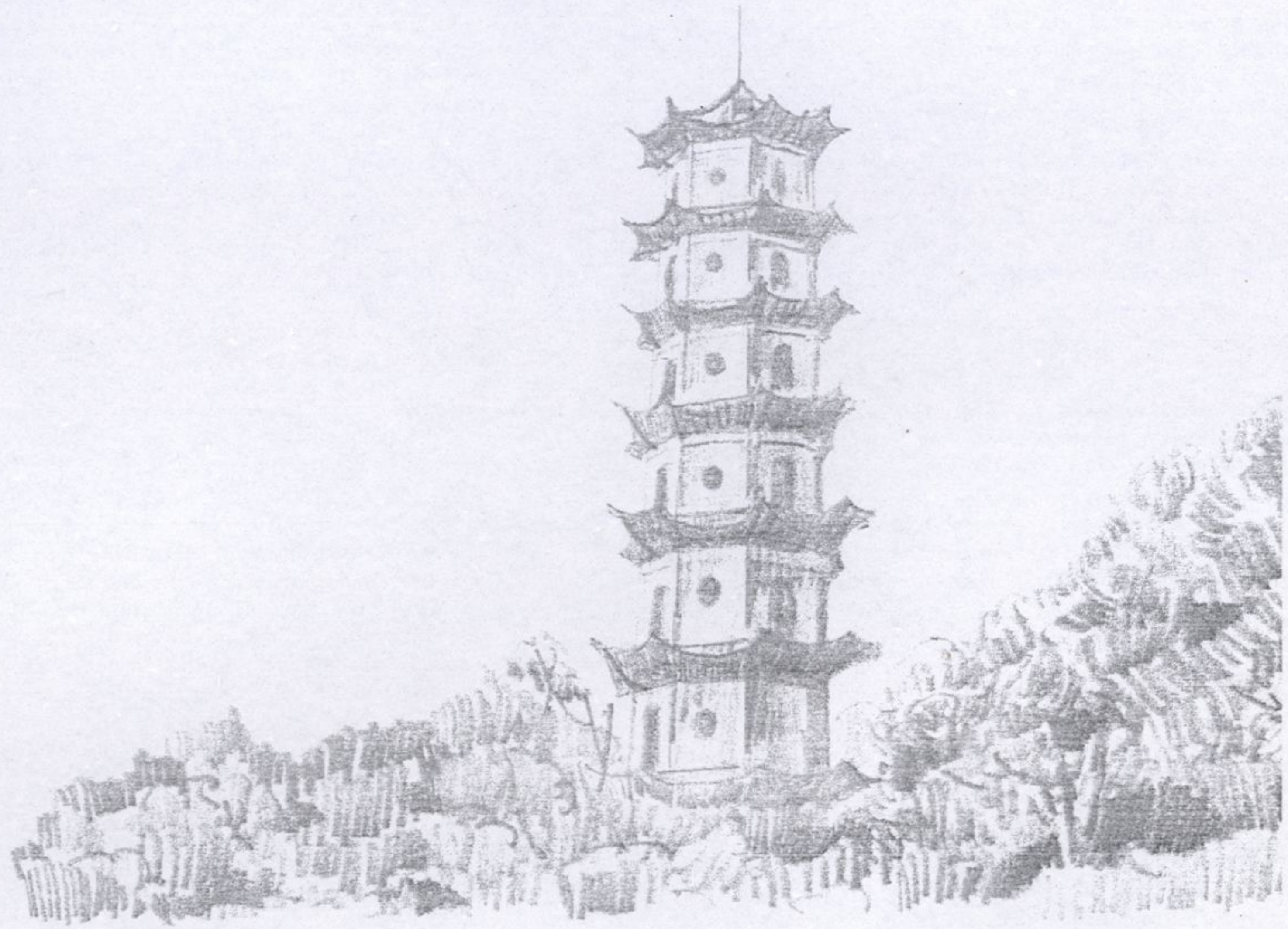
In forecasting future truck traffic, trucks of the size and type prevailing in 1969 were assumed for future years in order not to complicate the capacity analysis. In comparing future freeway and railway freight costs, however, the probable use of larger trucks was taken into account.

"Shadow" prices were not considered. There is presently no difference between the official exchange rate and the free market rate of the NT dollar. It is anticipated, furthermore, that the external economic position of the country will continue to improve. Finally, the rate of unemployment is relatively low, especially among skilled workers of the types which would be needed to build the freeway. It was assumed, therefore, that the market wage rates used to compute labor costs reflected real costs to the economy.

Priorities were established on the basis of an internal rate of return analysis. All study sections were placed on equal time duration bases, however, for estimating benefits.

A sensitivity matrix was developed to test the internal rate of return of the project by varying the critical elements in the project analysis.

All benefits and costs over the life of the project were computed in terms of 1969 values. Thus, no assumptions were made with regard to the effect of future increases in wages and prices, nor with regard to unequal price inflation.



chapter II

TAIWAN--PAST AND PRESENT

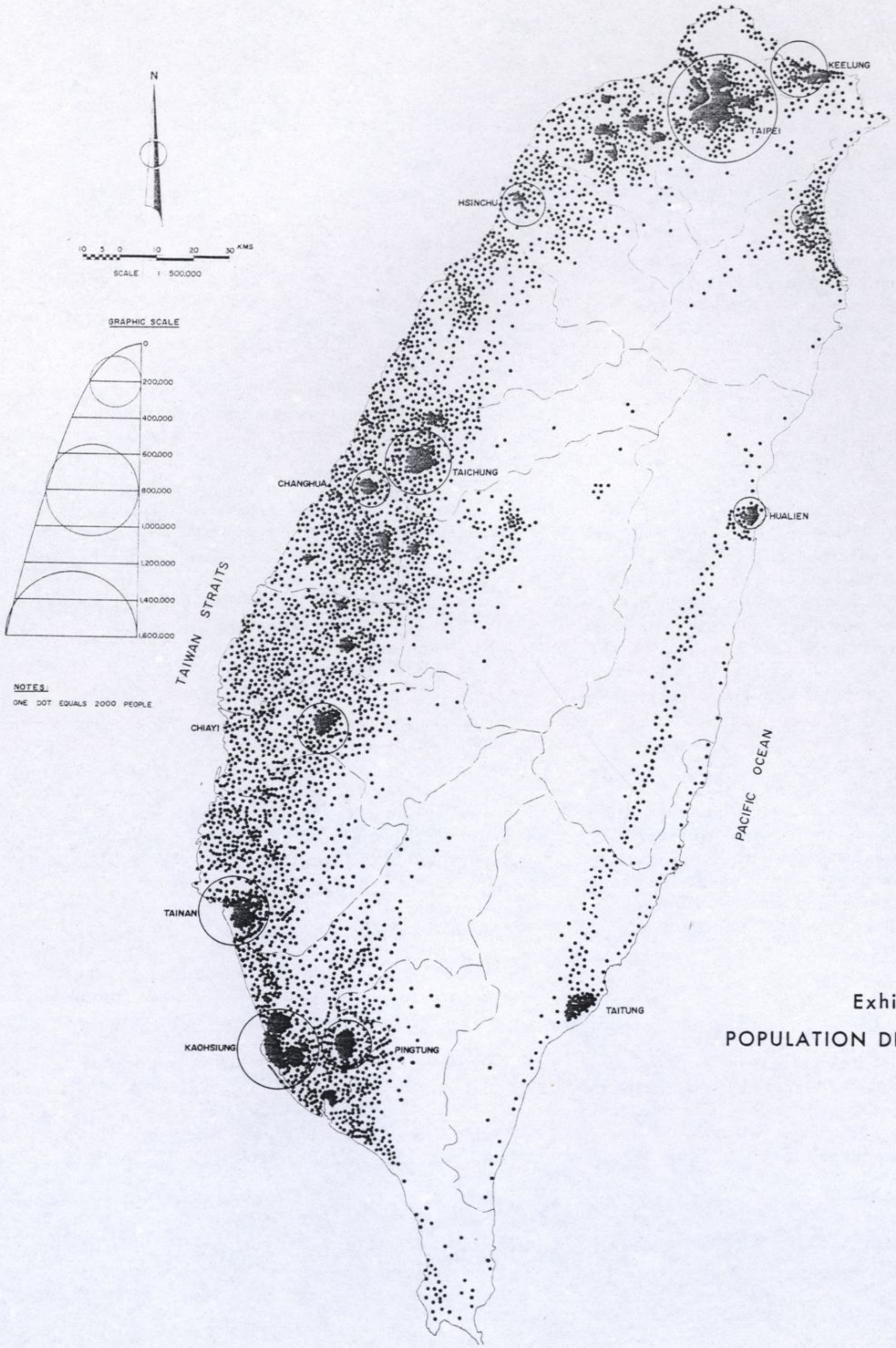


Exhibit II-1

POPULATION DISTRIBUTION 1969

TAIWAN--PAST AND PRESENT

HISTORICAL BACKGROUND

Before the impact of a major freeway project can be fully evaluated, Taiwan must be understood as a whole.

Administered by the Government of the Republic of China, Taiwan has a population of approximately 13.5 million. The Island is experiencing spectacular economic growth.

Geography

The Island of Taiwan is bounded by the Straits of Taiwan, the East China Sea, and the Pacific Ocean. It lies approximately 150 kilometers (90 miles) southeast of the coast of the China mainland, between east longitudes 120° and 122°, and north latitudes 22° and 25°. Approximately two-thirds of the Island is extremely mountainous. The remaining area is a flat, heavily populated strip of lowland running nearly the full length of the western side of the Island. The total Island area is about 14,000 square miles, the lowland area constituting about 3,500 square miles.

Approximately 80 percent of the total population of the Island lives in the western lowland area. See Exhibit II-1 for population distribution. This area has the major cities and industrial plants, the seaports, the railways and highways, the irrigation canals, and the fertile farmlands. The eastern lowlands have three smaller cities and lesser, but important, agricultural areas.

Taipei and Kaohsiung are centers of population at the two ends of the western lowlands. Most of the Island's people live along the axis between these two cities. Since the major economic activities of the Island take place along this axis, the patterns of communication are also oriented to it.

Population

The population of Taiwan is slightly over 13.5 million excluding inhabitants of the Pescadores and other off-shore islands under the jurisdiction of the Province of Taiwan. Of the total, about 11 million live in the western lowlands where the average density is estimated to be about 3,500 persons per square mile.

The population consists predominantly of Taiwanese people. These are the descendents of Chinese who migrated from the mainland of China during the last 300 years. The next largest segment is composed of approximately 1.5 million mainland Chinese who migrated to Taiwan in the late 1940's because of political unrest on the mainland. A small, but ethnically interesting, segment of the population is made up of an estimated 150,000 aborigines. These people appear to be of Polynesian ancestry, their first appearance on Taiwan predating the arrival of all other peoples.

Political History

The political history of Taiwan is a story of invasion by migrants. The Island was occupied long before recorded history by Polynesian migrants--today's aborigines. Small numbers of Chinese came from the mainland as far back as the sixth century, but the most important migration occurred during the early 17th century when many Chinese farmers and merchants migrated to the Island from the crowded southeast coast of the mainland.

In 1624, the Dutch established a base on Taiwan which they held for 37 years, but they did not colonize the Island or establish any kind of Island-wide government. In the late 17th century, the Manchus of the mainland conquered the Island and controlled it for the next 200 years. Some commerce with western traders developed during this period. It was the Portuguese who named the Island "Formosa", the Beautiful Island.

In 1895, after the Sino-Japanese war, the Island was ceded to Japan. The Japanese occupied and governed the Island until the end of World War II in 1945. Taiwan was then returned to the Republic of China, under which it has developed rapidly.

Taiwan is the largest body of land presently under the control of the Republic of China. The seat of the Nationalist Chinese Government was moved from the mainland to Taiwan on December 8, 1949. The democratic form of government established under Dr. Sun Yat Sen in 1911 still prevails. Although the mainland is presently controlled by a communistic regime, the Republic of China provides for representation for each of the mainland provinces of China in its government, and Taiwan is one of the mainland provinces. The capital of the Republic of China is the city of Taipei.

ECONOMY OF TAIWAN

Despite a lack of known mineral resources, Taiwan's rich agricultural resources and competent labor force have enabled the economy to advance rapidly for many years. The rich soil and abundant rainfall, together with the agricultural expertise of the Chinese, have enabled Taiwan to become a net exporter of foodstuffs. Although the country's agricultural production has been growing, it has been declining proportionately since the industrial and services sectors have been growing more rapidly. Economic growth has been accelerating in recent years. Coupled with a declining rate of population growth, this has meant an accelerating rise in per capita income.

Growth of the Taiwan Economy

The government of the Republic of China launched the first in a series of four-year development plans in 1953. The Fourth Four-year period ended in 1968, and the Fifth Four-year period began in 1969. These plans, although ambitious, have generally underestimated growth during the period they covered, and most planning goals have been surpassed.

The average annual real growth over the 16 years of the first four plans, i.e., 1953-1968, was 8.6 percent; the growth over the first half of the period averaged 7.2 percent per annum, while the average 1961-1968 growth was 10.0 percent per annum. The slowest real growth in any year was 4.7 percent in 1956, while the greatest annual rise was 13.5 percent in 1964, which was followed by a 12.4 percent expansion in 1965. The 1968 rise was 10.3 percent, the Gross National Product (GNP) amounting to approximately NT $166.2 billion (US $4.15 billion).

Economic expansion during the first half of 1969 continued at a high rate, with GNP growing at an annual rate of nearly ten percent.

Per capita income rose at an average rate of 4.6 percent per annum over the entire 1953-1968 period, and at a higher annual rate (6.4 percent) over the second half of the period. Using the population estimate arrived at by this study (13,644,000 in 1968), the per capita income was calculated to be approximately NT $9,740 (US $244).

The acceleration of economic growth in the last several years has been due largely to the expanding portion of GNP directed to fixed capital formation. This investment averaged about 12 percent over the 1953-1955 period, climbed to an average of around 15 percent during the 1960-1962 period, and, in the past three years (1966 to 1968) has increased from 18.6 percent to 21.8 percent.

Despite the extended period of rapid economic growth in Taiwan, inflation has not become a serious problem. Wholesale prices have not risen by as much as three percent in any one year since 1963; in 1965, prices actually fell by over four percent, and in subsequent years, the rises have been by only 1.5, 2.5 and 2.0 percent. The total rise, over 1964-1968, amounts to only about two percent.

The Agriculture of Taiwan

Major crops in Taiwan include rice, sugar cane, fruits, vegetables, sweet potatoes, wheat, soybeans, and peanuts. Of these, rice is by far the most important.

In 1968 more than 2.5 million metric tons of rice were produced in Taiwan, with a value of NT$ 14,105 million (US $353 million). Values of other principal agricultural commodities in 1968 were as follows: sweet potatoes - NT $2,890 million; bananas - NT $1,825 million;

sugar - NT $1,703 million; peanuts - NT $803 million; citrus fruits - NT $673 million; and pineapples - NT $398 million.

The real growth in agricultural production in Taiwan over the period of the first four development plans (1953-1968), averaged 5.2 percent per annum while in 1968, the expansion was 6.1 percent. The most rapid growth in the agricultural sector has been in the fisheries industry, which experienced an average annual rise in production of 9.1 percent over the 1953-1968 period, and expanded by an astonishing 20.4 percent in 1968. The average annual increases in production of other industries within the agricultural sector over the 1953-1968 period were: 7.2 percent for livestock, 5.8 percent for forestry, and 4.5 percent for crop production. After impressive rises of 11.0 percent and 13.9 percent in 1966 and 1967, respectively, the production of livestock slowed to a rise of 5.7 percent in 1968. The growth in food crops in 1968 was 4.9 percent, up from 4.1 percent the previous year, and the growth in forest products was 5.0 percent, which was the greatest annual rise since 1964.

The productivity of labor in the agricultural sector has increased steadily (except for small declines in 1959 and 1963). While production was more than doubling during the 1952-1966 period, agricultural employment rose by only about 14.4 percent; productivity per worker rose by 75.8 percent. In the years 1964, 1965, and 1966 (complete employment figures for the agricultural sector are not available for later years), labor productivity rose by 10.5, 7.1, and 3.6 percent, respectively.

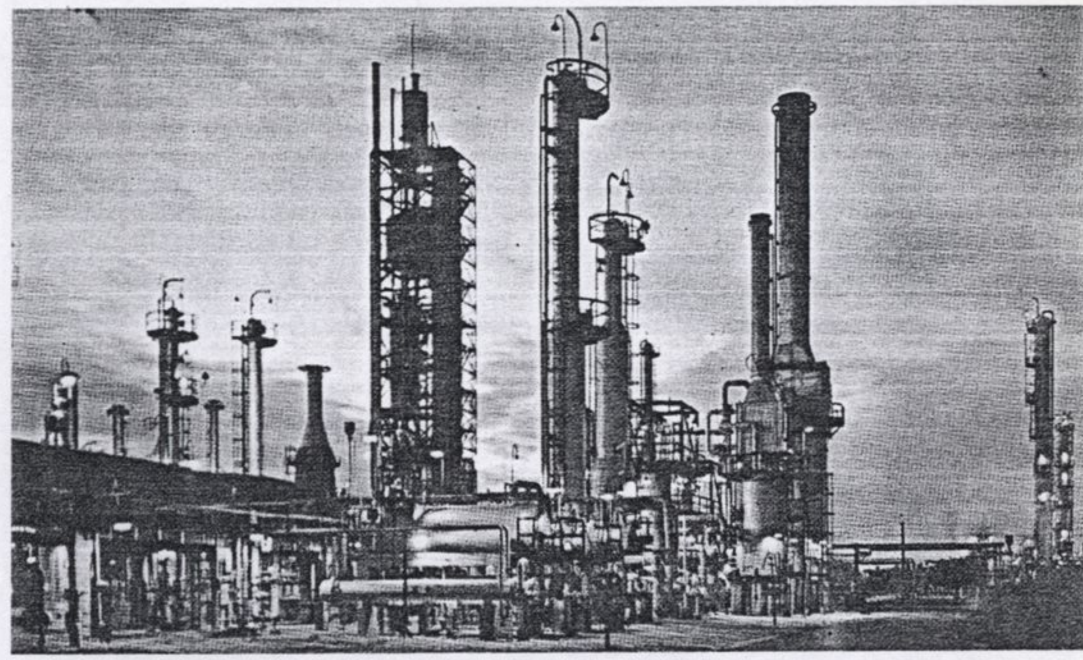
Not only have the Chinese been successful agriculturalists in their own country, but several years ago they embarked on a program of extending agricultural technical assistance to other countries. The program began with aid to Vietnam in 1959 (which has continued to the present), and has expanded to include 20 countries of Africa as well as Saudi Arabia, the Philippines, the Dominican Republic, Brazil, and Chile. There are additional missions classified as "non-agricultural" which nevertheless include technical aid to this sector. Among these are a fishery mission in Cameroun, an irrigation engineering team in Libya, a mushroom planting mission in Malta, and a grain silo project in Singapore.

The Industrial Sector

While Taiwan's agricultural resources are great, the Island's resources to support the industrial sector are rather meager. Until recently, when domestic production of crude petroleum and natural gas assumed significant proportions, the only important mineral resources were coal, marble, dolomite, and sulphur. Of these four, marble is by far the most abundant, with an estimated reserve of approximately three billion tons. There are workable reserves of around 245 million tons of coal, over two million tons of sulphur, and nearly 120 million tons of dolomite.

Taiwan's coal has been important for thermal power production in the northern and central portions of the Island; the dolomite (used in cement making) and the marble have been used extensively to support the construction industry; and the sulphur has aided an increasingly important fertilizer industry. Taiwan still imports most of the crude oil needed to meet its requirements.

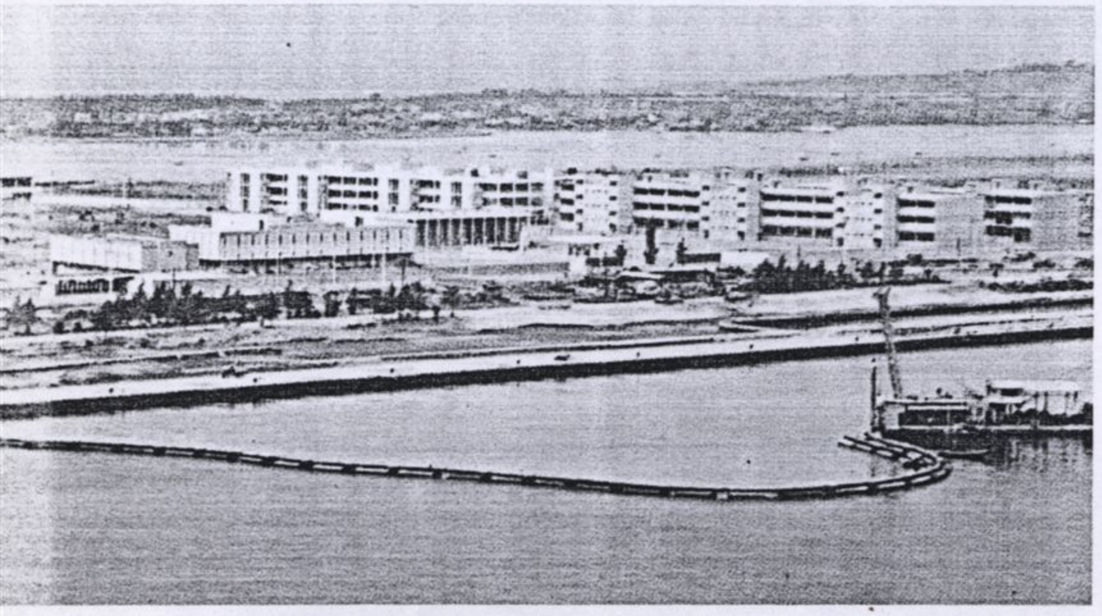
Taiwan has a dearth of metal ores. Only small amounts of gold, silver, copper, iron ore, and manganese have been found. This scarcity of ores not only has retarded the growth of a metals industry, but has also slowed the growth of other heavy industries.



Petroleum and Petrochemicals

Realizing that the outlook for heavy industry in Taiwan was unfavorable, the Chinese Government has concentrated industrial development efforts on light industry. This governmental decision has paid off handsomely, and has been largely responsible for the very high rate of growth of the industrial sector. Over the 1953-1968 period, industrial production expanded by an average annual rate of 13.9 percent, with manufacturing growing at a 14.8 percent per annum average rate, utilities growing by 11.4 percent per annum, and mining output expanding by an average of 6.0 percent. The rate of growth of manufacturing increased in the later years of the period, however, and showed over the 1964-1968 period annual rises of 21.3, 19.6, 16.4, 17.9, and 23.3 percent. The growth of utilities ranged from 9.7 percent in 1965 to 17.2 percent in 1968. Growth in mining output, however, has slowed considerably, being less than four percent in every year since 1964--production in 1968 actually declining by 0.2 percent.

Industrial productivity increased 222 percent over the 1952-1966 period, as output expanded by nearly six times while employment increased only about 75 percent. The productivity rises in 1964 and 1965 were especially marked, being 15.6 percent and 16.2 percent, respectively; the rise in 1966, the last year for which employment figures are complete, was 9.2 percent.



Kaohsiung Export Processing Zone

Kaohsiung Export Processing Zone - Assembly Line for Electronic components

Over the period of the first four development plans, 1953-1968, the output of electric power expanded sevenfold, coal output more than doubled, the production of wheat flour grew by approximately 20 times, the refining of crude oil grew more than twelvefold, and paper, fertilizer and cement production each expanded by around eight to nine times. A few items which were produced only in very small quantities prior to 1953 showed even more spectacular growth. The production of steel bars, for example, expanded by around 25 times; the production of "general" machinery grew by nearly 30 times; and tonnage production of ships expanded well over a hundredfold.

Exports and Imports

As rapidly as Taiwan's production has been advancing, its pace has not been as rapid as the growth in China's foreign trade. Over the 1960-1968 period, Taiwan's imports grew fourfold, or by an average annual growth rate of around 19 percent; exports rose even faster, expanding by more than 4.8 times, for an average rate of nearly 22 percent per annum. In 1968, imports expanded 21.0 percent, and exports climbed 24.7 percent.

The composition of exports has changed markedly over the period of the development plans. In 1952, industrial products made up only 4.8 percent of total exports, while agricultural products comprised the remainder. Unprocessed agricultural goods represented 26.9 percent of total exports, while processed agricultural products represented 68.3 percent. In 1968 industrial products accounted for 66.4 percent of total exports, agricultural products declining to only 33.6 percent, of which 13.0 percentage points were of unprocessed commodities while 20.6 percentage points represented processed agricultural products. Over this same period, two commodities, sugar and rice, declined from 77.7 percent of total exports to only 7.7 percent.

In 1968, of a total export value of nearly US $842 million, the principal product categories, in order of total values, were as follows: textiles--US $183 million; metals and machinery--US $146 million; bananas--US $57 million; plywood--US $55 million; sugar--US $51 million; lumber and timber--US $36 million; canned asparagus--US $33 million; canned mushrooms--US $31 million; chemicals--US $25 million; canned pineapple--US $19 million; and cement--US $16 million.

The composition of imports has also undergone substantial change although the change has not been as drastic as that for exports. In 1952, capital goods imports represented only 13.1 percent of the total, but their share climbed to 35.2 percent in 1968. Actually this share of the total represented a slight decline from a high of 37.6 percent in 1967. Raw materials, both agricultural and industrial, fell from 74.2 percent of the total in 1952 to 57.4 percent of all imports in 1968. Consumer goods represented a small portion of the total in both years; in spite of the fact that they nearly tripled in value over the period, consumer goods declined from 12.7 percent of total imports in 1952 to only 7.4 percent of imports in 1968.

The principal commodity categories in 1968, in order of their total values, were as follows: machinery and tools--US $136 million; vehicles, vessels, and parts--US $129 million; electrical materials--US $118 million; ores, metals, and products--US $115 million; chemicals--US $96 million; wheat and other cereals--US $61 million; raw cotton--US $48 million; beans and peas--US $45 million; and crude and fuel oil--US $42 million. The total value was US $1,026 million.

Taiwan's trade deficit in 1968 was US $184 million (US $74 million if imports are valued f.o.b.). This represented Taiwan's fourth consecutive annual trade deficit, and the ninth in the last ten years. The outlook in 1969, however, seems to have improved, as exports and imports in the first six months were nearly in balance.

The External Economic Position of Taiwan

Despite Taiwan's recurrent trade deficits and the resultant deficits on current account, the country's external position has remained generally satisfactory. While Taiwan sustained a current account deficit in nine years, over the 1959-1968 decade, the capital account surplus was sufficient in five of those nine years to offset the deficits on current account, and to permit Taiwan to realize net surpluses in its overall balance of payments. Taiwan had a cumulative balance of payments surplus over the ten-year period of approximately US $260 million. At the end of the period, Taiwan held official foreign exchange reserves of approximately US $380 million.

The most important factor, accounting for the recurrent surpluses on capital account, has been the official grant and loan funds from the United States although in the most recent years, 1966-1968, the total of private transfer payments, direct investment, and net private loan capital has become more important than the official capital inflow from the United States. Over the 1959-1968 period, a total of US $434 million in grants were made available to Taiwan, and a gross total of US $278 million in loan funds.

Taiwan's official US dollar debt at the end of 1968 was about US $338.5 million, of which about US $233.5 million was owed to the United States Government; the remaining US $105 million was owed to Japan (US $58.4 million) and the World Bank Group (US $46.6 million). The World Bank has indicated that service on this debt is equivalent to only about six percent of current account receipts, and that debt service is expected to rise to a level of around ten percent of current receipts by the mid 1970's.

The Growth of Tourism

One of Taiwan's greatest resources is its natural beauty. It should not be surprising to anyone who has traveled Taiwan's eastern coastal highway, journeyed through the Island's Taroko gorge, or sojourned at the country's Sun-Moon Lake, that the number of foreign visitors to the Island has been rising rapidly. So rapid has the rise been, in fact, that the growth rate even surpasses the rate of expansion of foreign trade.

In 1956, the number of visitors to Taiwan totaled slightly fewer than 15,000. In the 12 succeeding years, the number of visitors grew more than twentyfold, for an average annual expansion of 29.9 percent over the 1956-1968 period. As with production and foreign trade, the average growth rate has accelerated in the past few years. Over the 1962-1968 period the average rise in the number of visitors to Taiwan was 34.1 percent per annum. The rate of increase did slow in 1968, however, to 19.2 percent.

The total number of visitors in 1968 was 301,770, excluding about 50,000 American servicemen. The most important source of tourism for many years was the United States, but in 1967 the number of American visitors was slightly exceeded by those from Japan. In 1968, Japanese tourists totaled more than 103,000 while American visitors numbered approximately 76,000. The only other main group of visitors are overseas Chinese; these numbered about 51,000 in 1968.

The estimated foreign exchange earnings from tourism in 1967 (the 1968 total has not yet been published) were equivalent to US $52.3 million. This was up substantially from US $20.1 million in 1966, and only US $14.7 million in 1965.

TRANSPORTATION SYSTEMS

The major segment of Taiwan's transportation system extends along the western side of the Island between the Island's two major ports, Keelung and Kaohsiung. The most important transport mode, historically, has been the railway, although highway transport has been steadily gaining in importance relative to rail. Whereas a decade ago the railway accounted for 55 percent of land intercity passenger-kilometers and nearly nine-tenths of land freight service ton-kilometers, by 1968 the railway's respective shares had declined to 47 and 73 percent. Neither shipping nor air transport have been important for the movement of domestic passengers or cargoes, but shipping has been of great value to the Island due to the important role of foreign trade in fostering economic expansion, and air transport is of growing importance because of the rapid growth of foreign tourism in the country.

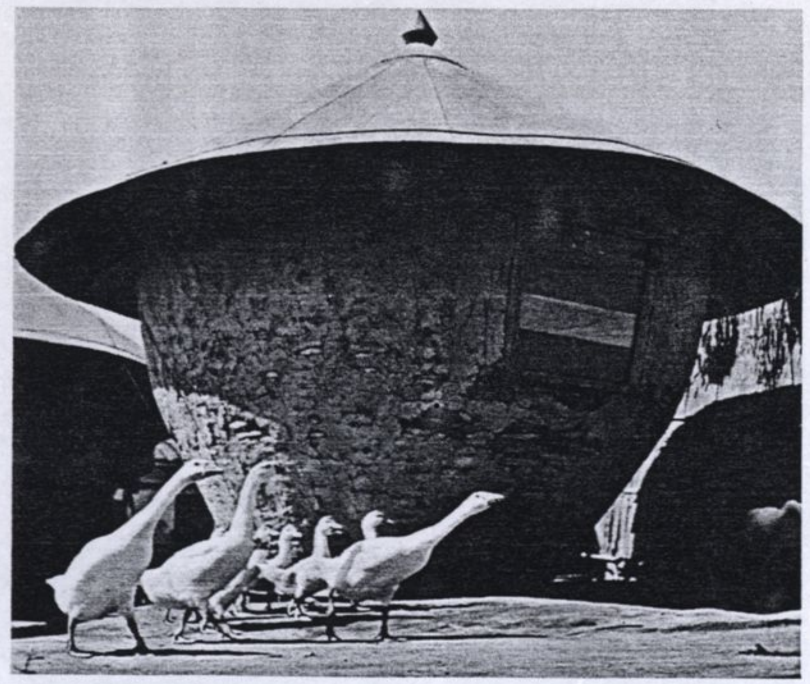
Later chapters provide a cost analysis of the present transportation system, discuss planned improvements in the system, and analyze past and probable future growth of transportation in the country. The following discussion describes existing facilities and indicates the adequacy of those facilities for present and future traffic volumes.

Highway System

As of October 1969, Taiwan had a total of 15,461 kilometers of highways excluding city streets and village roads. Of this total, 5,343 kilometers were paved, while the balance--about two-thirds of the total--were gravel roads. These highways are classified for administrative purposes into four categories, as follows: provincial roads (2,342 kilometers); hsien roads (2,724 kilometers); rural, or town and village highways (10,061 kilometers); and exclusive highways (334 kilometers).

The primary highway network is classified on a basis of location into five systems as follows: the Round-Island System; the Cross-Island Highway System; the Inland Arterial Highway System; the Coastal Highway System and the Connecting Roads System. These systems are shown in Exhibit IV-2. The Round-Island Highway System includes the North-South Arterial, which roughly parallels the proposed freeway route from Taipei to Fengshan, and then continues southward to Oluanpi, for a total length of 501 kilometers. The only other highway in the Round-Island System is the Eastern Arterial, which continues for 515 kilometers, originating at Taipei and terminating at Fengkong. Not all of this highway is paved, and some of it, in fact, is only one lane wide and can be used only in the dry season because it passes through some river beds, rather than bridging them.

The Cross-Island Highway System includes three roads: the Northern, the East-West, and the Southern Cross-Island highways, totalling 640 kilometers in length. Actually, the Southern Cross-Island Highway remains to be completed. The Inland Highway System includes three roads totalling 978 kilometers; the Coastal System includes 13 roads totalling 711 kilometers; and the Connecting Road System includes 21 roads with a total length of 497 kilometers.



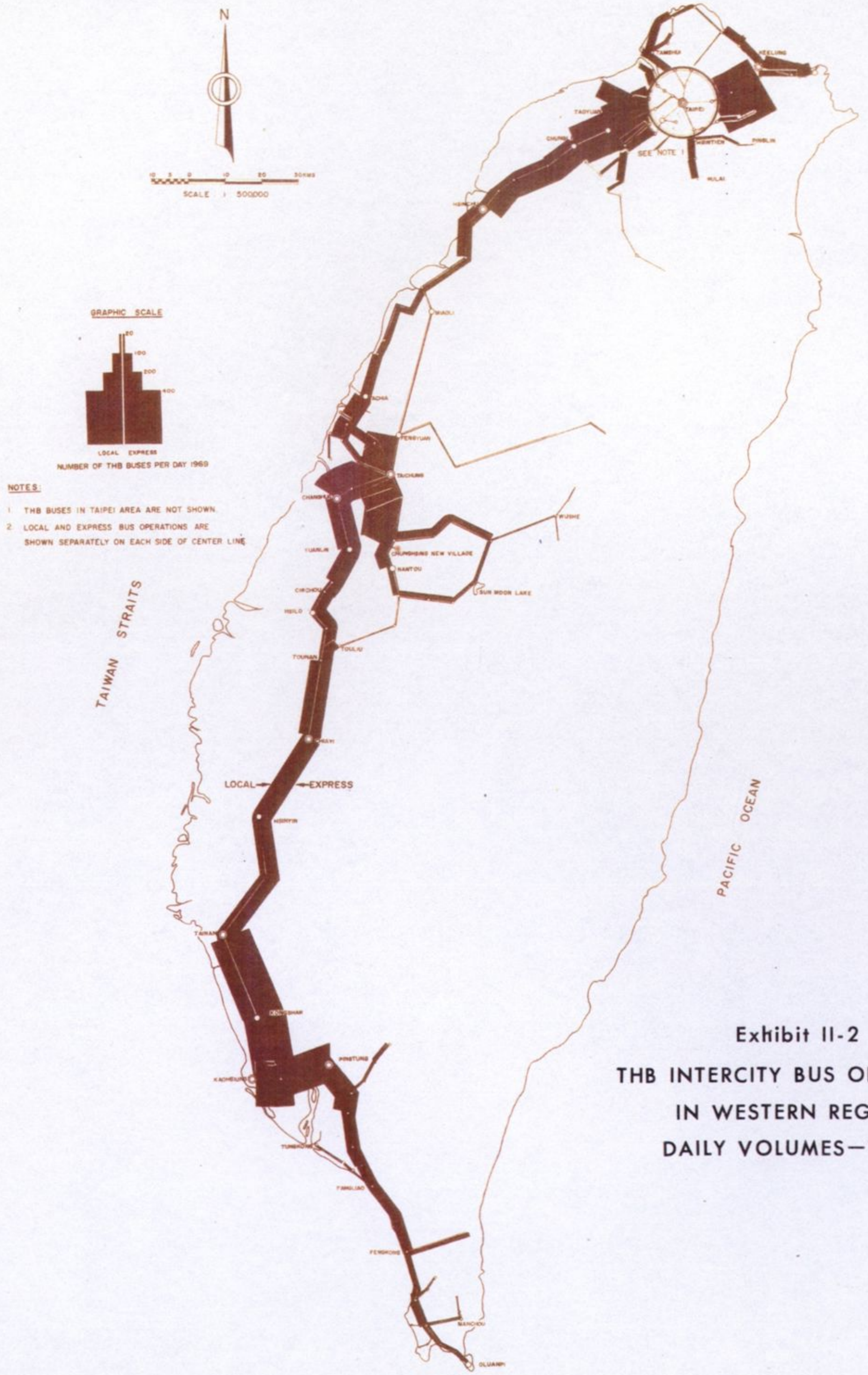


Exhibit II-2

THB INTERCITY BUS OPERATIONS IN WESTERN REGION DAILY VOLUMES—1969

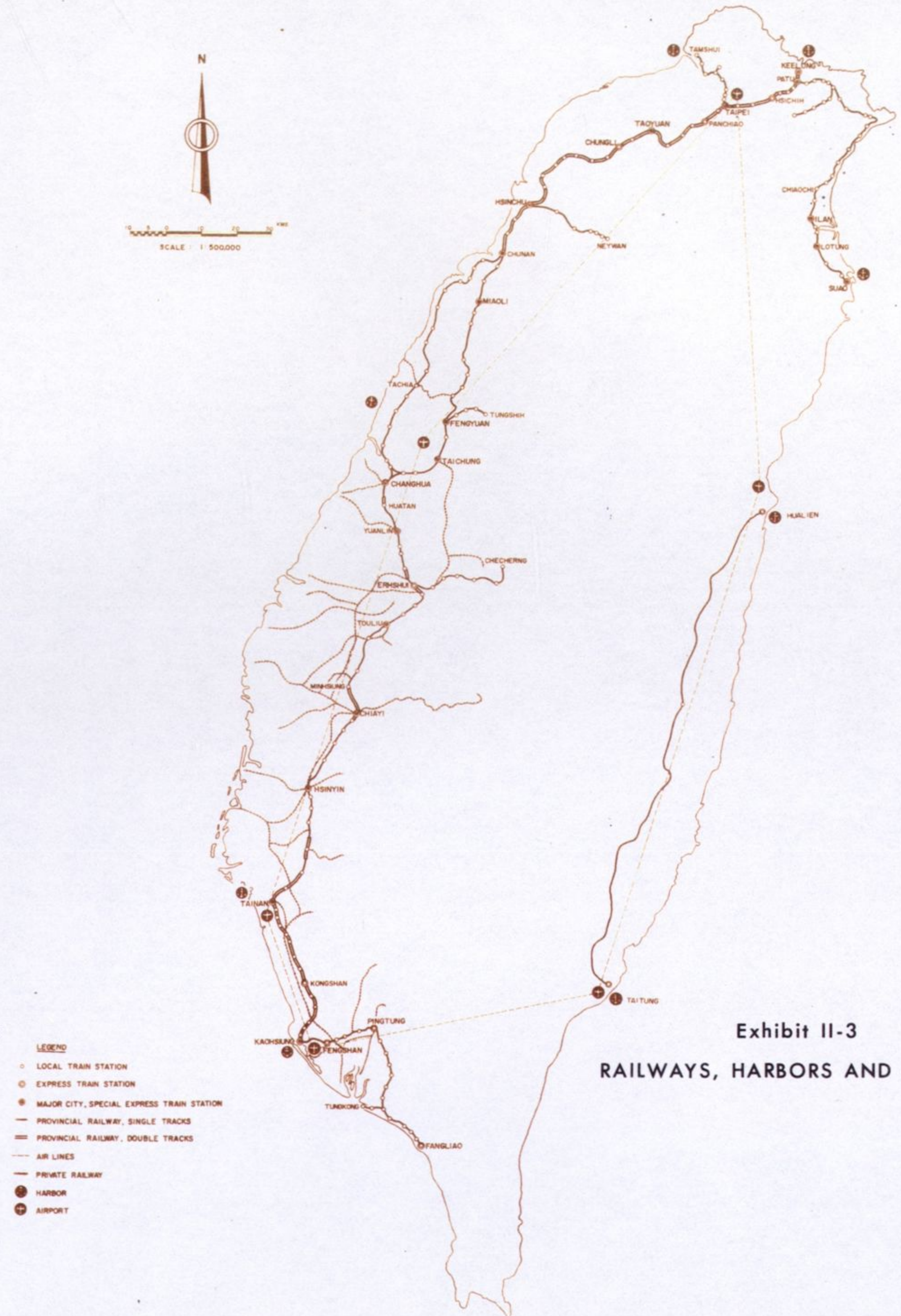


Exhibit II-3

RAILWAYS, HARBORS AND AIRPORTS

Taiwan's paved roads are well maintained and provide a good riding surface. While the road system is adequate for light traffic with few large vehicles, traffic volumes in Taiwan have increased until highways are generally congested, and speeds average only about 50 kilometers per hour. Moreover, controls over imports of road vehicles have recently been liberalized and growth of domestic production has been accelerating so that the highways are rapidly becoming even more congested. Finally, the highways are woefully inadequate to handle large vehicles such as large trailers which seem certain to be in common use in a few years.

Highway Transportation

Overall highway transport in Taiwan has become quite motorized, and the numbers of motorized vehicles are expanding rapidly. However, as of July 1969, there was still a considerable number of non-motorized vehicles in use including some 58,400 ox-carts, 16,200 manually drawn carts, and 6,300 pedi-cabs. After several years of rapid growth, the number of registered motorized vehicles increased by nearly 15 percent in the first six months of 1969, alone. Of the various vehicle types, the rate of growth was surprisingly even, as registrations of motorcycles, light trucks, and heavy trucks all increased between 15 and 16 percent while the number of autos grew by slightly less than 15 percent; only the number of buses rose at a slower rate, increasing by slightly less than six percent over the half-year period.

The growth of trucking in Taiwan has been commensurate with the rise in the number of truck registrations; trucking freight service (measured in ton-kilometers) expanded by 26.1 percent in 1968, and averaged 15.3 percent per annum over the 1961-1968 period. Actually, the growth of other trucking (i.e., by firms providing their own trucking) may have been even more rapid; no data are published on this trucking volume, but the number of registrations has been growing more rapidly than the number of trucks owned by trucking companies (e.g., over the first six months of 1969, the number of light trucks owned by trucking companies actually decreased and the number of heavy trucks grew by less than 12 percent; over the same span, other light truck registrations increased by 18 percent and other heavy truck registrations rose by about 25 percent).

By the end of 1968, there were 1,384 trucking companies in Taiwan, owning a total of 11,753 trucks; these accounted for about 989 million ton-kilometers in 1968.

Highway passenger service is provided by taxis (and other hire cars) and by buses. Hire cars are of some importance in intercity transport in Taiwan, because there are so few privately-owned autos in the country. In June 1969, privately-owned autos totaled only 18,306, and cars for business use (preponderantly taxis) totaled 16,752.

By far the largest portion of highway passenger service, however, is provided by buses. In 1968, buses transported nearly 950 million passengers for a total of nearly 8.9 billion passenger-kilometers. These totals include urban transport. This service was provided in almost equal proportions by the Taiwan Highway Bureau (THB), by 23 private bus companies, and by various cities and hsiens operating buses. In 1968, THB buses accounted for more than 3.3 billion passenger-kilometers, private company buses accounted for more than 2.9 billion, and city and hsien buses totaled more than 2.6 billion. The THB service was provided by 1597 buses (end-year), operating over nearly 3,000 licensed kilometers (see Exhibit II-2 which indicates THB's intercity bus operations). The private companies (including three companies providing urban service in Taichung, Tainan, and Hualien) owned 1,942 buses at the end of 1968, and operated over 12,514 licensed kilometers. The totals for the city and hsien bus operations (including Taipei City, Keelung, Kaohsiung City, Chiayi hsien, and Penghu hsien) were 1,094 buses and 1,190 licensed kilometers.

Railway System

The railways in Taiwan are operated by the Taiwan Railway Administration (TRA), the Taiwan Sugar Company, and the Taiwan Forestry Bureau. Of these, the railways operated by TRA are of the greatest importance, even though the TRA route length is little more than half the route length of the Taiwan Sugar Company. In 1969, TRA railways accounted for nearly 5.4 billion passenger-kilometers, in contrast to 135 million for the other railways; TRA ton-kilometers totaled approximately 2,543 million, compared with a combined 142 million for the Sugar Company and the Forestry Bureau. Most of the freight traffic of the Sugar Company and Forestry Bureau is internally generated, and is based on hauling raw material to be processed. This traffic has been declining in importance in relation to TRA freight traffic.

Exhibit II-3 indicates the location and extent of these railway systems. TRA operates just over 1,000 route-kilometers, of which 825 are the West Line Railway and 176 are the East Line. The West Line is 1.067 meter gauge, its length being almost equally divided between the main line and branch lines; the East Line is narrow gauge (0.762 meter). Approximately 213 kilometers of the West Line consist of double track, while the entire East Line is a single track railroad.

The following assessment has been made of the track facilities of TRA railways:

> "Both West and East Lines are well maintained. The West Line standard of construction, with mostly 37 kg./m (kilogram per meter) rails, gravel ballast, wooden sleepers and dog-spikes is adequate at present. However, with increasing traffic density and greater train and car weights, a gradual improvement to 50 kg./m rail, concrete sleepers and welding of rails is necessary and is planned by TRA. The permanent way of the East Line, equipped with 30 kg./m rail is being re-ballasted to allow for an increase of maximum axle load from 8 to 10 tons after full dieselization."[1]

The route-kilometers of the Taiwan Sugar Company railways total approximately 1,743, all of which consist of narrow gauge track, while the route-kilometers of the Taiwan Forestry Bureau railways total 196. Its track, too, is narrow gauge.

---

[1]-World Bank, "China: Third Railway Project", May 15, 1969.

At the end of June 1969, the various railways had rolling stock as follows:

	Locomotives	Diesel Railcars	Freight Cars	Passenger Cars
West Line	265	72	6,259	811
East Line	33	20	531	48
Total TRA	298	92	6,790	859
Sugar Company	303	-	21,511	188
Forestry Bureau	27	-	1,711	44

The number of freight cars owned by Taiwan Sugar Company seems disproportionate to its tonnage of freight traffic; each freight car, on the average, would have accounted for only about 6,200 ton-kilometers in 1968, or slightly more than 17 ton-kilometers per day. By contrast, TRA freight cars averaged around 375,000 ton-kilometers in 1968, or more than 1,000 ton-kilometers per car per day.

Much of the rolling stock is antiquated. More than 40 percent of TRA's steam locomotives (189 are steam and 109 are diesel) have been in service for over 40 years; the average length of service for all West Line steam locomotives (which number 168) was 37.5 years as of June 1969, while the average length of service for all East Line steam locomotives was 39.3 years. Many freight cars are more than 30 years of age, and ten percent of West Line passenger cars and 50 percent of East Line passenger cars have been in service for more than 30 years. The average ages of West Line freight and passenger cars as of that date were 20.6 and 9.6 years, respectively, while the respective average ages for the East Line cars were 30.7 and 31.0 years.

As further evidence that investment in rail rolling stock is in arrears, the World Bank has indicated that the 268 passenger cars and 600 freight cars, which are being financed inter alia under the Bank's third loan to TRA, "...would be fully utilized on procurement...".

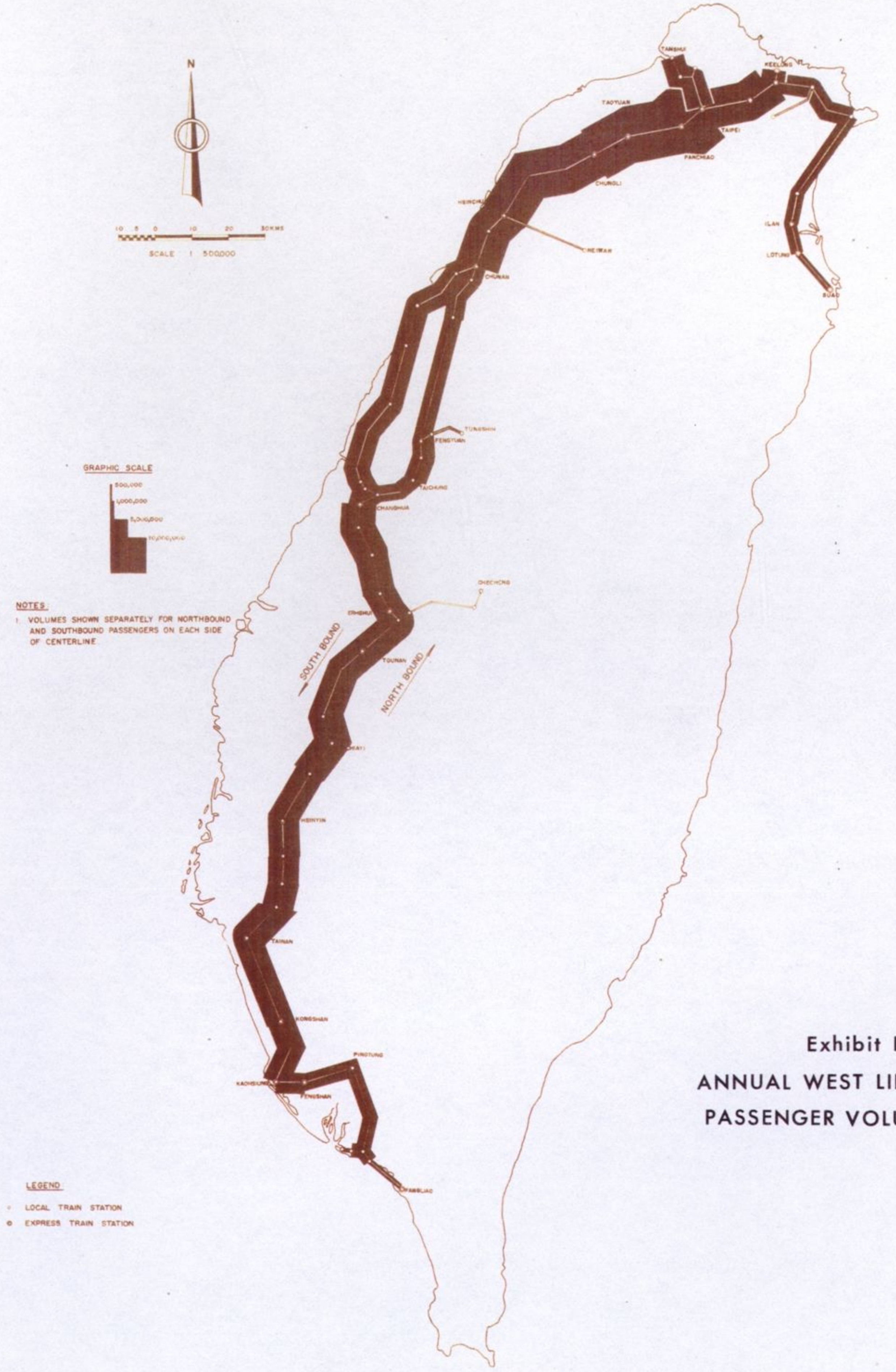


Exhibit II-4

ANNUAL WEST LINE RAILWAY PASSENGER VOLUMES—1967

Investment in TRA railway facilities and equipment other than rolling stock has also lagged. Most notably, the extension of double tracking along the entire main line of the West Line Railway has been long delayed. Largely for this reason, the West Line has had to refuse cargo shipments. TRA indicated that nearly 41 percent of rail cargo orders were turned away in 1968. Passenger travel is also constricted; average express train speeds are less than 70 kilometers per hour, and prospective passengers must make reservations days in advance to assure accommodation.

Despite the fact that its rail facilities are not adequate to meet present demand, TRA has achieved a relatively efficient operation. The World Bank indicates that the number of TRA employees per thousand train-kilometers was reduced from 1.00 to 0.83 over the 1963-1968 period, and that this "compares quite favorably with the performance on most U.S. and European railways...". Moreover, punctuality of trains is quite high; 94 and 90 percent of TRA passenger and freight trains, respectively, were on time in 1967. East Line trains were even more punctual with 97 percent on schedule.

Of the several rail lines in Taiwan, the West Line is by far the most important. This line would be directly competitive with the proposed freeway. The growth of West Line cargo traffic has not been very rapid in recent years, averaging only 3.4 percent per annum over 1961-1968. In 1968, however, the West Line Railway still accounted for approximately 69 percent of all land freight service ton-kilometers. About 90 percent of West Line cargoes are comprised of bulk commodities, coal alone accounting for approximately 25 percent.

Passenger traffic on the West Line has been growing more rapidly than freight. Including both commuter and intercity traffic, the growth averaged nearly 6.3 percent per annum between 1961 and 1968. The growth rate of intercity traffic was slightly higher than the average. Over the first half of 1969, total passenger traffic of TRA has shown a substantial rise of 10.0 percent. Exhibit II-4 indicates the distribution of West Line intercity passenger traffic in 1967. Much of this traffic represented travel by military personnel, all of whom travel at discount fares.

Harbors and Shipping

Although there are minor ports at Suao, Anping, Tamshui, and Makung, the three ports at Kaohsiung, Keelung and Hualien account for nearly all port traffic. Of these, Kaohsiung is the largest and most important. As of June 1969, it had more than 5,600 meters of deep-water wharves and berthing capacity for 66 ships of 3,000 to 20,000 dead-weight tons; the harbor had 143 working ships, including 20 tugboats and 25 barges, and 46 cranes with lifting capacity up to 120 tons.

In mid-1969, the port at Keelung had nearly 4,800 meters of deep-water wharves, 34 berths for ships of 3,000 to 25,000 tons, 55 working ships, and 33 cranes with lifting capacity up to 130 tons.

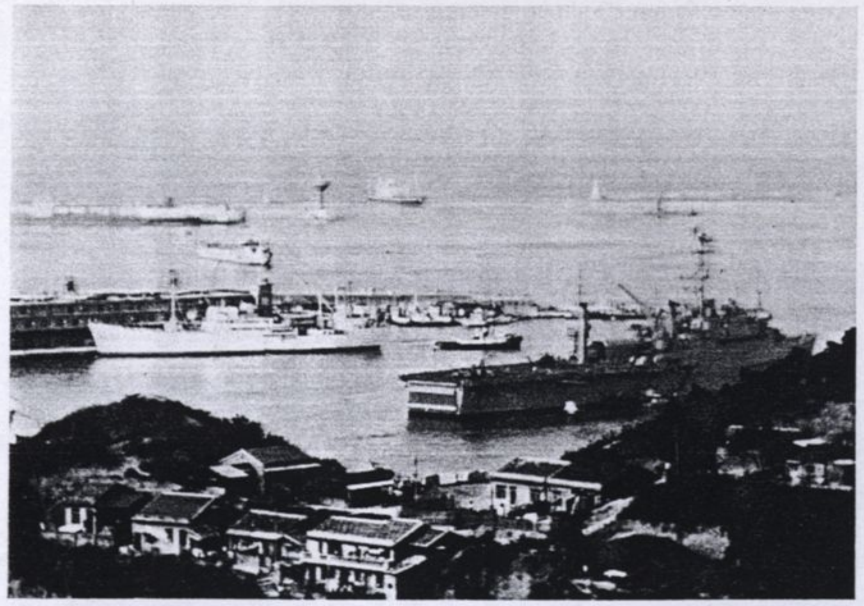
Both Kaohsiung and Keelung ports have become transportation bottlenecks, with ships having to wait as long as four or five days for a suitable berth. Extensive construction is underway in both ports, however, including container facilities. When construction at Kaohsiung is completed in 1972, the harbor is expected to have more than three times its current capacity.

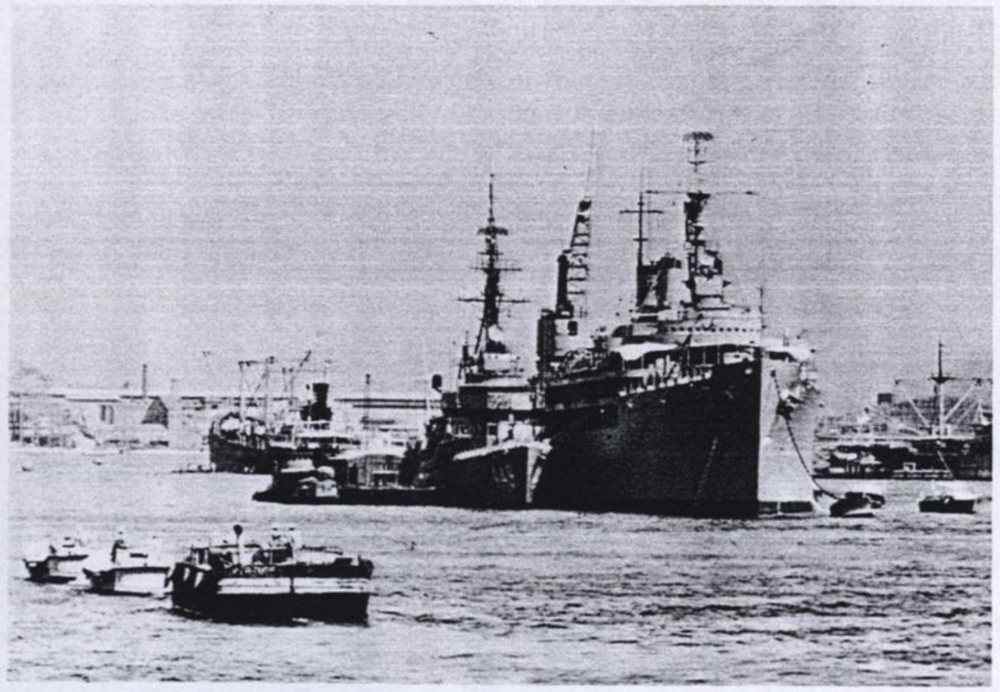
The port at Hualien is much smaller than the ports at Keelung and Kaohsiung. As of June 1969, the Hualien harbor had 730 meters of deep-water wharves, five ship berths for ships up to 10,000 dead-weight tons, six cranes, and seven working ships.

In 1968, Kaohsiung harbor serviced 4,050 incoming ocean-going ships; Keelung and Hualien handled 2,713 and 832, respectively. Tonnages handled by these ports in 1968 were nearly 19 percent above 1967, totaling more than 14.1 million metric tons. Of this tonnage, over 9.6 million represented incoming and less than 4.5 million outgoing freight. Approximately 95 percent of harbor cargoes represented international trade, with only about five percent stemming from Taiwan coastal shipping. Thus, shipping is of little importance in the movement of domestic cargoes. Kaohsiung harbor handled nearly 9.7 million tons of the total, while Keelung handled more than 4.1 million. Only about 335,000 tons went through Hualien.

The Chinese merchant shipping fleet had gross tonnage of approximately one million at the end of 1968; this represented an increase of about 15 percent over the

Keelung Harbor





preceding year. The number of Chinese-flag freighters grew from 312 to 354, an increase of more than 13 percent. In 1968, Chinese-flag vessels handled 27.2 percent of total imports and 44.1 percent of exports. By June 1969, the most recent month for which data are available, these proportions had risen to 44.1 percent and 44.9 percent, respectively.

Air Transportation

Domestic air transport has been unimportant in Taiwan for both cargo and passenger traffic. Air service accounted for about 7.0 million domestic ton-kilometers in 1968 in contrast to nearly 3.7 billion ton-kilometers for all domestic freight transport; thus air service represented only about one-half of one percent of the total. Domestic air services provided for about 101 million passenger-kilometers out of a total of around 14.4 billion, also less than one percent of the total.

As a carrier of international cargoes, air transport was no more significant, accounting for 9,000 tons of imports out of a total of nine million tons (i.e., only 0.1 percent), and transporting about 11,000 tons of exports of a total of more than 3.65 million, or about 0.3 percent.

In the transport of international passengers, however, air transport is becoming of importance in Taiwan. In 1968, about 320,000 passengers departed on international flights, and about 296,000 passengers arrived. All were handled at the Taipei International Airport, which was the Island's only international airport until early in 1969 when the airport at Kaohsiung was opened for international flights.

The Taipei International Airport is by far the largest in Taiwan. The runway has one-third more area than the runway at the Kaohsiung Airport; the taxiway is nearly 30 times as large and the apron has more than five times as much area. The terminal building is also larger. Moreover, the Taipei Airport is the only one equipped to handle night flights. Despite the size of the airport relative to others in Taiwan, it is not large by international standards, and international flights are to be shifted to a larger airport near Taoyuan within a few years. When this is done, the Taipei airport should then be adequate to handle domestic flights for many years.

In addition to the airports at Taipei and at Kaohsiung, there are smaller airports at Hualien, Taitung, Taichung, Tainan and Makung, as shown on Exhibit II-3.

Taiwan has two airlines, China Airlines (CAL) and Far Eastern Air Transport. The latter provides only domestic flights between Taipei and Kaohsiung (28 per week). China Airlines provides service for both domestic and international travel; at present its international flights serve only the Far East, but it is scheduled to commence flights to the West Coast of the United States in February 1970. The airline uses Boeing 727's for 32 of its 34 weekly international flights.

For its domestic flights, CAL uses DC-4's, C-47's, and C-46's. The airline's most important domestic route is between Taipei and Hualien, over which it flies 42 round trips weekly.

Taiwan's transportation system has not kept pace with the growth of the economy. Congestion has become serious on the Island's highways and railways, and in its harbors. The Government of China has recognized the seriousness of the present transportation inadequacy, however, and the Country's Fifth Four-Year Development Plan emphasizes transportation improvements. Major construction is already going ahead in the expansion of port facilities, and the harbor situation should be markedly improved by the greater use of containerization.

chapter III

ANALYSIS OF TRANSPORTATION COSTS

ANALYSIS OF TRANSPORTATION COSTS

Vehicle operating costs and passenger-time values were established as a prelude to assigning traffic to the existing highway network and proposed freeway network and to estimating user savings. Railway ton-kilometer and passenger-kilometer costs were also estimated as a basis for comparison with highway costs, and to establish a framework for forecasting future railway transportation costs. Since cargo time values are negligible for individual vehicles, they were not considered in this chapter, but are taken into account in the chapter discussing comparative benefits.

Coastal shipping and air traffic along the proposed freeway corridor constitute a very small percentage of the total volume, as explained in Chapter V under "Forecast of Transportation Demand". Therefore, their cost analyses are not included.

HIGHWAY TRANSPORTATION

Vehicle Operating Costs

Vehicle operating costs were estimated separately for four vehicle categories--automobiles and taxis, light trucks, heavy trucks, and buses. In addition to information obtained from the Taiwan Highway Bureau (THB) bus operations, interviews were conducted with large trucking and bus companies as well as with operators of taxis and private vehicles. Data were gathered on fuel and oil consumption, tire life, maintenance and insurance costs, initial cost of vehicles, and average annual travel distance per vehicle.

These data were analyzed and modified in view of special reporting conditions and of forecast average vehicle types for the study period 1969-1990. Operating costs were divided into two components--distance and time. Distance costs included fuel, oil, tire and vehicle depreciation, and maintenance costs. Time costs considered vehicle interest, depreciation, maintenance and insurance, and the wages of the driver and his assistant. Both distance and time costs were calculated with and without taxes.

In separating operating costs into time and distance components, depreciation and maintenance costs cannot be taken entirely as time or distance costs. A part of the depreciation must be attributed to the amount of travel of the vehicle. Similarly, maintenance costs cannot be entirely attributed to the operation of the vehicle since certain maintenance is required as a function of time, even if the vehicle is not operated. Therefore, one-third of the depreciation cost and two-thirds of the maintenance cost were taken as distance costs for all types of vehicles. Two-thirds of the depreciation costs and one-third of the maintenance costs were taken as time costs.

In determining the benefits to the economy of the country, taxes on vehicle operating costs should be deducted. Such taxes include custom duties, production tax, road user taxes, and all other taxes on fuel, oil and spare parts used in maintenance as well as taxes on the vehicle itself. They also include income taxes on the wages of drivers and helpers on commercial vehicles.

Computations of the operating costs are shown in Tables III-1 through III-4. Operating costs, excluding passenger time values, are summarized below.

SUMMARY OF AVERAGE VEHICLE OPERATING COSTS

(With Taxes)

Type of Vehicle	Distance Cost Per Kilometer	Time Cost Per Minute
Automobiles and Taxis	NT$ 1.00	NT$ 0.40 (taxis only)
Light Trucks	1.70	0.71
Heavy Trucks	2.43	1.00
Express Buses	2.43	1.00

Operating costs for automobiles and taxis were estimated at NT$ 1.00 per kilometer and NT$ 0.40 per minute. The time cost shown is for taxis only. This is because time saved for an auto used commercially would result in the vehicle being used for an increased number of operating trips over any given time period with a resultant lower time cost per trip. Savings in vehicle operating time for a privately-owned auto probably would not increase the number of trips for which it was used. As a result, there would be no change in the time cost per distance unit traveled and private auto time costs should not influence the choice between alternative routes. Later, when operating costs including passenger time values were computed, estimated taxi and private automobile percentages for the study period were incorporated in the final figures.

Operating costs for light trucks were estimated at NT$ 1.70 per kilometer and NT$ 0.71 per minute. These were considered to be distance and time costs for an average two-ton light truck. They were computed by averaging costs for one-ton and three and one-half ton trucks. The truck capacity survey described later (Chapter IV) indicated that the two-ton truck was the most commonly used light truck in the country.

The distance component of vehicle operating cost on freeways was assumed to be equal to the cost on existing highways. Although distance costs on existing highways were higher than normal because of congestion on many sections, especially through towns, this cost would be at least partially offset by higher fuel costs for high-speed freeway travel. Therefore, it was estimated that distance costs for vehicles would be the same on existing highways and the future freeway. Time costs, on the other hand, were computed on the basis of specific speeds assumed on existing and freeway network links.

Adjustment of Operating Costs for Grades

Many studies have been made to evaluate the effect of grades on fuel consumption and on other cost elements. In general, the increase in cost of vehicle operation on upgrades is greater than the decrease in cost of operation on downgrades. All vehicles except automobiles are more expensive to operate on any hilly road; this is also true of automobiles when grades are greater than five percent. Adjustments were made for distance costs on this basis with the further assumption that operation is more costly in rolling and mountainous terrain than on level terrain because of the braking and gear use required on certain downgrades. Adjustments to time costs were also considered. Both distance and time adjustment factors were computed by using the tables and graphs from the reference books listed at the end of this chapter.

For this study, terrain conditions were classified in three categories: flat--grades of zero to three percent; rolling--grades of three to five percent; and mountainous--grades above five percent. All traffic assignment networks were coded for terrain type. The terrain condition assumed was the average for each link. The adjustment factors are summarized in the table below.

GRADE ADJUSTMENT FACTORS FOR TIME AND DISTANCE COSTS

Type of Vehicle	Flat (to 3%) Time	Flat (to 3%) Distance	Rolling (3-5%) Time	Rolling (3-5%) Distance	Mountainous (5% & Over) Time	Mountainous (5% & Over) Distance
Autos & Taxis	1.00	1.00	1.00	1.00	1.00	1.15
Light Trucks	1.00	1.00	1.10	1.10	1.10	1.30
Heavy Trucks	1.00	1.00	1.15	1.20	1.60	1.55
Buses	1.00	1.00	1.15	1.20	1.60	1.55

(Type of Terrain)

Passenger Time Values

Time values originate in economic values. An economic system is a system of values. This system places a price on goods and services according to the demand for and the supply of all goods and services. Such a system emerges from collective human valuations, modified to some degree by government actions, scarce resources, popular attitudes, war, and other conditions which affect society in fundamental ways. A buyer of goods or services is directly affected by these variables.

A passenger seeking transport between cities may choose among air, rail, bus, taxi or auto, and even ship; his choice is affected by price, available income, urgency, purpose of travel, relative comfort and convenience, and schedule of times of departure and arrival. Both the type of vehicle he chooses and the conditions which affect his subjective choice are influenced not only by his value judgments, but by those of his society as a whole. Society may not have provided him the money to travel by air, even though he might prefer that mode. His income is dictated by the valuations made by others according to the kind of work he does, and the product or service he produces.

As a result of this system, some people can afford to pay a high price for transport while others can afford nothing. The total number of rail express passengers traveling in air conditioned confort is far smaller than the number of ordinary rail passengers. Express rail service costs twice as much as ordinary rail service. Express trains travel almost twice as fast as ordinary trains. To go between Taipei and Kaohsiung (375 kilometers), the ordinary rail passenger spends 10.33 hours and NT$ 99.37. The cost per minute of travel is NT$ 0.160. The express rail passenger spends only 5.65 hours in travel, but NT$ 182.6 in fare. His cost per minute of NT$ 0.538 is nearly 3.6 times that of the ordinary rail passenger.

In a society with a relatively large middle class, with few extremes of poverty or wealth, most members of the system have a free choice as to mode of transport. They will be constrained in their choice mainly by purpose of trip, etc. Since this is largely true of Taiwan relative to transport prices, a typical passenger may elect to pay a premium price if he is in a hurry, or if he seeks comfort as well as speed. His decision will reflect his total evaluation of all factors, and the price he pays will indicate the importance to him of speed, comfort and convenience. Of these factors, speed is the only one which can be measured in terms of money or hours in travel time. Comfort is subjective, being related to each man's idea of comfort. He might like the sociability he would find on an ordinary train or local bus. Convenience depends on departure and arrival time, frequency of departures, distance to and from stations, and purpose and duration of trip. Neither comfort nor convenience can be easily quantified.

Passenger fares basically reflect the value passengers place on time. A schedule of passenger fares in Taiwan will show that the relative price per kilometer of travel by local bus, taxi, airplane or rail creates a system of prices which each passenger must consider in choosing his mode of travel. That choice weighs many factors in addition to price, as discussed above, in a modern complex society. The premium paid for more rapid travel by some measures the value placed on time by those who are better paid than others. Time is worth something, but how much?

To measure the value of time for passengers traveling by different modes, it was assumed that passengers traveling by the least expensive mode would have zero time values. They would, in effect be paying only a distance cost. The fare per minute of travel by this conveyance, then, would represent the distance cost for all conveyances. The fare per minute differentials between the cheapest mode of travel and other transport modes would be equivalent to the minimum value of time, comfort and convenience to passengers traveling by other modes.

Among the transport modes considered (i.e., excluding motorcycles, bicycles, ox-carts, and so forth), the least expensive transportation is by local bus; dividing fares by minutes of travel, it was found that the average cost per passenger-minute is NT$ 0.135. Table III-5 shows how the costs of traveling by other modes compared with the per passenger-minute cost of traveling by local bus. The table also shows the minimum time values per passenger-minute. This represents the incremental cost of traveling by the various other modes in comparison with traveling by local bus.

The costs per passenger-kilometer via express bus, local and express rail, and airplane were obtained in the same manner as was used to find the fare per passenger-minute of local bus travel, i.e., the fares were divided by the travel times over various trips to arrive at average cost per minute. For express rail, averages of the fares and travel times of the flyer, the tourist, and the limited express were used.

The costs per passenger-minute for private automobile and taxi trips were not as easily computed. In both cases, average observed speeds (as found from the road survey) were used to convert distance costs into time costs. The average highway speed of both taxis and private autos is 50 kilometers per hour.

The average discount fare for taxi travel on highways was estimated at NT$ 2.00 per kilometer. Thus, at an average speed of 50 kilometers per hour, the hourly fare would be NT$ 100, and the per-minute fare would be NT$ 1.667. The average number of taxi passengers on the highway was observed to be three. Therefore, the cost per passenger-minute would be NT$ 0.556 (i.e., NT$ 1.667/3). When the distance cost per passenger-minute (NT$ 0.135), was subtracted from NT$ 0.556, the remaining cost per passenger-minute would be NT$ 0.421. This represented the minimum time value per taxi passenger per minute.

For private automobiles, it was assumed that one person would usually bear the entire cost of a trip, or would be willing to bear the entire cost. Therefore, the entire vehicle time and distance cost per minute would represent the cost per passenger per minute.

The cost per kilometer via private auto was computed to be NT$ 1.00. Since the average auto speed was 50 kilometers per hour, the total distance cost would be NT$ 50 per hour, and the distance cost would be

NT$ 0.833 per minute. The time cost for private autos was computed to be NT$ 0.25 per minute, and the total of distance and time cost, therefore, would be NT$ 1.083 per minute. This would be equivalent to the passenger cost per minute, and the minimum time value per private auto passenger per minute would thus be NT$ 0.948 (i.e., NT$ 1.083 less NT$ 0.135).

The time values shown for taxi, private auto, and express-bus passengers were used to determine total user costs as discussed below.

User Costs

User costs were estimated by adding passenger time values explained in the preceding discussions to the time components of vehicle operating costs. These values were then used in assigning traffic and in estimating user savings.

The revised time cost for the automobile and taxi category was NT$ 1.23 per minute. This included 60 percent of the private automobile time cost of NT$ 0.95 per minute and 40 percent of the taxi time cost of NT$ 1.66 per minute. The 60-40 distribution of automobile and taxis, respectively, was estimated on the basis of traffic forecasts for the study period 1969-1990.

The traffic survey of 1969 performed under the Consultant's supervision revealed that there were, on an average, three occupants in every automobile. The time cost of NT$ 0.95 per minute for the private automobile includes only the time value for one occupant. However, no time value for the automobile itself was considered. The same survey found an average of three passengers in every taxi. The total time value for these passengers (three times NT$ 0.42 per minute per passenger) was NT$ 1.26 per minute. This amount was added to the taxi and driver time value of NT$ 0.40 per minute to obtain the total time value of NT$ 1.66 per minute for a taxi.

Since light and heavy trucks have no passengers, no revision was necessary in their time costs. These costs, as explained earlier, include the time value of the driver for light trucks and the time values of the driver and helper for heavy trucks.

In the case of express buses, NT$ 3.50 per minute was added as the time value of passengers--an average of 35 passengers at NT$ 0.10 per minute per passenger--to NT$ 1.00 per minute (the time value of the vehicle, driver and helper) to arrive to the total time cost of NT$ 4.50 per minute for each bus. Although the traffic survey indicated an average bus occupancy of 31 passengers, a slightly higher average occupancy was forecast for the study period.

The resulting user costs for each vehicle category is summarized below.

SUMMARY OF USER COSTS

Type of Vehicle	Distance Cost per Kilometer	Time Cost per Minute
Automobiles and Taxis	NT$ 1.00	NT$ 1.23
Light Trucks	1.70	0.71
Heavy Trucks	2.43	1.00
Express Buses	2.43	4.50

Passenger and Cargo Costs

In calculating the passenger-kilometer and ton-kilometer costs, the distance and time components of vehicle operating costs were combined. The time cost was converted to a distance cost based on average speed of the vehicle, and this figure was added to the initial distance cost of the same vehicle.

If a bus travels at 26.2 kilometers per hour (as in the case of a local bus), it travels 0.437 kilometers in one minute. This corresponds to a time cost of NT$ 2.288 per kilometer based on the bus time cost of NT$ 1.00 per minute previously established. The resulting time cost of NT$ 2.29 per kilometer added to the bus distance cost of NT$ 2.43 per kilometer gives a total value of NT$ 4.72 per kilometer. Cost per passenger-kilometer was computed by dividing this total cost by the average number of bus passengers. For the local bus described above, the average passenger-kilometer cost was NT$ 0.135. For an express bus the cost was NT$ 0.109. The difference reflects the higher speed of the express bus.

For a heavy truck with a time cost of NT$ 1.00 per minute and a distance cost of NT$ 2.43 per kilometer, and traveling at an average speed of 40 kilometers per hour, the total cost would be NT$ 3.93 per kilometer. The average ton-kilometer cost of NT$ 0.914 was computed by dividing this total cost by the average truck load of 4.3 tons estimated from analyses of traffic survey data.

RAILWAY TRANSPORTATION

General

Operating and financial reports of the Taiwan Railway Administration (TRA) reveal internal inconsistencies which make it difficult to rely on any reported data as a basis for analysis of operating costs. Rather, several sets of reported figures are used throughout this study, and an interpretive analysis has attempted to approximate the actual level of total costs. By this method it was possible to compare reported costs with interpreted costs, and to evaluate the effects which passenger and cargo demands have had upon capital investments and operating costs. The TRA cost data are shown in Table III-6. Total costs of passenger service for the West Line have doubled during an 18-year period while the volume of passengers rose 27 percent. The comparative rates of annual growth were 9.3 percent in costs and 3.1 percent in usage. These rates reflect comparisons between an average three-year period (1958-60) and the most recent period (1966-68). During this time, passenger-kilometers of transit riding rose 4.5 percent per year while passenger-kilometer costs rose, on average, from NT$ 0.1526 to NT$ 0.2187, or at 4.6 percent per year.

Freight costs rose at an average rate (1958-60 compared with 1966-68) of only 4.3 percent per year while usage increased at an average rate of 3.1 percent. Ton-kilometers carried also rose 3.1 percent, while reported costs per ton-kilometer rose , on average, from

NT$ 0.2204 to 0.2402, or 11.0 percent. This rate of rise in costs per ton-kilometer was 2.4 times that of the rise in costs per passenger-kilometer. As with all railways, this apparent difference resulted partly from the procedure used to separate rail costs into passenger and cargo costs. Such procedures are inevitably arbitrary and based on experienced judgment. Costs--generally reported for total operations--include fuel, labor, maintenance, and depreciation together with operating costs for stations, track, signalization, and so forth. These must be allocated between the two services. Similarly, new capital investments in rolling stock, handling equipment, double-tracking, and repair and maintenance facilities must be allocated. This is usually done on the basis of the estimated usage of equipment by the two services. Cost estimates used in this study followed the proportionate allocations made by TRA.

Financial statistics of TRA indicate an enterprise extending beyond rail matters. As railways do in several other countries, TRA provides freight forwarding and warehousing services to cargo customers. Annual accounting of TRA includes the financial accounts of these dual services within the total rail reports, which affects the final summary of costs per ton-kilometer. In a similar way, the TRA operates hotel, restaurant, and passenger car services, and those accounts are also mingled with those of TRA generally in annual reporting. Data on TRA operating costs include the costs of these services; revenues from these services are included in total revenues.

West Line Railway

In order to evaluate the West Line rail separately from total rail services, a financial analysis was made to allocate the accounts reported by TRA. This assignment of costs is shown in Table III-7. Passenger services are shown to produce a cost per passenger-kilometer of NT$ 0.239 while cargo services resulted in a cost per ton-kilometer of NT$ 0.350 in 1968. The various costs which enter the total for each service are shown separately as expenses of traffic, stations, maintenance, and so forth. This detailed account for 1968 indicates higher average costs per passenger-kilometer and per ton-kilometer than the costs reported by TRA in summary form, namely NT$ 0.2273 per passenger-kilometer and NT$ 0.2528 per ton-kilometer. The costs excluded by TRA in some accounts but included in others cannot be known with certainty since rounding of figures, revisions of basic data, and purpose of report all influence not only costs, but the passenger-kilometer or ton-kilometer base on which such data are analyzed. The aim of the Consultant's study was to determine relevant total costs rather than to accept one set of accounts. Approximations of these costs appearing in Table III-7 will be repeated in later tables. The separation of passenger and freight costs (58.6 percent for passengers and 41.4 percent for freight) derives from the TRA's allocation of expenses in detailed reports. Depreciation and maintenance accounts have been intermingled in these reports. This obscures the capital accounting of fixed assets as a charge on current income. For this reason, and for the further reason that annual capital accounting is distorted, total capital and operating costs are shown together in Table III-8.

Annual capital requirements of TRA may be viewed as a recurrent item of total operating costs, with depreciation of such costs being of secondary importance. Prior tables showed that 94.6 percent of total operating costs of the whole line were West Line costs. It is estimated that of capital consumed annually in total East and West Line operations, 80 percent has been spent on the West Line. Total East Line rolling stock, stations, trackage, and bridges amount to the following percentages of total facilities: locomotives--6.7 percent; diesel-electric railcars--21 percent; passenger cars--6.5 percent; freight cars--8 percent; stations--20.6 percent; trackage--12.4 percent; and bridges--16 percent. With this relationship, capital costs for passenger and freight service on the West Line have been separated in the same proportion as total operating costs (58.6 percent passenger and 41.4 percent freight). Table III-8 compares total West Line costs--which include capital costs as a recurrent annual expenditure item (non-depreciated)--with reported accounts which reflect depreciated capital as an item of total costs.

The purpose is to compare total annual costs including the portion of annual expenditures represented by new capital additions. Capital costs per passenger-kilometer (NT$ 0.0563 in 1968) are seen to be falling in proportion to total passenger-kilometer costs, rising 0.8 percent less rapidly than total costs per passenger-kilometer. Ton-kilometer costs tended to rise 2.0 percent faster than total costs. As percentages of total costs, freight and passenger capital costs per ton-kilometer and per passenger-kilometer declined from 22.9 percent in the average period 1958-60, to 21.0 percent in 1966-68. This change suggests that budgetary limitations have restricted capital outlays despite rising demands. Even though freight capital costs have risen more rapidly than ton-kilometer demand, they rose less rapidly than total costs. The reverse of these conditions would have indicated that TRA was preparing for a rise in demand with investments which would tend to reduce operating costs. However, TRA's efforts to reduce costs have been hampered by dependence on foreign financing for cost-reducing capital improvements. Local availability of such equipment would have permitted a higher

rate of investment since locally-generated TRA funds would have been adequate to meet such requirements.

Passenger Costs

The distribution of passenger classes which travel by West Line rail are tabulated on Table III-9. The tariff schedule for the 12 classes shows that three main groups are served: full-fare passengers, commuters, and military. Within each group are discount fares. Only 9.4 percent of all passengers pay the average cost per passenger-kilometer or more. These are the express passengers; the mark-up paid by this group over the average cost per passenger-kilometer of NT$ 0.2273, reported for 1968, ranges from 136 percent to 256 percent. For the remaining 90.6 percent of passengers, all pay less than average total cost, ranging from a discount fare 96.8 percent of cost (for ordinary class: full-fare) to a fare 8.8 percent of cost for student commuters. The classes which account for the most passenger-kilometers of rail traffic are also discount passengers: full-fare express--21.6 percent; ordinary full-fare (discount) --27.5 percent; commuter--18.4 percent; and military --32.5 percent.

Table III-9 shows the distribution of the earnings base relative to the passenger-kilometer distribution of passengers by classes. This table shows that 78.4 percent of revenues are derived from 49.1 percent of the passengers. Of this group, 21.6 percent are express passengers who pay 48 percent of revenues. This revenue alone is sufficient to cover all deficits resulting from discount passengers.

The regional distribution of rail passenger classes shows that the number of discount passengers boarding at all major cities exceeds the volume of full-fare passengers. The ten major cities on the main line of the western corridor produce various volumes of passengers which may be separated by class to show the relative numbers of discount versus full-fare passengers, or near full-fare passengers (ordinary class). The relative numbers by station indicate that every section of the country is affected by the pricing structure of TRA; conversely, TRA could not revise its rate schedule without affecting every area of the country.

Cargo Costs

The regulatory body which sets TRA cargo tariff policies has made a study of the pricing policies of foreign railroads. It has established a tariff schedule based on general rail practices throughout the world. The result has been to burden TRA with a complex system of excess charges which vary with almost every category of cargo. As on most other railroads, the financial loss from operating outmoded passenger service with discount fares for commuters and other special interest groups is offset by the profits from freight operations. Table III-10 shows the present structure of rail rates for cargo and passengers, both schedules resulting from the policies of regulatory bodies within TRA. Basic ton-kilometer costs of rail cargo services were reported in 1968 to be NT$ 0.2528; but for all cargo classes except oil and gas it can be seen that price mark-ups range upward to 217 percent of cost, with marked discrimination against perishable cargoes, fragile cargoes, and manufactured goods. The latter discrimination is not based on potential damage while in transit, as such costs are recoverable from the higher handling costs (loading, unloading, valuation registration, and so forth) which apply as ton costs rather than transit costs. The transit costs alone--(i.e., ton-kilometer rates) are discriminatory in that they operate as taxes on value (or even as added self-insurance of the rail system against damage claims), to provide surplus revenue.

Despite the published tariffs, TRA is obliged to grant discount rates to government and special commodities groups. Military cargoes travel at 50 percent discount; rice and fertilizer cargoes pay 75 percent of cost (prior to 1969 these cargoes were carried at 50 percent discount, and when destined for export markets, were carried free); coal is carried at 10 percent discount; and special rail cargoes traveling in the rail cars of government corporations (cement, oil, and so forth) are given a 15 percent discount. Thus, as with passenger classes, government-imposed discounts cause losses which can be offset only by excessively high rates for carrying other categories of freight.

Cargo Handling Charges

Rail transit costs are significantly lower than truck transit costs. The cost of loading and unloading rail freight, however, greatly exceeds the corresponding costs for trucked freight since most shipments by rail have to be trucked to or from the railroad (or both). This imbalance creates the basis for rivalry between railroads and truck carriers. It is a primary concern of rail authorities everywhere, therefore, to reduce handling costs. Inasmuch as no market mechanism in use by either trucks or rail services places a value on time, the faster delivery offered by trucks, especially over shorter distances, becomes a factor which cannot be diminished by any adjustment of a railroad's handling charges.

The present rail handling charges have been evaluated according to their average impact and relative frequency of application for the three main types of cargo;

agricultural produce, mining products, and manufactured goods. Table III-11 shows the principal charges per ton as they apply to various types of cargo, just as transit ton-kilometer costs apply to these cargoes. Ten basic charges which apply most often are listed; these have been selected as representative of the kinds of handling charges. Two kinds of time charges are shown: holding for consignee (7) and cargo delay time (8). The first is an actual rail charge; the second is a nominal derived charge based on analysis of the average value of time in the economy to cargo shipments. For a 17-hour delay per day experienced by the average freight train, the loss of time is valued at a time value rate per hour of NT$ 0.00003832 times the average value per ton (NT$ 4079) times the hours delay. This cost is borne by the shipper: NT$ 2.65 per ton per day. Average valuation registrations (10) required of shippers is a tax on value which applies as shown to the three different categories of cargo with a sharply increased penalty on manufactured goods. Based on 1980 average values per ton, these charges would be NT$ 11.78 on agricultural produce, NT$ 1.22 on minerals, and NT$ 57.38 on manufactured goods. These are average values for each

sector. The apparent costs to shippers in 1969 were less than these amounts, however, and the lower 1969 charges were used in this analysis.

The basic (minimum) present charges, before valuation registration charges, add to NT$ 69.50 plus cargo time delay costs of NT$ 2.65. The latter is not charged by TRA, but is included as an economic cost to reflect the prevailing price differential between rail and truck which exists in the minds of shippers. The total price structure confronting shippers of rail cargo is estimated at: NT$ 76.13 for agricultural products, NT$ 73.27 for minerals, and NT$ 100.28 for manufactured goods for an average ton of cargo shipped in full-carload lots.

COMPARISON OF HIGHWAY AND RAILWAY COSTS

Truck operating costs approximate NT$ 3.93 per vehicle-kilometer for heavy trucks. This figure excludes administrative and other business costs. Regulated charges per ton-kilometer are set at a basic charge of NT$ 2.00 per ton-kilometer. For an average heavy truck of six-ton capacity fully loaded, this indicates revenue of NT$ 12 per kilometer. If one-way loads prevailed generally, revenues would be NT$ 6.00 per vehicle-kilometer. The profit potential for truckers appears to be very great. Because of regulated prices and penalties on price competition exacted by the regulatory body, however, it is probable that few competitive forces exist to reduce these rates. It is considered likely, on the other hand, that overloading is practiced, so that truckers may offer hidden discounts to shippers. Trucking is competitive by nature, notwithstanding regulatory practices, which suggests that the full-price policy may be followed to the degree possible but that tonnage reports are often falsified.

The 1969 rail and truck rate schedules are shown in Table III-12. Against these rates, estimated present costs of rail and truck operation are shown. The disparity between prices and costs may be compared for a 40-kilometer distance and a 100-kilometer distance to see the influence which excess pricing may have on competition between the two modes. Reported truck loadings of cargoes, and the average distances per kilometer of truck cargoes, tend to camouflage the actual existence of many long-distance cargoes which are known to be carried by trucks. But by this comparative pricing system, only manufactured goods could be carried as far as 40 kilometers by trucks, and at 100 kilometers truck prices would exceed truck costs by almost 210 percent in most categories of goods.

The loading and unloading costs of both truckers and railroad operators would be thought to be regulated externally by market prices for labor. Labor costs for trucks at Taipei and Keelung are set at NT$ 10 per ton, while other cities show average costs of NT$ 6 per ton. These prices are the stipulated prices which the trucking industry must pay to labor, according to the THB guidelines established for trucks. However, TRA pays rail labor an average of NT$ 5.25 per ton. Average truck loading and unloading charge is estimated as NT$ 19.89 per ton. These charges are additionally affected by charges upon the distances which labor must carry goods to be loaded or unloaded, and by delay charges for idle truck time. The handling charges set for trucks also include a stipulated mark-up on the value and perishability of goods received. But these charges apply as a ton-kilometer rate rather than as a per ton cost. The average estimated influence of these valuation charges is shown on Table III-12 as valuation costs included in ton-kilometer costs. The difference between rail and truck in the application of these valuation charges serves largely to create even greater handicaps for truckers because in some cases the additional ton-kilometer valuation charge is as high as the rival rail rate per ton-kilometer taken alone. Discussions with rail and truck authorities reveal that pricing policies may indeed have as their aim the equalization of truck and rail rates at some arbitrary competitive level (say, of 40-50 kilometer distance rivalry), in order to assure a market-sharing distribution in which the existing jurisdictions of each service may be guaranteed. Changing technological rivalries and altering cost structures for both services in an expanding market would indicate that the sheer force of external conditions on these services would cause the opposite result, if prices were set by independent market forces.

Table III-13 is a comparison of truck and cargo prices based on a reconstruction of truck costs. In this table, truck ton-kilometer prices are set at the level of calculated actual ton-kilometer costs (NT$ 3.93 per truck-kilometer divided by 4.3 tons per truck equals NT$ 0.914 per ton-kilometer), plus estimated business costs not already included in truck operating costs (or ton-kilometer costs times 125 percent equal NT$ 1.142). This estimate therefore assumes an arbitrary business cost as fixed overhead per ton-kilometer. Reconstructed truck costs are calculated on the basis that these costs are the ones which actually apply to relevant prices offered by truckers under existing regulatory and vehicle operating conditions. Confirmation of this is found in the fact that only two rail cargoes in 1967 actually traveled average distances less than 90-kilometers. Discounts inherent in truck overloading and possible under-reporting of truck tonnages carried are presumed to account for the statistical discrepancies between the reported and observed (from 1969 traffic survey) average truck trip lengths. Reports to THB by truckers in 1966 and 1968 disclose that the range of trip lengths was between 13 and 63 kilometers. The 1969 heavy truck traffic survey found the average trip length to be over 67 kilometers. Table III-13 shows that with the potential for price competition which currently exists, resulting rivalries with rail shipments extend to 70-kilometer trips for agricultural cargoes, to 80 kilometers for mining cargoes, and to 110 kilometers for manufactured goods. For purposes of comparative analyses with forecast future rivalries resulting from freeway conditions, an average truck-rail rivalry of 90-kilometer distance was accepted. At this level, which would result from competitive truck operation and which approximates actual pricing conditions, the real cost-price relationships which govern existing conditions may be compared with the forecast real cost-price conditions which govern freeway operation. By these comparisons, real differences may be found. Real benefits may only be calculated by employing comparisons of real costs. The present arbitrary pricing structure which is not dependent on actual costs should not be used for the calculation of benefits. Such a step would overstate benefits to the economy. The benefits which would accrue to price rationalization should be considered independently of the freeway operation as such.

chapter IV

SURVEY OF EXISTING HIGHWAY TRAFFIC

SURVEY OF EXISTING HIGHWAY TRAFFIC

EXISTING TRAFFIC DATA

Previous Traffic Surveys

The Taiwan Highway Bureau (THB) has been conducting traffic surveys throughout the Island for many years. During April of every year, one-day traffic counts are conducted at more than 2,000 locations. The Highway Bureau reports published in 1968 document the rapid growth of traffic from 1954 to 1967. The annual average traffic growth rate during this period was 15 percent for the overall provincial highway network, and 19 percent for the existing North-South Arterial Highway. This growth rate includes the rapidly increasing motorcycle traffic. In the same period, the number of light trucks increased more rapidly than other vehicles. No continuous traffic counts were made in previous years and there are no automatic traffic counters in operation. Seasonal traffic variations, therefore, are not documented by traffic counts. Traffic is being indirectly recorded on a continual basis at each toll station, and toll station revenue statistics provide an indication of seasonal variations.

The daily two-way traffic on the North-South Arterial Highway in 1968 was about 7,000 vehicles in the Taoyuan area, 5,000 vehicles between Chungli and Hsinchu and 2,000 vehicles between Miaoli and Chiayi except near Changhua, where about 5,000 vehicles were counted. Between Tainan and Pingtung, the count ranged from 4,000 to 7,000 vehicles. Near Taipei, traffic on the Taipei bridge was about 20,000 vehicles with an almost equal count on the Chunghsing bridge. Between Taipei and Keelung, there were some 5,000 vehicles per day on the MacArthur Thruway and some 4,000 vehicles on Highway 5. These numbers represent rural traffic volumes outside of towns and do not include motorcycles. Motorcycle traffic amounts to about half as much as four-wheeled vehicle traffic in the rural areas and even more near towns.

The 1969 traffic flow in the study area along the northwest coast is illustrated on Exhibit IV-1 with the band width proportional to the traffic volumes. Highways with less than 500 vehicles per day, excluding motorcycles, are not indicated.

Toll Facility Statistics

Five highway toll stations within the study area provided useful traffic data for the three most recent years. Other toll stations, being in operation during only part of this period, were not analyzed. The toll station locations are indicated on Exhibit IV-2. Monthly toll revenues in 1966, 1967 and 1968 are shown on Table IV-1. Average monthly revenues of the five facilities together were calculated as a percentage of the yearly revenue as well as of the April revenues. Annual growth rate for each facility was computed. Exhibit IV-3 illustrates the monthly revenue variations at the five facilities.

Toll rates are usually NT$ 5 for automobiles and light trucks and NT$ 10 for heavy trucks and buses. The rates are doubled on the Hsilo bridge, and tripled at Chien-Feng. Large vehicles, which are generally considered equivalent to two automobiles, pay twice as much toll as an automobile. The toll revenue is therefore indicative of the traffic volume including the effect of large vehicles. The toll rates were not changed during the three years covered by the study, and traffic can be considered to have been directly proportional to toll revenues.

Growth averaged 46 percent per year for the five facilities combined. It was very high on the Chunghsing bridge due to closing of the Taipei bridge in 1967, and very low on the Tsaotun-Puli highway. The three other facilities averaged about 30 percent per year growth in the 1966-1968 period.

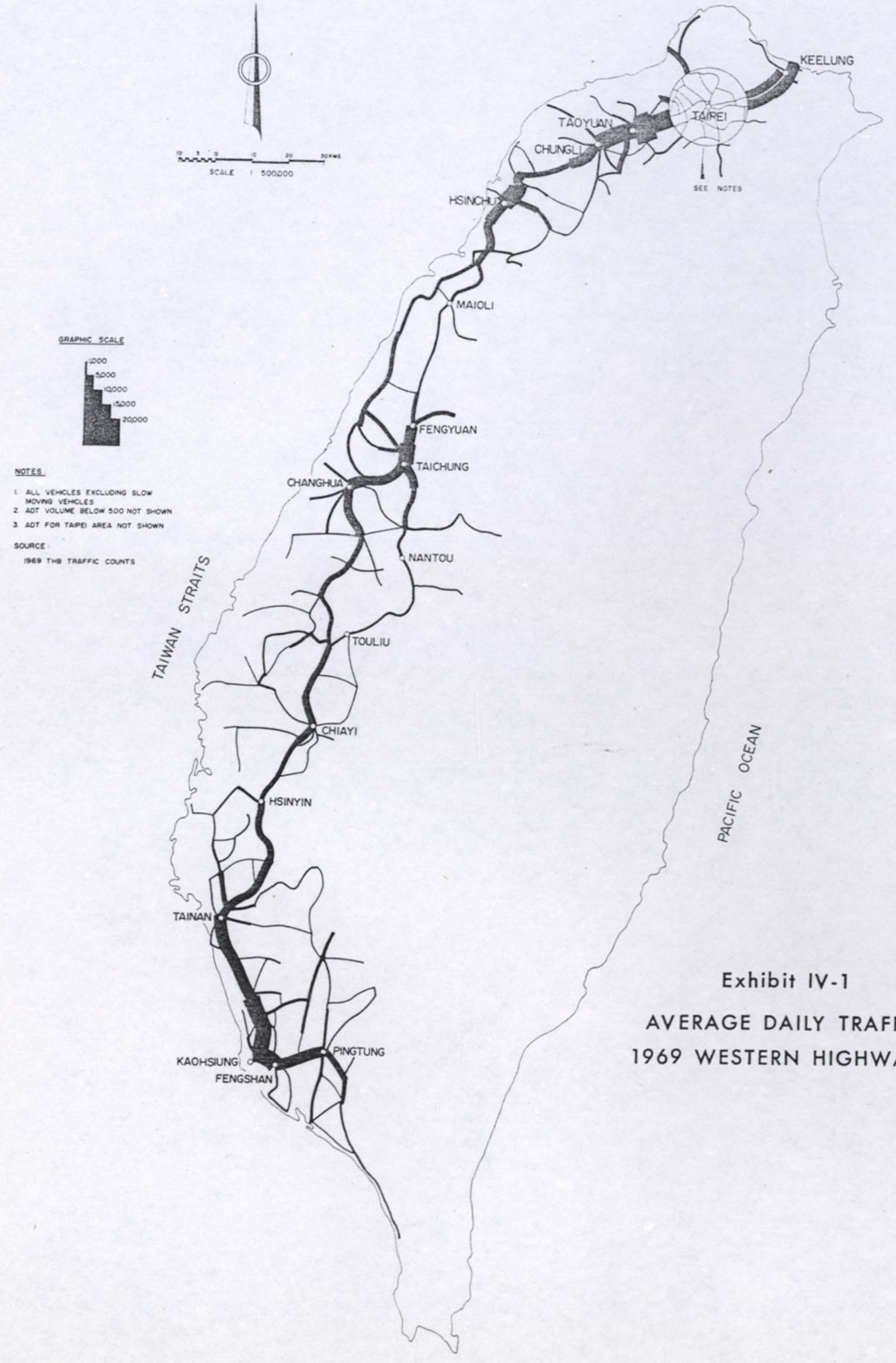


Exhibit IV-1

AVERAGE DAILY TRAFFIC
1969 WESTERN HIGHWAYS

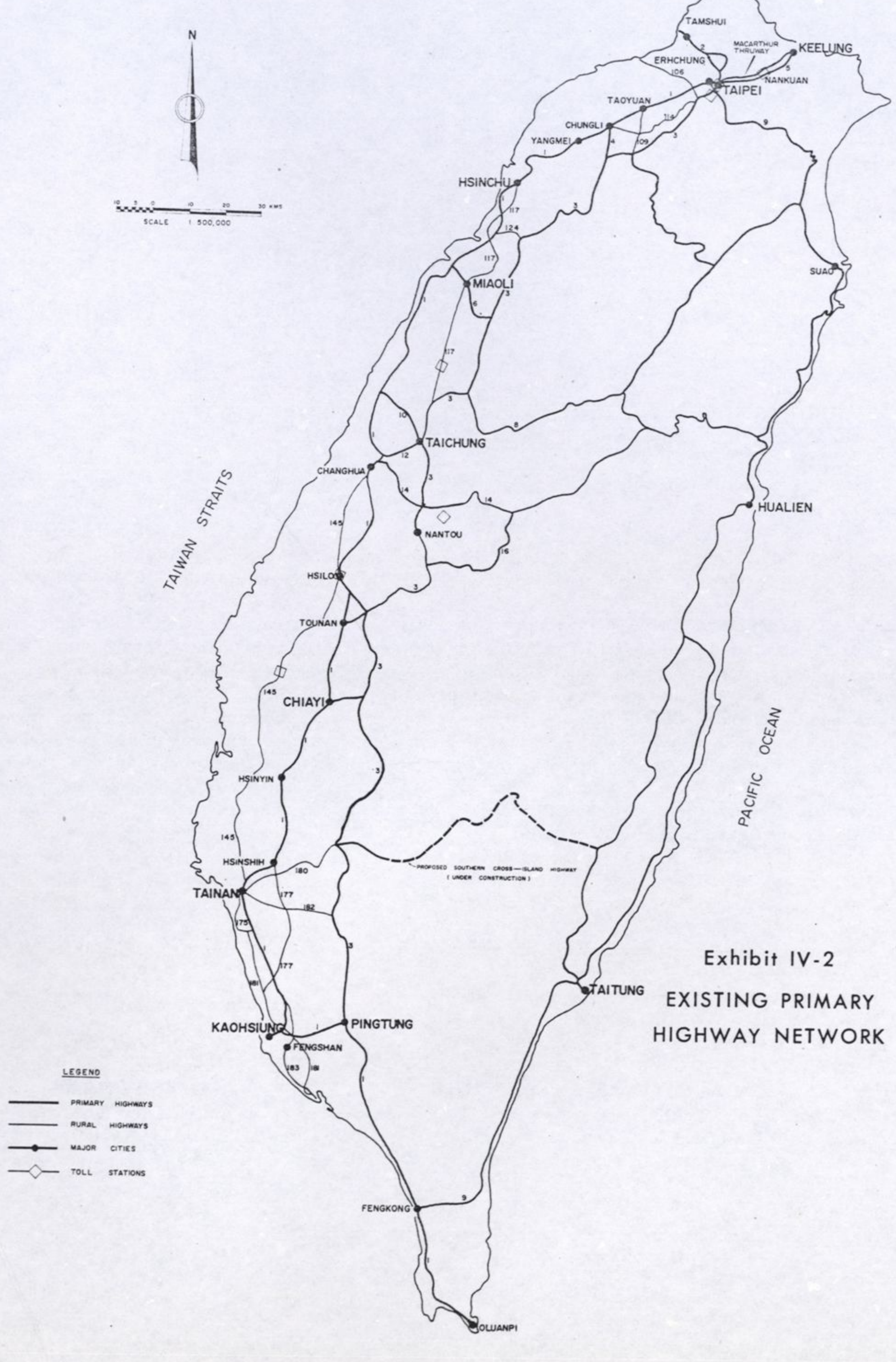
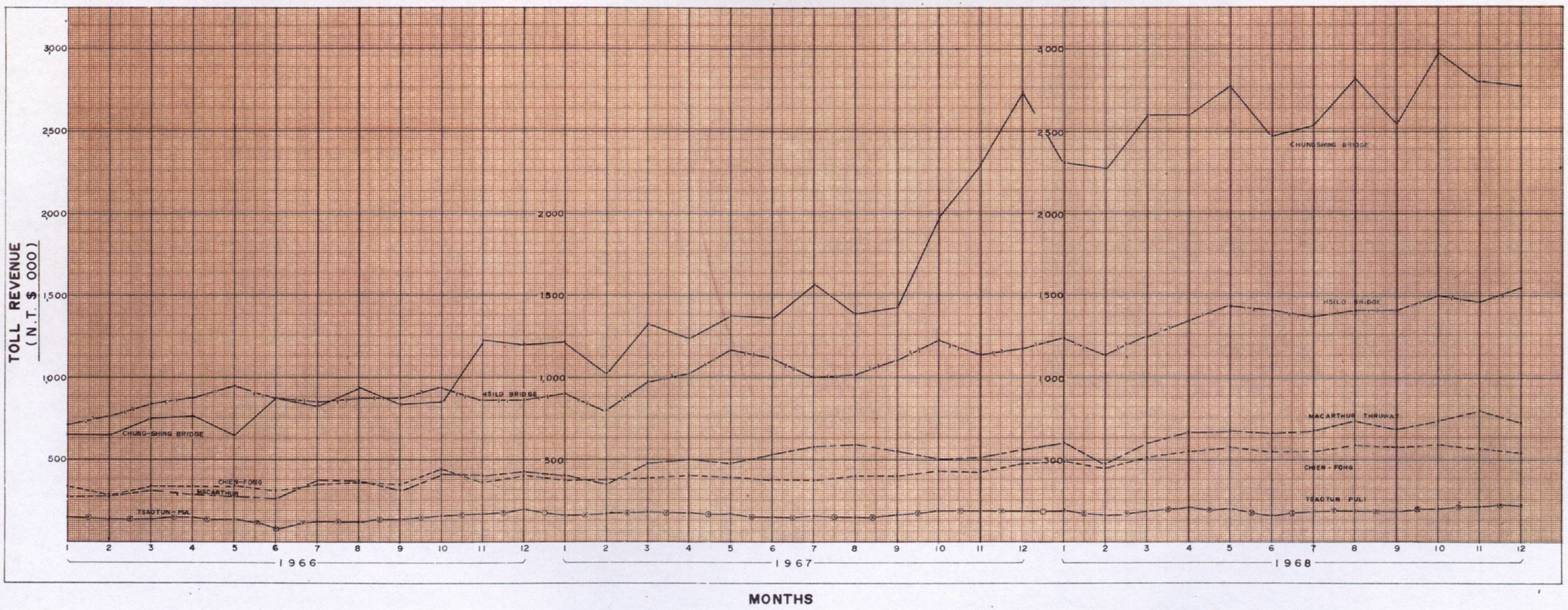


Exhibit IV-2

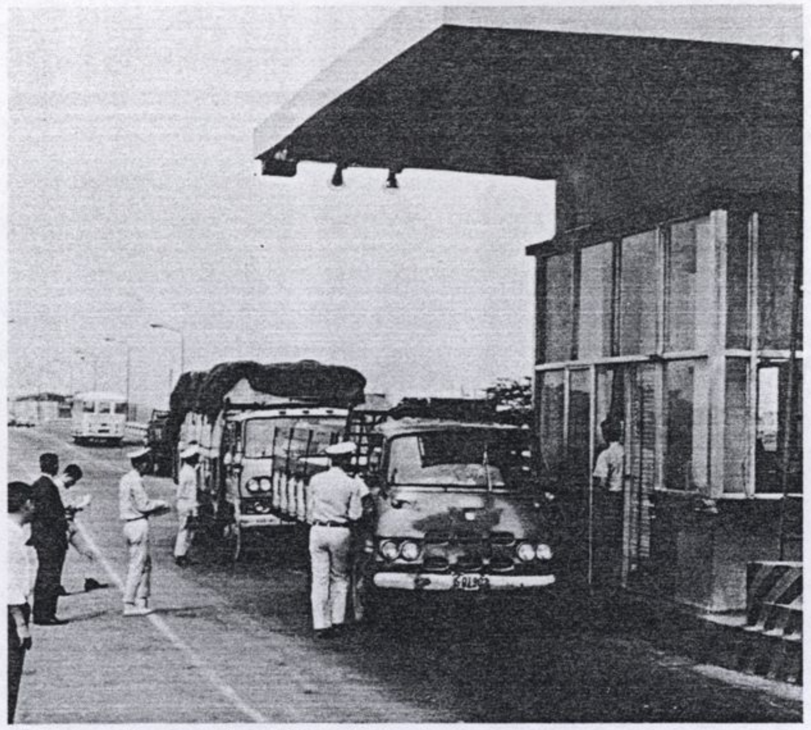
EXISTING PRIMARY
HIGHWAY NETWORK

Exhibit IV-3

MONTHLY TOLL REVENUE VARIATIONS
at
Chung–Shing Bridge, Hsilo Bridge, Chien–Fong, MacArthur Thruway, Taostun–Puli



There is little seasonal variation in traffic. Traffic is higher in summer than in spring, but lower than in the following winter. The most evident variation in traffic is due to the continued growth. It was noted that traffic in April is close to the yearly average. The survey month of April 1969 was considered representative, therefore, for the year 1969.



McArthur Thruway Toll Plaza

1969 TRAFFIC SURVEYS

Continuous Classification Count

Vehicles were counted continuously by type on arterial Highway No. 1 at the western limit of Taipei Hsien from April 1 to June 30, 1969. The continuous count station was located on the main artery in a rural area. Except for some local traffic of the nearby village, it represents traffic which might use a freeway. Traffic survey crews recorded and classified each vehicle. An hourly total for each direction was tabulated for 24 hours, seven days a week, during this period.

Vehicles were classified according to the following definitions:

1. Cycles, carts: Small vehicles with no motor or small motors such as bicycles, motorcycles, scooters, pedicabs, hand-carts, and animal-carts;
2. Motorcycles: Small two-wheel motor vehicles with engines above 50 cc (black plate with yellow numbers);
3. Tri-wheelers: Small motor vehicles with three wheels, mostly for cargo;
4. Autos: Medium size private motor vehicles with four wheels to carry up to nine persons (red plate with white number);
5. Taxis: Medium size commercial motor vehicles with four wheels to carry up to five persons (white plate with red number);
6. Buses: Large motor vehicles with six wheels to carry ten persons or more (blue and white plate);
7. Light trucks: Medium size motor vehicles with four wheels to carry cargo (red and white plate, up to 3.5 tons gross weight);
8. Heavy trucks: Large motor vehicles with six wheels to carry cargo (blue and white plate, over 3.5 tons gross weight);
9. Special: Cranes, tractors, etc., not classified above;
10. Military: Military vehicles, subdivided also according to the above listed vehicle types 4, 6, 7, 8 and 9.

Some vehicle types were combined and reclassified as follows:

Types 1+2+3	Classed as small vehicles or Class B vehicles
Types 4+5	Classed as autos
Types 4+5+7	Classed as medium size vehicles
Types 7+8	Classed as trucks
Types 6+8	Classed as large vehicles
Types 4+5+6+7+8	Classed as Class A vehicles

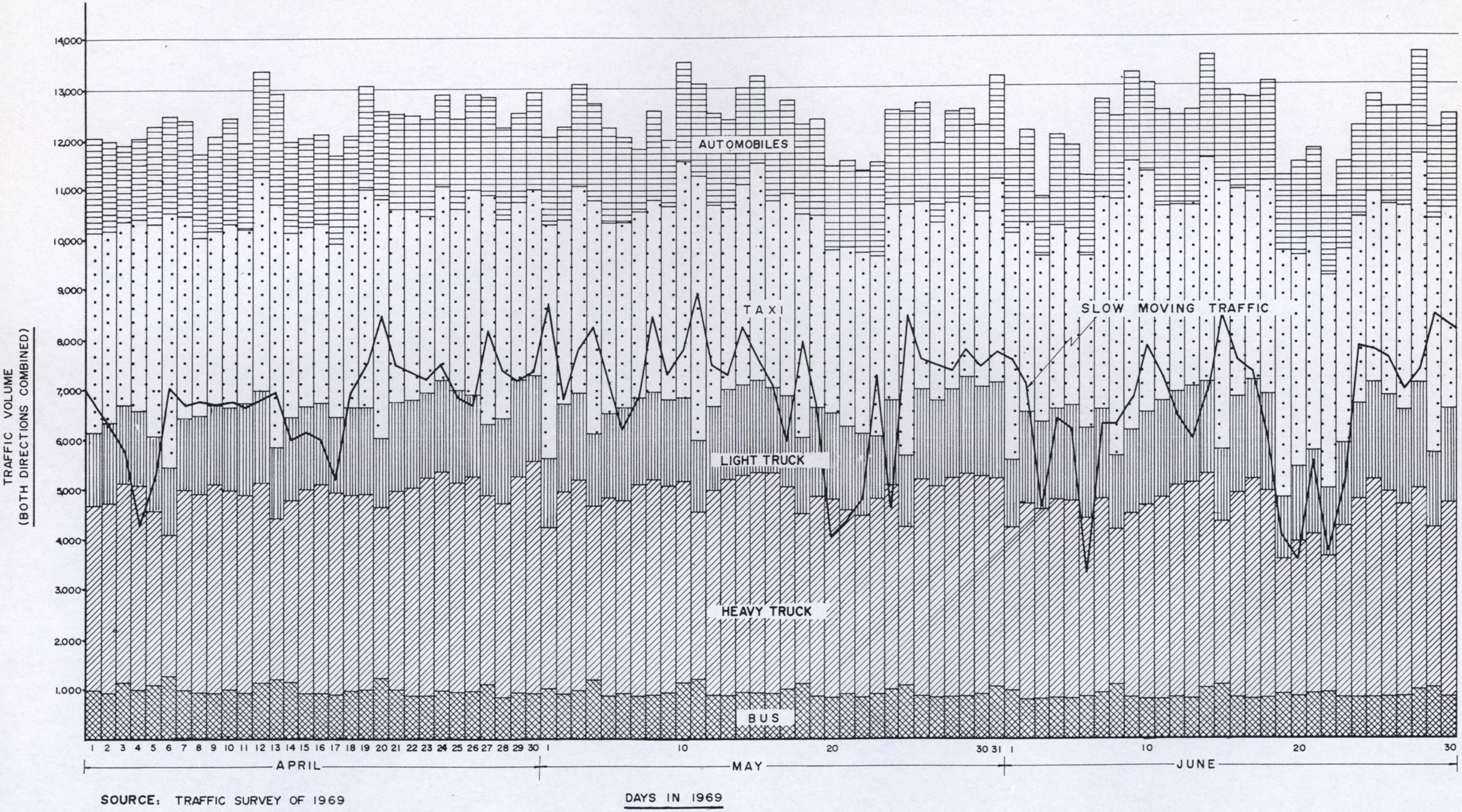
Daily traffic in both directions averaged some 18,000 Class A and Class B vehicles. There were about 35 percent Class B vehicles and 65 percent medium and large Class A vehicles. Among the 12,000 Class A vehicles daily, there were about 15 percent autos, 33 percent taxis, 8.0 percent buses, 12 percent light trucks, 31 percent heavy trucks and 1.0 percent special vehicles. Military vehicles accounted for only 6.0 percent of the Class A traffic and were not analyzed separately, therefore, but combined with the corresponding civilian vehicle types.

The daily variation in volumes of each vehicle type during the three-month survey is illustrated in Exhibit IV-4. Total traffic was relatively stable, while truck and auto traffic fluctuated visibly. The weekday summary (Table IV-2) indicates that total traffic on Saturdays and Sundays was about as high as on other days of the week, but that there are fewer trucks and more autos. The number of trucks was about 20 percent lower on Sundays than on weekdays. For the other vehicle types, the weekday traffic can be considered as representative of annual average daily traffic (AADT). Adjustment of survey results by weekday factor would be negligible since a six-day work week is customary in Taiwan while people engaged in agriculture, small trades and services also work on Sundays. Only large industries and administrative offices observe a general Sunday recess.

An analysis of hourly traffic indicated that traffic peaks occur around 9:00 a.m. and 6:00 p.m., but traffic volumes remained high between these peaks. Traffic flow was also quite heavy at night, especially for long-distance trucks. Traffic flow was lowest around 4:00 a.m. This is typical of rural areas with long working hours. The one-way peak hour traffic amounted to seven percent of daily one-way traffic. The three-hour peak equalled 20 percent of average daily traffic.

DAILY TRAFFIC VARIATION

Exhibit IV-4



SOURCE: TRAFFIC SURVEY OF 1969
DATE: APRIL — JUNE 30
LOCATION: TALIAOKAN, TAIPEI HSIEN

Two-way peak hour traffic was only six percent of daily traffic. The hourly variation in traffic by vehicle type for one typical day of the three-month survey is illustrated in Exhibit IV-5. These seasonal, daily and hourly characteristics of traffic, which are typical for Taiwan, influenced the preparation and carrying out of the origin-destination survey by roadside interviews.

Truck Capacity

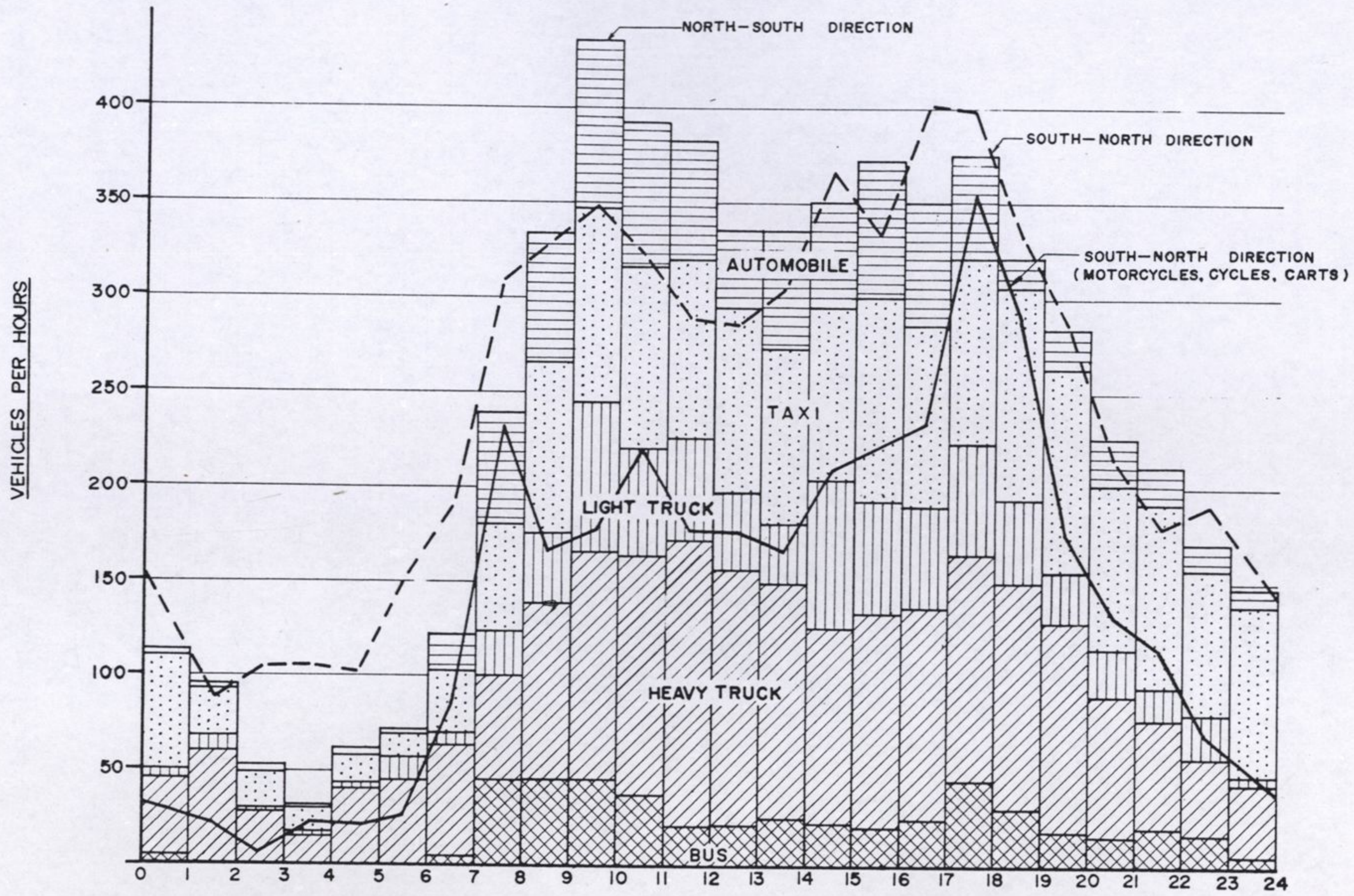
A short survey of truck capacities was performed separately. The tonnage painted on the door was recorded for each truck by type during 24 hours on May 2, 1969 in one direction. The two survey locations were the Hwa Chiang bridge southwest of Taipei and the MacArthur Thruway. These locations are representative of suburban and freeway conditions, respectively, and toll stops at each point permitted accurate readings.

The most frequently observed truck type had a capacity of 7.0 tons. Such trucks accounted for one-third of all trucks surveyed. Trucks with a load capacity of 6.0 tons were the next most frequent, followed by those with a capacity of 2.0 tons. The remaining trucks surveyed had capacities ranging from 0.1 tons to over 9.0 tons. The percentages of trucks by capacity by location were as follows:

Load Capacity in Tons	Location: MacArthur Thruway	Location: Hwa Chiang Bridge
0.1 to 1.9	9.4%	10.0%
2.0 to 2.5	10.3	16.6
2.6 to 5.5	10.3	13.8
6.0 to 6.5	34.8	26.4
7.0	34.2	28.2
over 7.0	1.0	5.0
Total	100.0%	100.0%

HOURLY TRAFFIC VARIATION
TYPICAL WEEKDAY

Exhibit IV-5



SOURCE: TRAFFIC SURVEY OF 1969
DATE: TUESDAY APRIL 8, 1969
LOCATION: TALIAOKAN TAIPEI HSIEN

There are presently very few three-axle trucks with more than six wheels in Taiwan. Light and heavy trucks were defined for the O-D survey as cargo vehicles with four wheels versus six wheels or more. For registration they are defined by gross weight up to 3.5 tons or above 3.5 tons, which determines the red or the blue license plate. This limit corresponds to approximately 2.5 tons load capacity. Only about five percent of all trucks surveyed weighed more than 3.5 tons.

Generally, there are now about one-quarter light trucks and three-quarter heavy trucks on rural highways in Taiwan. Near cities, small trucks become more numerous, as illustrated by the Hwa Chiang bridge. In cities, small trucks predominate.

Origin-Destination Survey

The Taiwan Highway Bureau conducted a limited origin-destination survey in 1963. Data had been analyzed to determine the amount of through traffic and trip purposes. It was not useful to update that survey, due to the unusually rapid traffic growth and shifting of traffic patterns. An entirely new origin-destination survey, therefore, was included in the project program.

Roadside interviews and counts were conducted at 37 locations throughout the study corridor in April 1969. Traffic at each station was counted continuously by direction for three days. Monday through Wednesday or Thursday through Saturday. Vehicle drivers were interviewed during at least 24 hours in the middle of the three-day period, either on a Tuesday or on a Friday.

Crews of five to ten men counted all vehicles and interviewed a sample of 30 to 100 percent of the autos, buses and trucks. Vehicles of all kinds, except small two and three-wheel vehicles and the scheduled buses, were stopped. The drivers and passengers were asked about their trip origins, destinations, and purpose of trips. The vehicle type and number of occupants were noted as well as cargo tonnage and commodity carried by each truck.

Exhibit IV-6

STATION AND SCREENLINE LOCATIONS
1969 TRAFFIC SURVEY

The survey stations were located on major arterials along the study corridor at selected screenlines. These were at each hsien (county) limit, and at some intermediate points or city limits (Taipei, Tainan, Kaoshiung). The arterials concerned were Highway No. 1 and usually one parallel rural highway of importance (Highways 3, 5, 117 or 145). Provincial Highway No. 3, at the edge of the corridor, carries very little traffic, because it has steep grades and the mountain is unpaved. The stations are listed on Table IV-3, with their number, location and traffic volumes. They are indicated on Exhibit IV-6 with the hsien limits and sector limits.

The exact procedures for the survey were prescribed in instructions specially prepared for this purpose, containing all pertinent details, and distributed in Chinese by the THB. Training sessions were conducted with THB staff engineers in each of the four engineering districts, explaining the O-D survey instructions and the usage of the printed survey forms. Section engineers conducted the survey with local personnel with the general assistance of the Consultant.

The interview survey program was fulfilled on schedule between April 7 and April 30, 1969. Special dispositions were required only near Taipei due to very high traffic volumes and some manpower shortages.

All data from each interview had to be coded for subsequent analysis by computer. A code was prescribed with each classification of vehicle type, trip purpose, and commodity in the written instructions. Origins and destinations were coded according to a list of administrative districts.

Geographical subdivisions of the study area were carefully examined to determine the most practical system of assigning traffic zones. There are 11 hsiens which are politically subdivided into 11 to 36 administrative districts (Chen or Hsiang). These were each assigned a coded designation starting with a letter for each hsien, followed by a digit for the engineering district, and a double digit consecutive numbering for zones within each hsien. This system

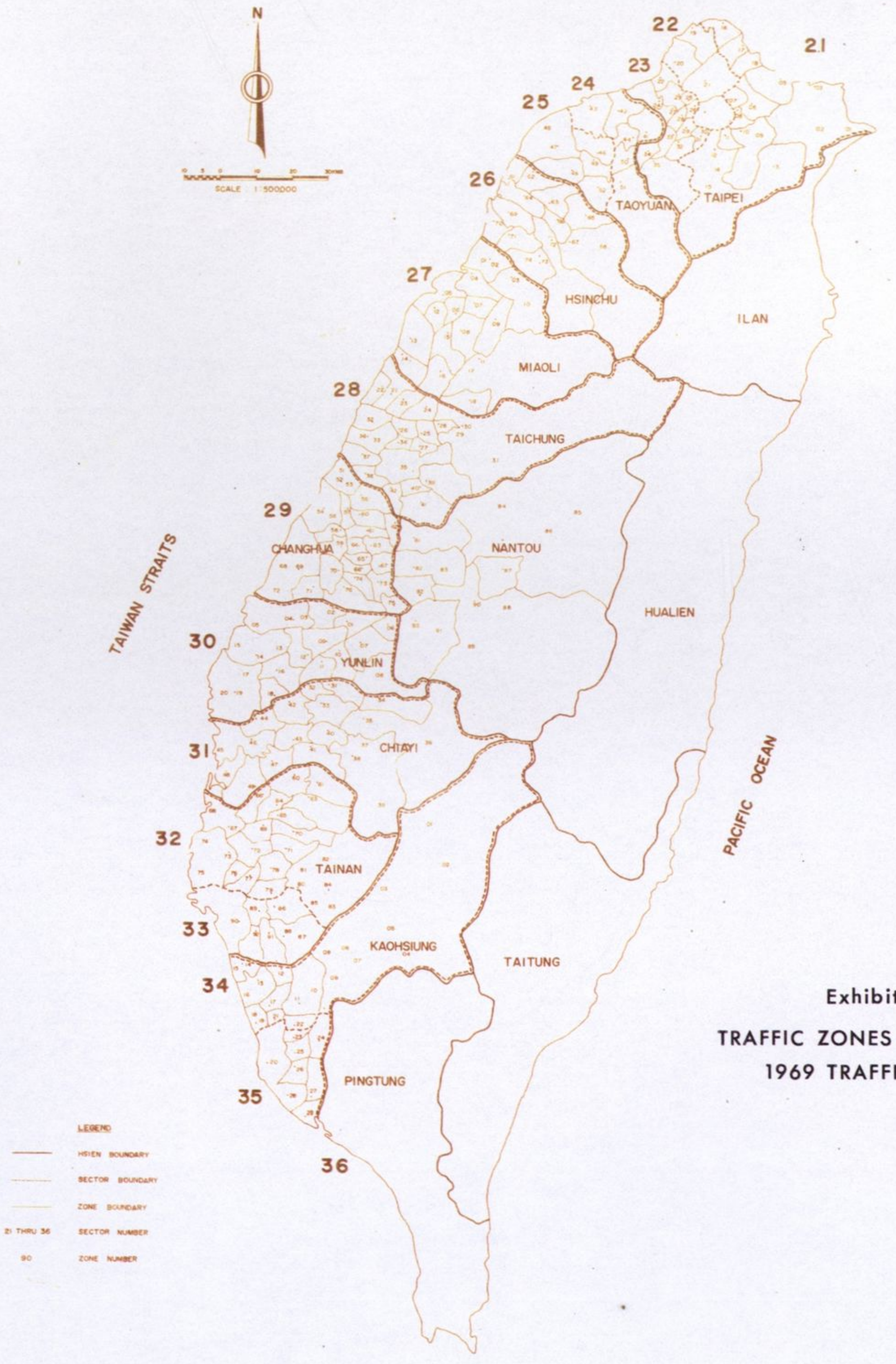


Exhibit IV-7

TRAFFIC ZONES AND SECTORS
1969 TRAFFIC SURVEY

is clear and flexible, and it has been an effective tool for other statistical studies; it proved to be a practical method to check location coding. The administrative district and hsien numbering system is indicated on Exhibit IV-7.

Later, some small administrative districts were grouped. The resulting traffic zones were recoded by computer to consecutive numbers 1 to 183, as required for traffic simulation programs. These numbers appear later on Exhibit IV-8.

Four large hsiens (Taipei, Taoyuan, Tainan, Kaohsiung) were divided into sectors by the screenlines which pass through survey stations and follow boundaries of zones. This resulted in 15 sectors, numbered 21 to 35. Their boundaries were formed by the 15 screenlines numbered 1 to 15, by the coast, and by the mountain ranges. These geographical subdivisions are also illustrated on Exhibit IV-7.

The interview forms were coded by the survey crews and reviewed by the crew chief for clarity. The codes were then checked by specially trained THB staff engineers for completeness and reliability. Interviews which were not complete or did not seem logical were eliminated. Thus, the quality of the interview sample was assured.

At each of the 37 stations, traffic was counted in each direction by vehicle type for 72 consecutive hours. The hourly totals were summarized for three days and the average daily traffic was calculated in each direction.

Analyzing each of the two directions separately throughout the entire simulation made it possible to check deviation and detect possible arithmetic errors. The two values should logically be very close. Their difference is a measure of accuracy and survey reliability of the data, which was found to be satisfactory. Both directions were combined on many tables in this report for simplification.

Traffic volumes with and without motorcycles are listed by station in Table IV-3. Traffic with motorcycles in 1969 is not comparable with traffic in 1968,

Origin-Destination Survey

because it also includes bicycles and carts not counted in 1968. Traffic without motorcycles is comparable and shared in the general traffic increase throughout the country.

Traffic composition by vehicle type shows an average of 38 percent autos, 12 percent buses, 12 percent light trucks, and 38 percent heavy trucks. The composition varies by station, depending on its proximity to a city--where there are more autos, light trucks, and local stop buses than in rural areas.

Peak-hour two-way traffic as a percentage of daily traffic was found at the survey stations to vary from 6.0 to 8.7 percent for all vehicles. Traffic during the three peak hours accounted for 17.0 percent to 25.5 percent of daily traffic. This showed that the traffic peak was not excessive in any one hour, but rather was spread over several hours, as was also indicated by continuous count station data.

Data by vehicle type at all stations revealed that auto traffic had a higher peak and bus traffic a lower peak than all vehicles combined. But these and the truck traffic characteristics varied according to the location of the station, and especially to proximity to single large traffic generators--either industrial, residential, or urban centers.

Small vehicle traffic--motorcycles and other cycles and carts--showed similar peaking characteristics at the survey stations. They averaged 4.3 percent to 9.7 percent of daily traffic during the peak hour, and 12.2 percent to 27.4 percent during the three-hour peak period. The peak occurred at the same period as that for medium and large motor vehicles, thereby affecting the highway's capacity at the most critical time.

ANALYSIS OF SURVEY RESULTS

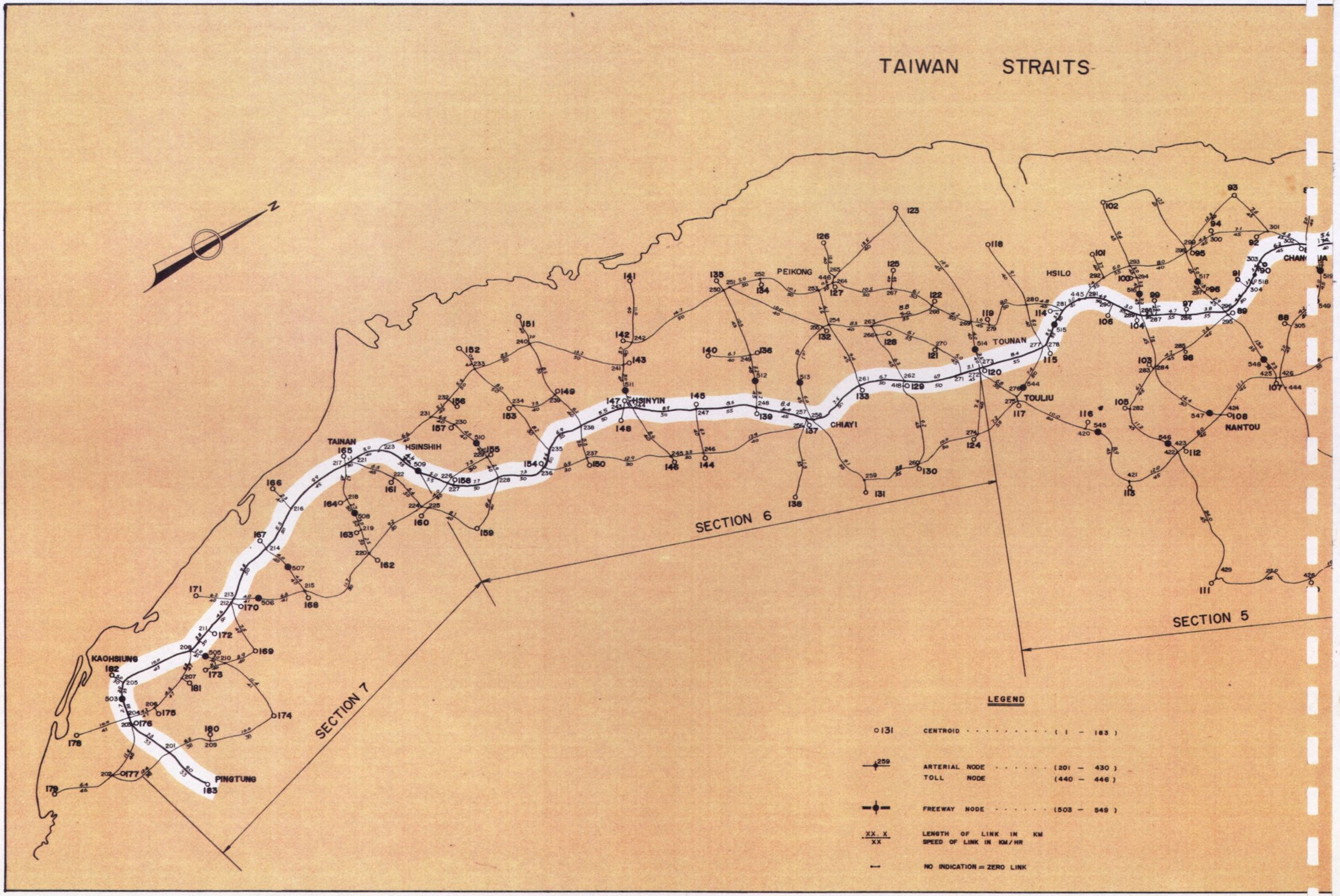
After preliminary analyses of data from all stations, interviews from some of the stations were not further analyzed by computer. It is customary to survey at a few more locations than finally required for simulation, for three reasons: to train survey crews; to assure sufficient data for the specific survey; and to gain additional data for related analyses.

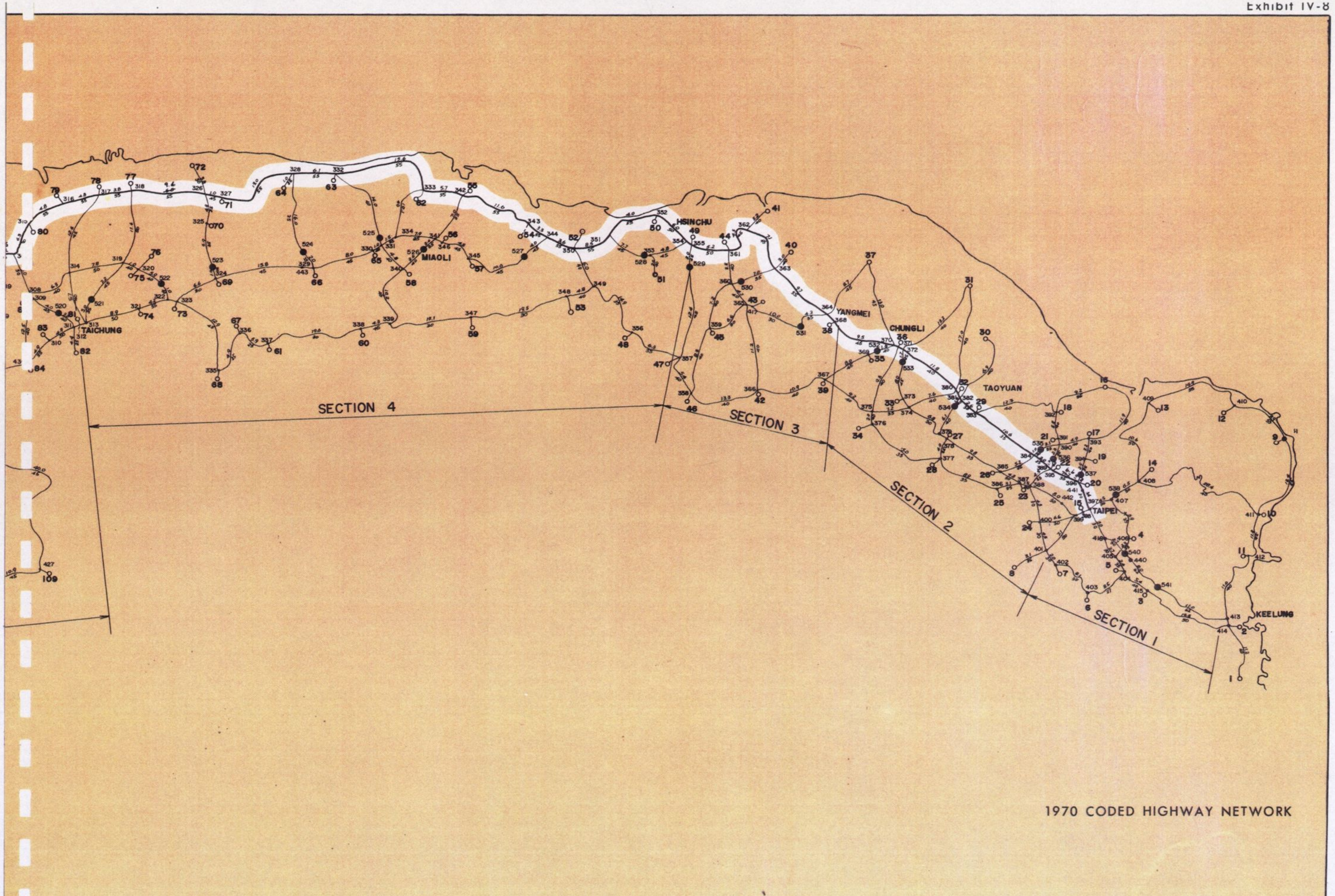
Among the 37 survey stations, the 24 most important stations were further analyzed by computer and the data used as a basis for the simulation of present and future traffic. Ten stations around Taipei (old city boundary) were analyzed manually to determine the through-trip pattern. Two stations were also used to calculate traffic diversion between Highway No. 5 and the MacArthur Thruway.

Taipei Cordon Traffic

The ten stations on the old boundary of Taipei City control vehicle entry and exit. They form a complete cordon around the city. They are numbered 1, 3, 4, 4E, 5, 6, 7, 8, 9 and 10, and are located on or near bridges over the Keelung, Tamshui, Hsintien Chi and Shuang Chi rivers. Analyses of data from all of these stations will be useful for consideration of city bypass highways.

The O-D interviews, analyzed manually, yielded the following results. An average daily total of 65,000 vehicles and 132,000 bicycles, motorcycles and carts entered the city during the three survey days. In round numbers, there were 14,000 autos, 27,000 taxis, 9,000 buses, 7,000 light trucks and 8,000 heavy trucks. About the same amount of traffic left the city in a 24-hour period.


TAIWAN STRAITS
N
PEIKONG
HSILO
CHANGHUA
TOUNAN
TOULIU
NANTOU
HSINYIN
CHIAYI
TAINAN
HSINSHIH
KAOHSIUNG
PINGTUNG
SECTION 5
SECTION 6
SECTION 7
LEGEND
○131 CENTROID . . . . (1 - 183)
259 ARTERIAL NODE . . . . . . (201 — 430)
TOLL NODE (440 — 446)
FREEWAY NODE . . . . . . (503 — 549)
XX. X / XX LENGTH OF LINK IN KM
SPEED OF LINK IN KM/HR
NO INDICATION = ZERO LINK



1970 CODED HIGHWAY NETWORK

Traffic in Taipei

Only about 6.8 percent of the vehicles desired to pass through the city. These 4,460 vehicles included 330 autos, 750 taxis, 380 buses, 700 light trucks and 2,300 heavy trucks. About one-quarter of the heavy trucks, but only about one-fortieth of the autos, were driven through Taipei City. Drivers of cycles, motorcycles and carts were not interviewed, but it can be assumed that very few of these vehicles cross the city.

Through-trips, analyzed by zones of origin and destination at each station, were summarized by five major directions for all stations together. The result is illustrated on Exhibit IV-9. As expected from observation, movements between east and west were most numerous, with over 1,000 through-vehicles per day, followed by trips between north and west. Other through-trip groups included less than 500 vehicles per day.

This analysis of through-traffic indicates the need for a city bypass along the northern edge of Taipei.

Traffic Diversion Analysis

Two parallel highways connect Taipei and Keelung. These are the old Highway No. 5 through several small towns, and the new MacArthur Thruway, which is a wide controlled access freeway.

Traffic on each facility was surveyed during a full day at Stations 1 and 2. Data were analyzed by origins and destinations of autos, light trucks, and heavy trucks. Buses do not have a free choice, due to prescribed stops. Therefore, bus traffic was not analyzed for divertibility. Among the 3,430 vehicles surveyed in one direction, 63 percent of each of the three classes of vehicles traveled via the MacArthur Thruway and 37 percent via Highway No. 5.

On each facility, speeds were measured on several travel time runs, according to standard procedure. No relevant difference was found between average truck speed and average auto speed. Average speed on Highway No. 5 was found to be 45 kilometers per hour, and on the MacArthur Thruway, 55 kilometers per hour.

The tollway is 2.3 kilometers and 12.2 minutes of travel time shorter than the highway, but the toll charge is NT$ 5 for a medium size vehicle and NT$ 10 for a large vehicle. Total vehicle operating cost is NT$ 9 per auto and NT$ 6 per truck higher on Highway No. 5 than on the tollway, calculated as explained in Chapter III.

The relationship between cost difference and traffic volumes is important in diversion assignments and especially in toll revenue analyses. This study indicated that a nine percent average saving in operating costs resulted in an approximate 60-40 diversion between two parallel facilities for all vehicle types combined. A diversion curve was developed and later used for the toll analysis.

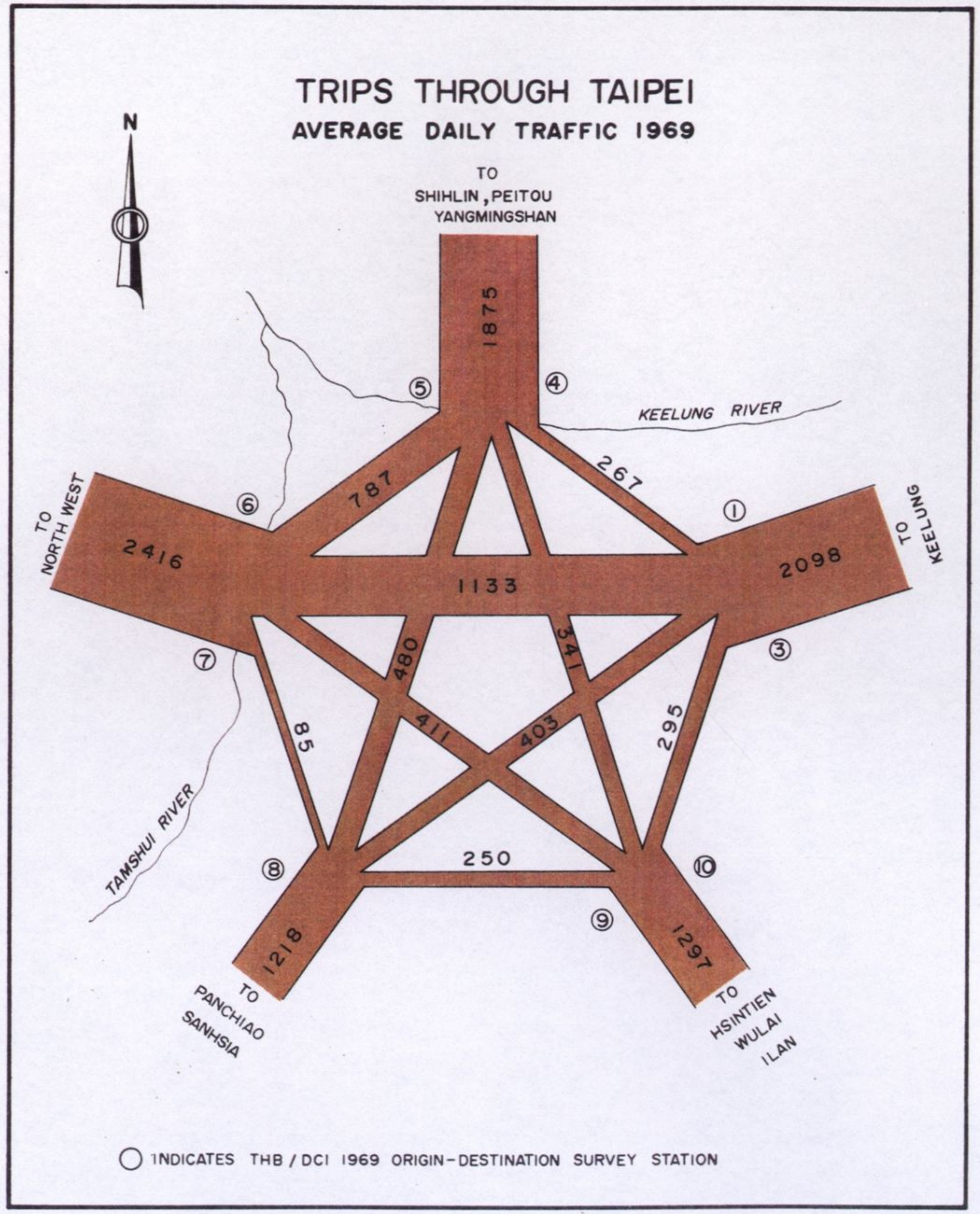
Computer Analysis of O-D Data

The origin-destination survey was analyzed with the help of a computer in Taipei. The interview data were punched and processed by China Data Processing Center under continuous supervision by the Consultant. Several programs were written especially for this study, but they could also be reused for a similar O-D analysis.

A simplified "work chart" (Exhibit IV-10) illustrates the work steps and their sequence. The interview data were first punched on cards, tabulated, and checked, then loaded on a tape for easier processing. Sample factors and multiple crossing factors were added, and after the necessary checks had been made, the trip table tape was produced and sent to the Consultant's computer center in Chicago for further computer simulation.

The coded data from interview forms were punched on cards at a rate of 10,000 interviews per day during 20 days for a total of 196,600 interviews. This work step was performed while other interviews were still being made, and was finished shortly after the interview period.

Exhibit IV-9



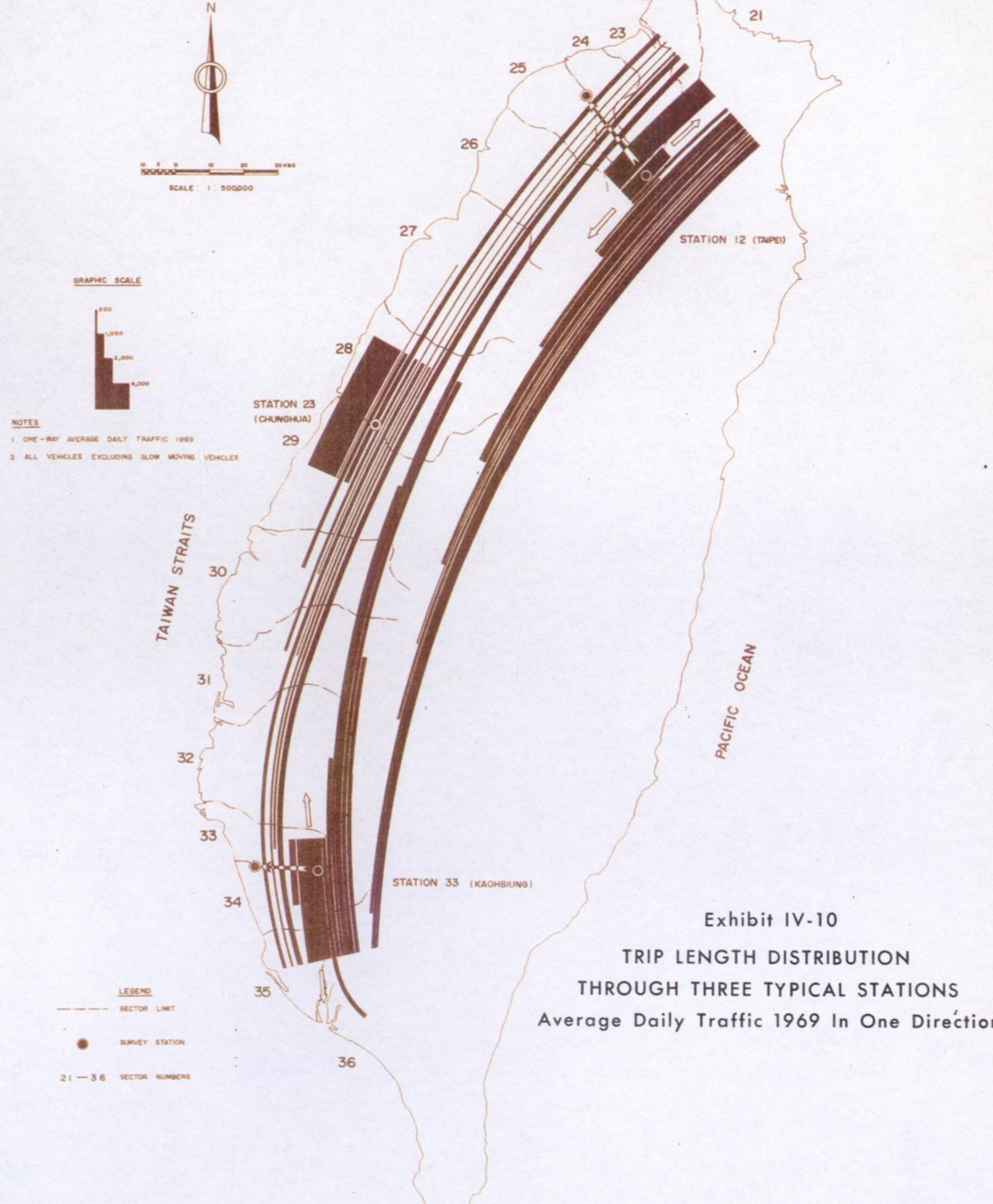
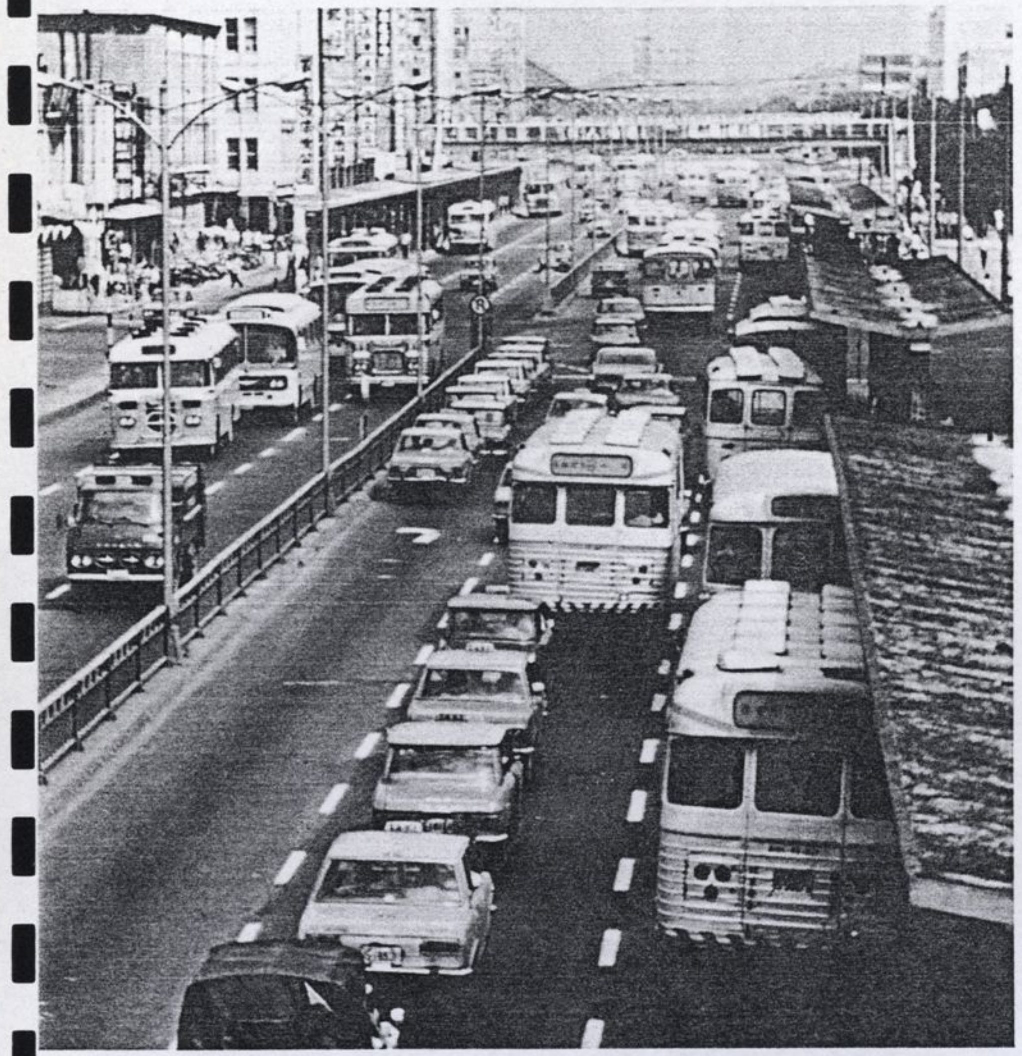


Exhibit IV-10

TRIP LENGTH DISTRIBUTION
THROUGH THREE TYPICAL STATIONS
Average Daily Traffic 1969 In One Direction



Traffic in Taipei

Successive tabulation by station, direction and hour allowed complete visual checking of all punched informations by THB engineers. Errors were corrected by repunching or eliminating some of the cards.

The valid interviews of the 24 selected stations were loaded on one computer tape in sequence by station, direction, and hour. Simultaneously, the codes for administrative districts were replaced by zone-centroid codes 1 to 183, and the sector codes 21 to 36 was also added for each origin and destination. The information was then sorted on another tape by the five vehicle types; autos, taxis, buses, light trucks, and heavy trucks. A listing of the 112,000 vehicles interviewed was compared with manually calculated summaries from original interview forms to confirm that the loading was complete.

The interview data were analyzed separately for each of the 24 stations by direction. Averages and relationships were sought for vehicle occupancy, truck loads, and auto trip purposes. Various computer programs produced three tabulations, each by station and direction:

- Number of vehicles and occupants, by vehicle types;
- Number of trucks by type and tonnage by commodities; and
- Number of each trip purpose, by automobile and taxi.

Results are summarized below:

AVERAGE OCCUPANCY OF PASSENGER-VEHICLES

Vehicle Type	Average	Range of Station Average
Auto	3.4	2.7- 3.9
Taxi	3.6	2.7- 4.9
Average-- Auto and Taxi	3.5	2.7- 4.7
Tourist Bus	41.7	27.8-46.4
Express Bus	30.2	20.0-33.7
Local Bus	31.1	19.0-35.3
Other Bus	21.5	12.2-40.0
Average-- All Bus Types	31.3	21.9-38.7

OVERALL AVERAGE TRUCK LOADS IN TONS
(All Commodities Combined)

	Light Trucks	Heavy Trucks	Combined
Average load (including empty trucks)	1.1	4.3	3.6
Average cargo load (excluding empty trucks)	2.1	5.9	5.3
Percent empty trucks	47%	27%	32%

OVERALL TRIP PURPOSE DISTRIBUTION
AUTOS AND TAXIS

Trip Purpose	Autos	Taxis	Combined
Home	32%	39%	37%
Work	37	23	26
Personal Business	18	27	25
Leisure and Other	13	11	12

At each station, interviews were made of a controlled sample of traffic, by direction, which had also been simultaneously counted. The number of valid interviews by vehicle type loaded on the computer tape was compared with the number of counted vehicles.

The data were expanded to average 24-hour traffic based on the three-day count. This operation was performed separately for three vehicle categories. Number of autos and taxis was expanded by a common average factor, and number of light and heavy trucks was expanded by a second common factor, in order to eliminate possible inaccurate classification in the traffic count. Buses were factored separately.

Most of the resulting 144 sample factors were close to 1.00, which represented a complete sample. Some were even lower than 1.00, since the actual traffic volumes on the day interviews were conducted were larger than the three-day average daily traffic. The highest factors were approximately 2.00, representing a 50 percent sample, for autos on Chungshin bridge. The bus factors over 3.00 at station 12 were due to no record of scheduled buses, which was corrected later.

The various factors were merged by computer onto the corresponding taped interviews. A new tabulation of the expanded records was checked and found to simulate correctly the counted traffic at each station by direction.

A special analysis was made for three typical stations to determine trip-length distribution. The vehicle types were sorted by origin and destination sectors. The volumes moving between each pair of sectors are shown on Exhibit IV-11 separately for the stations west of Taoyuan, south of Taichung, and south of Tainan.

Short trips are much more numerous than long trips. The number of trips between sectors is also influenced by the importance of the two sectors. Such characteristics were simulated by the subsequent computer forecasts.

It is important to note that an O-D survey at roadside stations cannot simulate trips which do not pass through one or more stations. Short trips within sectors--less than 15 kilometers in length, for example--and transversal trips (usually east-west across the general freeway alignment) were not surveyed and are not represented in subsequent data. Data on such trips are not necessary for analysis of North-South Freeway traffic since such trips would not use the freeway. They are pertinent, however, to improvements of transversal and feeder highways, and especially to urban transportation planning.

Long-distance trips along the study corridor passed through several survey stations. While not all drivers were interviewed more than once, the O-D data at all stations would statistically contain too many duplicate interviews for use without application of correction factors.

A trip is defined as one movement between origin and destination points, without major interruption, for one general purpose. A round trip is considered as two separate trips in opposite directions. A long trip with a major activity at an intermediate stop is also considered as two separate trips. In the study, the term "trips" normally applies to vehicles. The term refers to trips of persons only when so specified.

Interviews at all stations were sorted by pairs of origin and destination sectors. The number of screenlines between each pair of sectors represented the theoretical multiple recording of identical trips. Each interview, therefore, was given a weight inversely proportional to the multiple screenline crossings. A factor of 1.0 was applied to trips between neighboring sectors. Trips between Taipei and Taichung, for example, theoretically recorded at six stations, were factored by 0.16, and very few long distance trips were factored by 0.07.

The multiple crossing factor and the sample factor for each interview were multiplied and used as final factors. Interview data were weighted by the final factor in combining data from all stations to build trip tables.

The computer programs tabulated the totals for autos, buses, light trucks and heavy trucks between each pair of origin and destination sectors. Rectangular trip tables were built for these four basic vehicle types. Both directions of travel were then combined and summarized as triangular trip tables. These tables were used for manual calculations and screenline checks.

Trip volumes represented graphically in bands of proportionate width between each pair of sectors are called "desire lines". Exhibit IV-12 shows such desire lines for each vehicle type. This exhibit facilitated visual evaluation of traffic demand between sectors.

Screenline volumes were calculated by combining all trips between various sectors which crossed the same screenlines. Each screenline volume by vehicle type was compared with the traffic counts of the corresponding screenline. The volumes by vehicle types are listed on Table IV-4.

All computed screenline trips combined were only two percent lower than all traffic counts combined. This is very satisfactory, considering the various sample factors and multiple crossing factors involved. At each screenline individually, number of computer-simulated trips corresponded within a few percent to counted traffic. Some differences were explained by inaccurate station location and subsequent elimination of trips within sectors. In the Taoyuan area, however, regularly scheduled buses were not recorded by the survey crew. These data were reconstituted from schedules and counts, and then inserted into the trip table.

For an average day in 1969, the tables showed the following total traffic by type between sectors of the study area: 36,700 auto trips, 10,910 bus trips, 10,940 light truck trips, and 20,430 heavy truck trips for a total of 78,980 vehicle trips, excluding motorcycles.

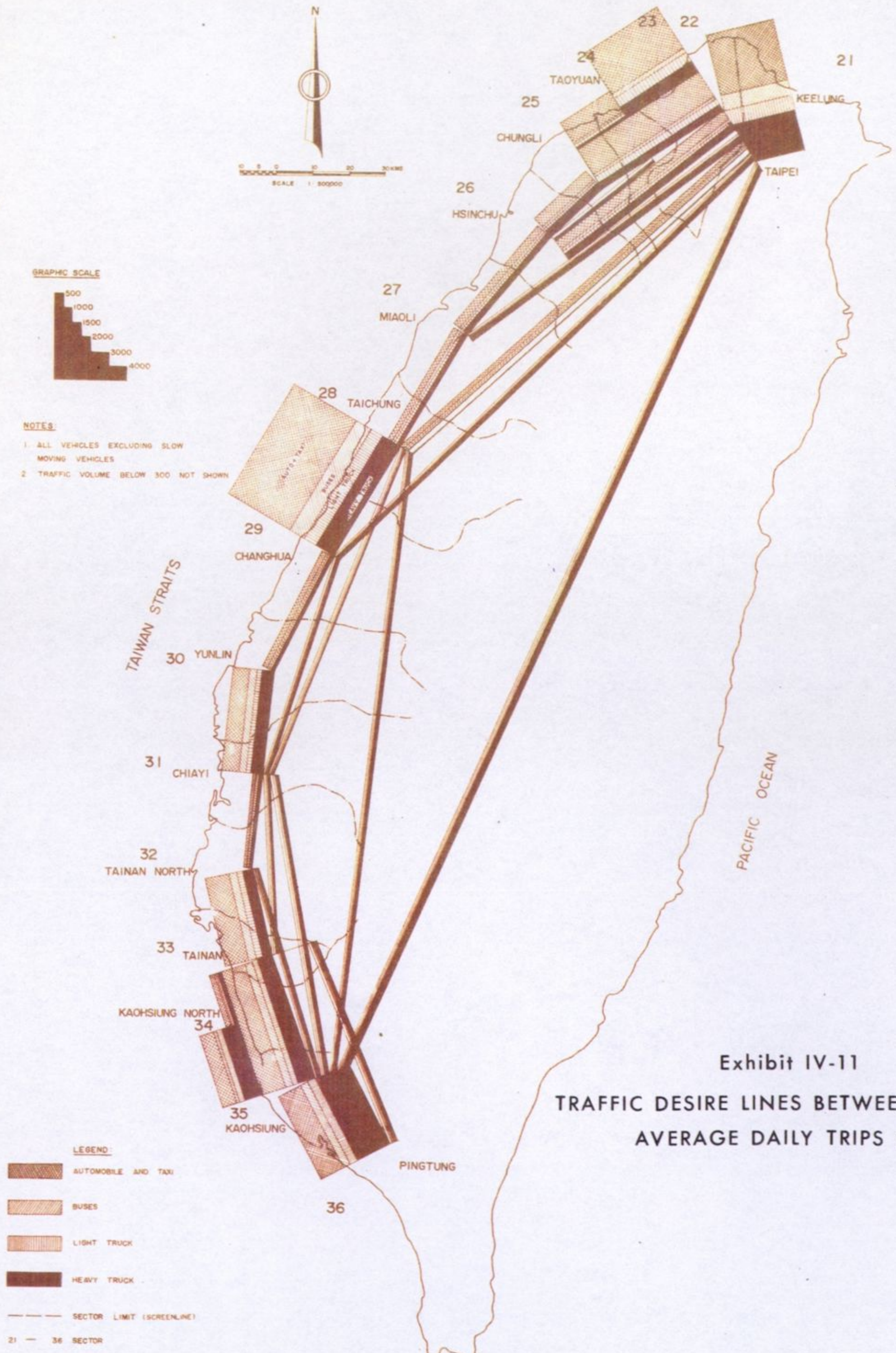
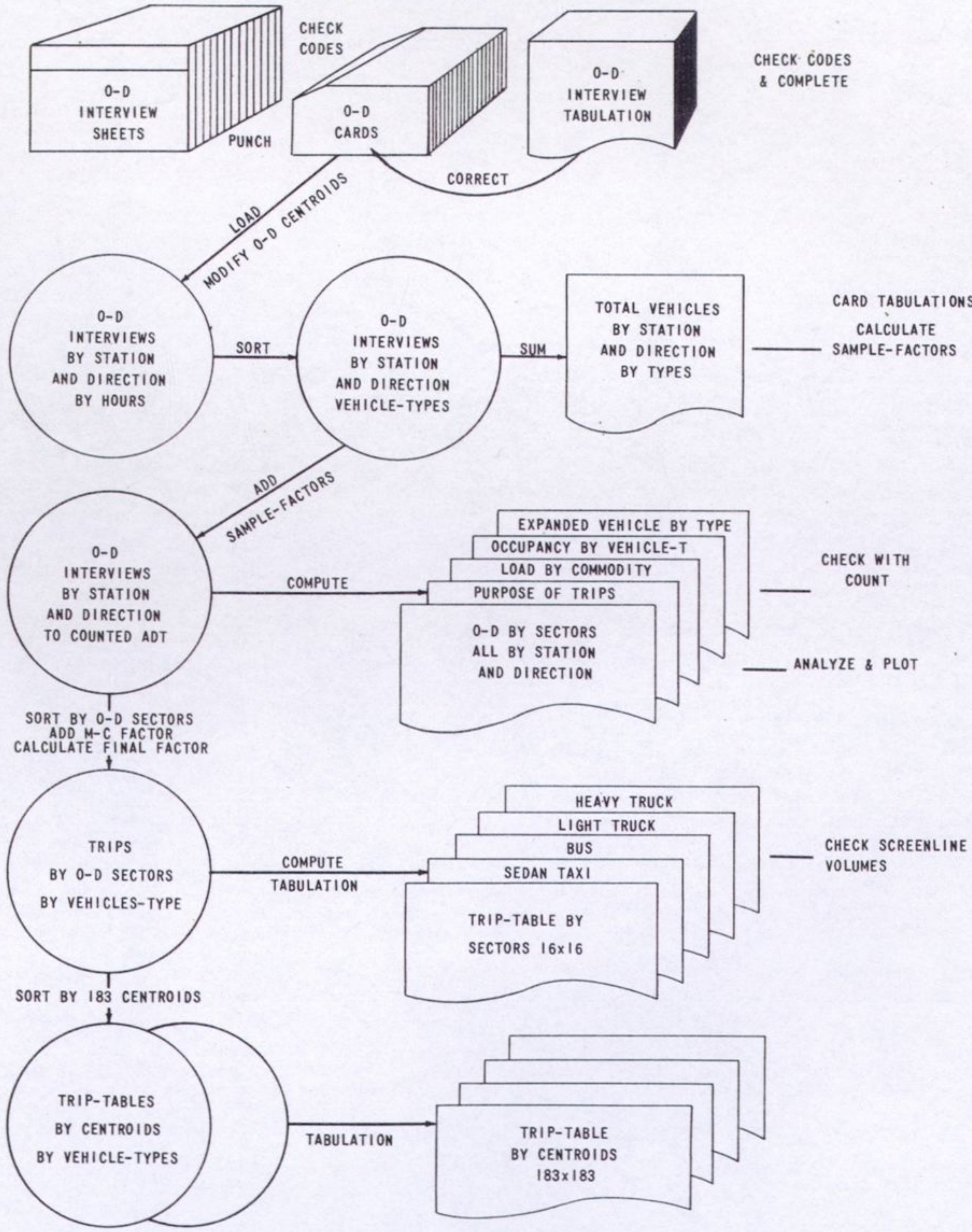


Exhibit IV-11

TRAFFIC DESIRE LINES BETWEEN SECTORS
AVERAGE DAILY TRIPS 1969

Exhibit IV-12

PROCEDURES FOR ANALYSES
OF ORIGIN-DESTINATION SURVEY RESULTS



Special consideration was given to an analysis of future utilization of the freeway by buses. Unlike drivers of other vehicles, the driver of a bus is not free to choose the fastest or cheapest route between origin and destination since he must make intermediate stops to serve his passengers. Local-stop buses, therefore, must be handled separately from express and other buses, which might use long portions of the freeway between widely-spaced stops. Breaking down bus trips into several short trips between intermediate stops was not warranted for this study.

The local-stop buses were sorted out by computer and found to account for 66 percent of the surveyed bus trip total. These buses usually traveled relatively short distances between adjacent sectors. Most local buses were operated by Taiwan Highway Bureau; a few systems were operated by bus companies. Local trips were not used in subsequent computer simulation, since they use only the highways. For capacity calculations, however, they were inserted manually at all highway intersections examined. In connection with forecasts, their growth was hand-calculated with one general factor and considered in capacity calculations relating to future highway conditions.

The remaining scheduled express buses or non-scheduled tourist, school or military buses, called here "E-Buses", accounted for only 3,740 daily trips between sectors. Their trip table by sector confirms that their travel distances are longer than those of local-stop buses.

A special truck cargo table was also produced by the computer for economic studies. It showed for each pair of sectors the total tonnage of each of the 24 commodities transported on an average survey day by light and heavy trucks combined.

Person trip tables were derived from auto and bus tables. In order to make them comparable with rail passenger tables by hsien, the sectors were grouped by hsien and trips within hsiens were eliminated. While it was easy to calculate auto passenger trips from auto trips and average occupancy, the bus and rail passenger estimates required special studies.

Buses making intermediate stops carry passengers between origin and destination points other than bus terminals. Express buses with few stops serve primarily long-distance passengers traveling between route terminals. A regular bus with many local stops, on the other hand, may handle many more passengers than its rated capacity during a bus one-way trip. These relationships were simulated manually in various special studies until a plausible bus passenger trip table was derived. It was not as accurate as the auto passenger trip table derived from direct interviews, but was adequate for estimating average modal split.

Rail-passenger trip volumes by origin and destination could not be derived directly from rail statistics. A simplified gravity model operation was performed manually to simulate a trip table. The number of passengers boarding or leaving each station within a hsien and the rail distance between centers of gravity were used for distribution by quadratic and by linear gravity formulae. Comparison of simulated passenger volumes and rail line volumes at the hsien limit made it possible to refine the trip table until the simulation appeared to be satisfactory.

On an average day in 1969, the total number of person trips between west coast hsiens from Keelung to Pingtung was approximately 64,000 by auto and taxi, 155,000 by bus, and 157,000 by rail. Numerous trips were made between neighboring hsiens while travel between distant hsiens was relatively low. The modal split averaged 18 percent by auto and 41 percent each by bus and by rail.

Estimated numbers of person trips between hsiens by various modes were later considered in forecasting future growth of travel demand by mode.

After various checks of survey data and the results of data processing, final 1969 trip tables were computed. Each interview, weighted by its final factors, sorted by vehicle type and by the 183 origin and destination zones, was accumulated into the zone trip tables.

The data were arranged in a special format required by the large computer simulation program. Six trip tables (autos, taxis, light trucks, heavy trucks, all buses, and E-Buses) were loaded on tape and tabulated. A duplicate tape was airmailed to Chicago as the basis for simulation of future traffic. Before making traffic assignments, auto and taxi tables were combined and all bus trip tables were eliminated from further study.

ASSIGNMENT OF 1969 TRAFFIC TO EXISTING HIGHWAY NETWORK

Coding of Existing Highway Network

The highway network within a study area must be defined and coded, so that its traffic patterns can be simulated by computer. The existing highways were studied to determine their function, jurisdiction, geometrics, and traffic volumes. A network was chosen for coding to fulfill the following criteria:

- Cover the area of influence of the freeway;
- Connect adequately all zone centroids;
- Represent all major highways accurately; and
- Minimize the number of links and nodes by combining parallel minor highways.

Committed improvements such as the new Tatu bridge and the Taipei bridge to be completed in 1969 were included. This network was titled "70" (Exhibit IV-8).

The coded network was composed of "centroids"--the centers of traffic zones; "links" representing highway sections defined by length and average speed; and numbered "nodes" representing major intersections. Each link was coded by its two nodes, its length, speed, toll if any, grade, jurisdiction (local, rural provincial, freeway), and study section.

While the lengths were determined from detailed highway inventory maps, the speeds had to be measured by trial runs. Speeds represent average daily traffic flow conditions. The average speeds of each of the four vehicle types were very similar except on highways with steep grades. For rolling and mountainous terrain, grade factors were introduced to adjust time and distance costs of operating trucks and buses.

Operating costs of each vehicle type with grade adjustment factors, as described earlier in Chapter III, were used for developing a cost network. The network was divided into seven sections to facilitate separate evaluations of economic return as well as to permit studies of alternatives and priorities. The sections, indicated on the overall network plan shown in Exhibit IV-8, were as follows:

Section 1 - Keelung-Erhchung

Section 2 - Erhchung-Yangmei

Section 3 - Yangmei-Hsinchu (included)

Section 4 - Hsinchu (excluded)-Taichung (excluded)

Section 5 - Taichung (included)-Tounan

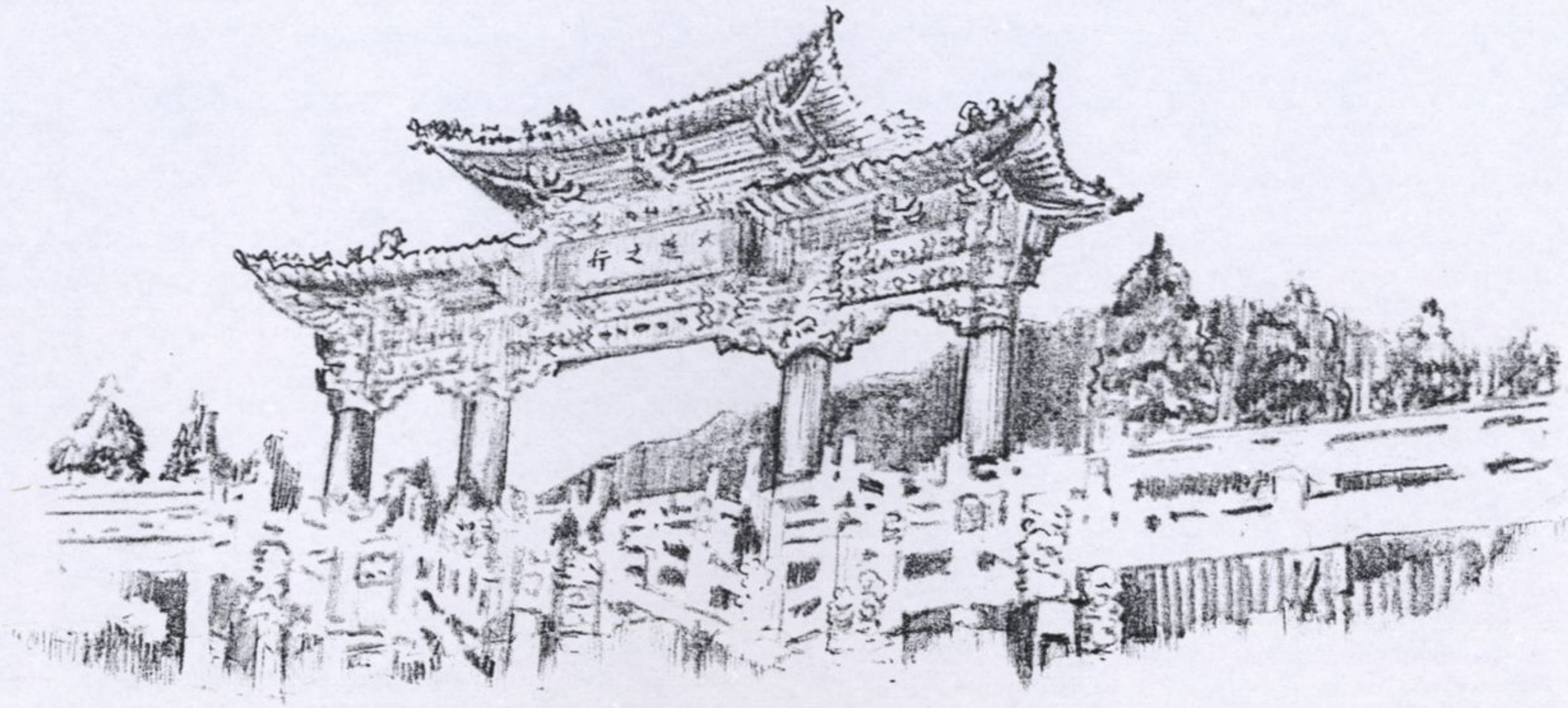
Section 6 - Tounan-Tainan (excluded)

Section 7 - Tainan (included)-Pingtung (excluded)

Such sections required some additional programming for this project, as did the toll links. Most other codes were conventional and the usual programs were applied.

Building and Testing Cost Networks

Simulation of traffic on highways is based on the fact that most vehicles travel via the routes that drivers deem to be the most economical. Thus, drivers strive to minimize travel distance and travel time, depending on their individual evaluations of distance and time costs. Drivers also consider tolls and delays due to traffic congestion.



The computer program determined for each pair of zones the minimum cost route. For three selected points (Taipei, Nantou, Tainan), the routes to any other centroids were printed out to be checked. These so-called "trees" for each vehicle type, a total of 12, were also drafted by the computer data plotter at a scale of 1:250,000. A visual check with THB engineers familiar with local driver habits and a comparison between the trees of various vehicle types made it possible to detect a few anomalies. Some link lengths, speeds, and/or grades were corrected by punching new cards after anticipated effects were carefully examined. Cost networks were then recomputed before assignments were made.

Assignment of 1969 Traffic

The 1969 zone trip tables were assigned to the coded committed highway network "70" by the "all-or-nothing" method. The computer performs such an operation by assigning each zone-to-zone traffic volume to the minimum-cost zone-to-zone route. The computer then accumulates total traffic on each link, by vehicle type.

The tabulated traffic assignment was checked at each screenline by comparison with the 1969 traffic count. It was found to be closer than ±10.0 percent at each screenline which was deemed to be satisfactory.

On parallel highways, the computer usually assigns more traffic to the better route than uses it, and less than actual traffic to the poorer route. This particularly of the "all-or-nothing" assignment program is a known small disadvantage, compensated for by its advantages.

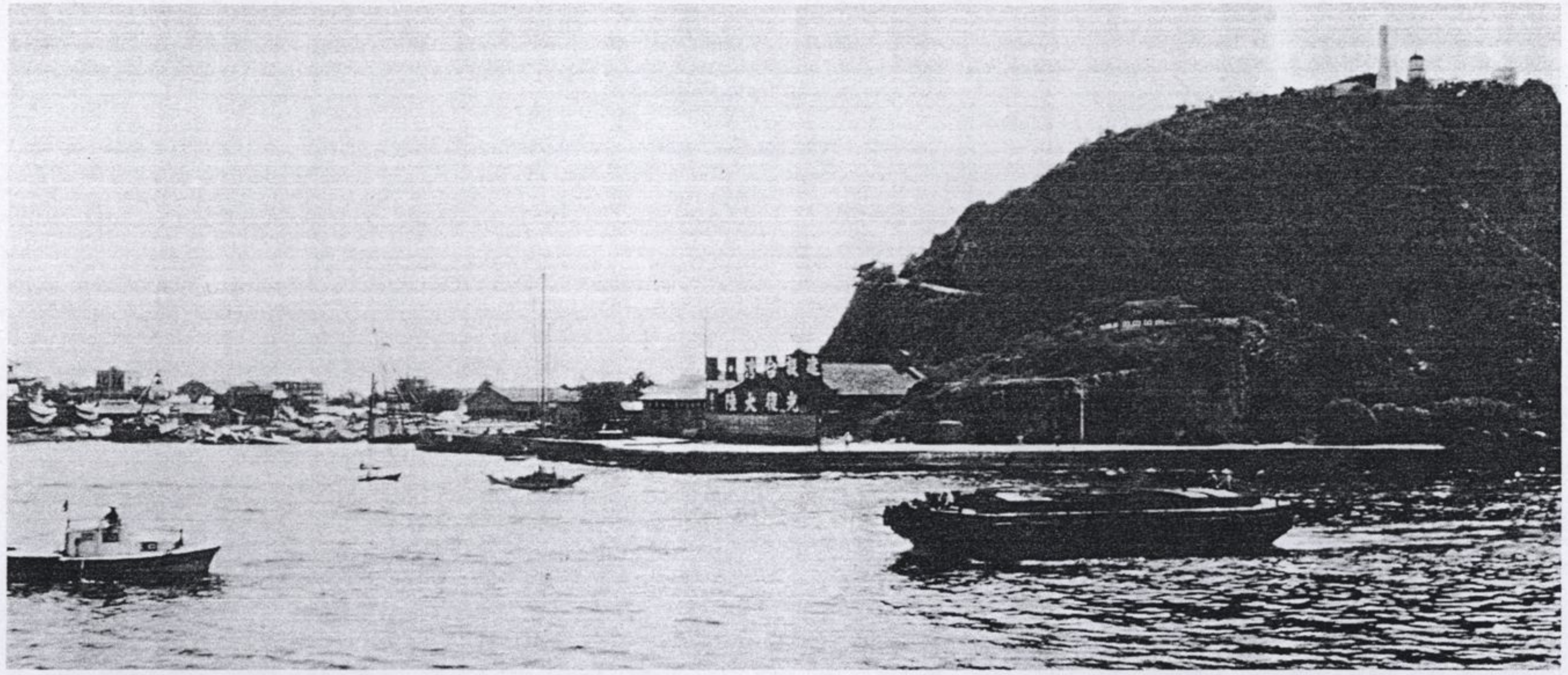
No further adjustments were necessary. The simulation of present traffic conditions proved that data and procedures were fully adequate. In addition, systems operation data were generated that could not practically be calculated manually. They are summarized on Table IV-5.

The computer accumulated--for all links within each of the seven sections separately--total vehicle-kilometers, vehicle-hours, and vehicle-costs for each of the four vehicle types. The average speed in kilometers per hour and the average cost in NT dollars per kilometer characterized all highway traffic combined in each section. This permitted an overall check as well as comparisons by vehicle type between sections.

chapter V

FORECAST OF ECONOMIC GROWTH AND FUTURE TRANSPORTATION DEMAND

FORECAST OF ECONOMIC GROWTH AND FUTURE TRANSPORTATION DEMAND



DESCRIPTION OF THE REGIONAL LAND USE PLANS

Land use in Taiwan is intensive and highly localized, particularly along the western plain. Historically, the land has undergone many types of utilization. These range from brushland to dry farming, from grassland to plantations producing bananas and tea, from subtropical hardwood forests to bamboo groves, and from sea beaches or sand flats to fish ponds. Since World War I, land use has had two distinct attributes. While acreage for food crops has increased, acreage for cash crops has decreased. The increased acreage and corresponding increase in agricultural production has resulted from the Government's implementation of a "land to tiller" policy. This policy of increasing agricultural production helped to stabilize urban growth by encouraging people to remain in rural areas. Even with this increase in agricultural production and the tendency for people to stay in the rural areas, however, the trend is toward industrial growth in metropolitan areas. This is particularly true for the northern, central and southern regional centers along the western plain.

Historical Review of Planning

The first urban planning in Taiwan was performed in 1896. This consisted of an investigation and a plan to improve the sanitation system for the City of Taipei. Shortly thereafter, a planning commission was formed which developed a building code and city plan for Taipei.

In 1935, a major earthquake struck the central portion of the island. While a catastrophe at the time, it brought about the preparation and application of 19 urban plans to rebuild the damaged areas. Two years later, the Japanese prepared regional and urban plans to facilitate development of industrial and defense works to meet the demands of the Sino-Japanese War. The Japanese continued to prepare urban plans up to the time of retrocession of the island. After retrocession, rapid urbanization took place. Out of the many urban plans grew three basic regional schemes covering the Taipei-Keelung, Taichung, and Kaohsiung areas.

Recent Planning Developments

In order better to cope with and solve the problems of urban and regional planning, the Government retained the services of several United Nations specialists. The Urban and Housing Development Committee (UHDC) was established in 1966 to render special consultation services. The Committee has conducted many worthwhile projects, among which are: reports on new town developments for the Taipei-Keelung and Kaohsiung regions; review of legislation for regional planning and preparation of recommendations; research on urban land problems; and preparation of a Taipei-Keelung Metropolitan Regional Plan.

Regional Planning for Western Plain

Geographically, the western plain is readily accessible for urban concentration, and the growth trend is concentrated in the three regional areas mentioned above. The western region contains the highest population density of the island, averaging 3,500 persons per square mile.

In discussions relative to descriptions of land utilization for these three regions, the various schemes will be referred to as the Northern, Central, and Southern Regional Land Use Plans. The basis for description of these land use plans is the previous work performed by UHDC. The description of the Northern Regional Land Use Plan is based on their Taipei-Keelung Metropolitan Plan. There are, at the time of this report, no up-to-date published regional plans for the central and southern areas. However, the UHDC staff has briefed the members of the Consultant's staff on the preliminary concepts developed by UHDC for these areas. The land use descriptions of these two areas are based on these briefings and on the other findings generated in preparing this feasibility report.

Description of Northern Regional Land Use Plan

The Northern Regional Land Use Plan contains the two major cities of the region, Taipei and Keelung. The region extends from Chungli in the south to Keelung in the northeast. Toward the southeast, the area is bounded by the Shihmen Reservoir and the Hsue Shan Mountain Range. The northwest area contains the Taoyuan Plateau, at an approximate elevation of 150 meters above sea level at the highest point, and the Linkou Plateau, at an average elevation of 250 meters above sea level. See Exhibit V-1.

The area included in this region comprises 250,000 hectares of land. The principal land utilization, with areas in hectares, are as follows: agriculture, 112,000; forest and mountains, 92,400; flood plain, 12,400; and urban areas, 33,000. Southwest of Taipei, the area is devoted predominately to rice paddy fields. The area to the south and northeast is predominately forested mountain land with slopes of 30 percent or more. Approximately 15 kilometers west of Taipei the land is used for growing tea.

Taipei, the capital city and center of tourism and industrial activity, is contained within such topographical restraints as the Keelung and Tamsui Rivers on the north, west and south, and by a formidable mountain range along the southeast. Its ultimate population will soon be realized. Population has already begun to move into cities and peripheral areas around Taipei.

In the ten-year period from 1950 to 1960, the region experienced a 68 percent increase in population. The suburbs of Taipei grew 126 percent, while Taipei itself grew 79 percent. Regional population presently is approximately 3,500,000. A 1990 population of 5,800,000 is projected by the Consultant.

Industrial growth is taking place largely in the peripheral suburbs of Taipei. Greatest growth has been in electrical manufacturing and chemically oriented industries. With the attractive labor market open to foreign business entrepreneurs, rapid growth is expected to continue, adding to the industrialization complexities of the area.

The future land use plan is shown in Exhibit V-2. The Tamsui River Basin, west of the Tamsui River, appears to be an ideal area for future population expansion. It has an average elevation of only 3.0 meters above sea level, however, and is highly susceptible to flooding. Hence, it may be preserved essentially for agricultural use. Additional cities slated for expansion are Tamsui, Yangmei, Chungli, Taoyuan, Neihu, and Shihlin.

Two important planned areas on relatively unpopulated land are on the Taoyuan and the Linkou Plateaus. The Linkou development has been approved by the Government and is planned to contain about 250,000 people by the year 1982. Still another new community is being planned in the Neihu area, near Sungshan International Airport. These expansion areas are being planned as self-supporting communities with industrial and commercial sites as well as residential areas. Undoubtedly, considerable commerce and travel will still take place between these new towns and Taipei City.

Description of Proposed Central Regional Land Use Plan

Contained within this west coast region are the two major industrial developing cities of Changhua and Taichung. The boundaries of the proposed Central Regional Land Use Plan are Tachia in the north, Poli towards the east, and Hsilo in the south.

This region comprises 216,000 hectares of land. The principal land uses are agriculture and forest land. Principal industries are sugar, textiles, chemicals, and paper and wood products. Taichung is the principal city in central Taiwan. It has become an important political center as the seat of the Provincial Government. Taichung is the central distribution point for the rice, sugar, and bananas produced in the central region.

Growth in the central region has been slower than that of the northern and southern regions. Exhibit V-3 shows locations of probable community and industrial developments. Population, presently 3,200,000, is expected to grow by 64 percent to about 5,250,000. With completion of the proposed third harbor at Wuchi, growth of this area will accelerate. The third harbor will permit a new approach to urban planning in a major population district seeking industrial and social growth. The Government is currently having a regional plan developed by UHDC. It is envisioned that this report will be similar to UHDC's Taipei-Keelung Metropolitan Regional Plan, and that it will cover in detail all phases of land use for this area.

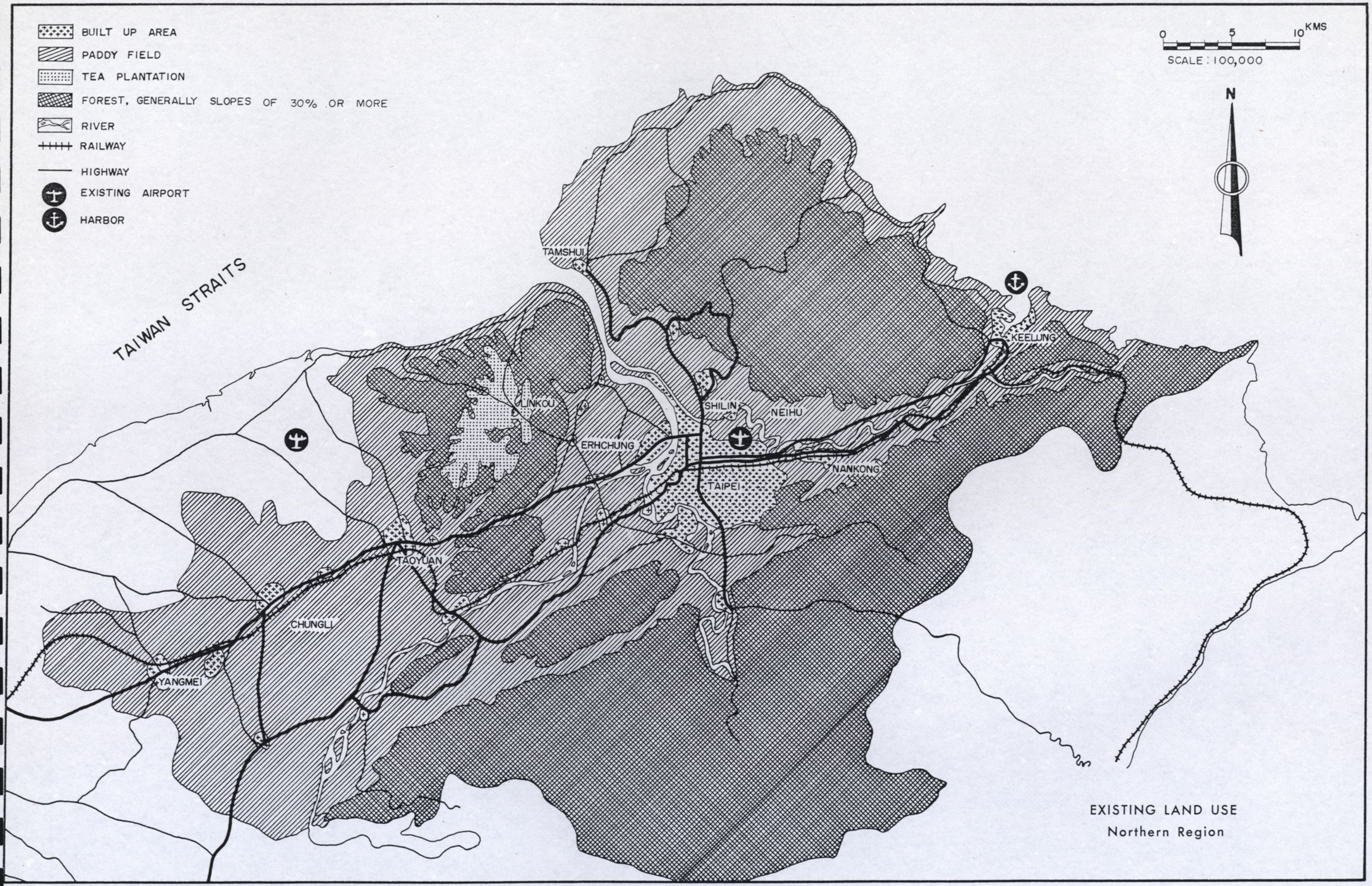
Description of Proposed Southern Regional Land Use Plan

Exhibit V-4 shows the proposed land use for Kaohsiung and the surrounding area. Boundaries of the proposed Southern Regional Land Use Plan are the cities of Yenshui in the north, Chishan towards the east, and Tungkong in the south. The area is approximately 356,000 hectares. Agricultural products include rice, sugar, and general farm crops. The primary importance of the region lies in import/export trade and industry. The present population of the region is 3,300,000 with 5,400,000 projected by 1990.

Proposed regional developments include improved highways, improvements to the existing airport for international travel, and Kaohsiung harbor expansion. The harbor expansion, begun in 1958 and scheduled for completion in 1975, calls for construction costs totaling US $95.3 million. Improvements consist of dredging and land reclamation, additons to wharves, and opening of a second entrance to the harbor. Details of regional land use are currently being prepared by UHDC. Their report will be submitted shortly to the Government.

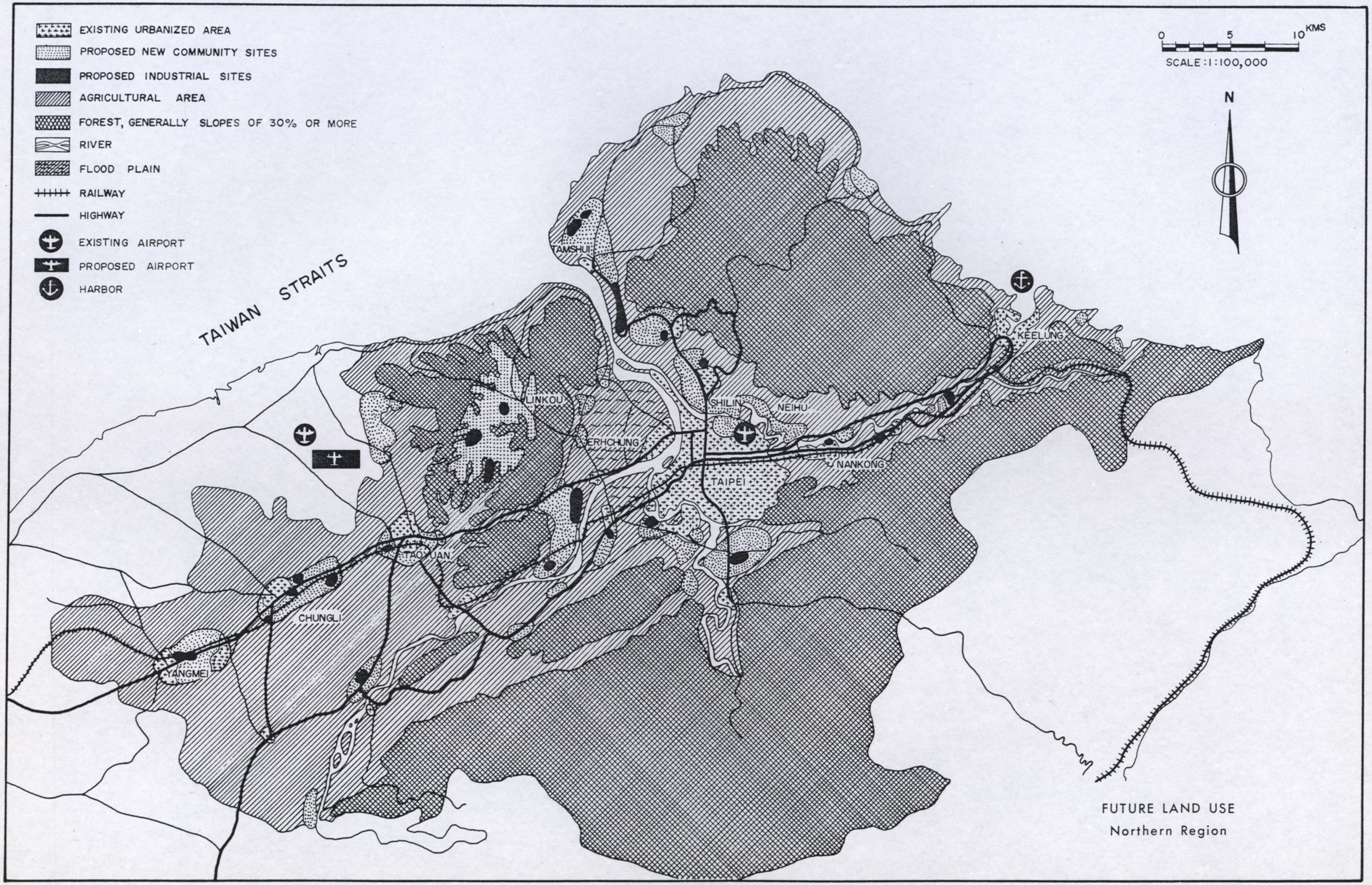
Master Planning Concepts

Recently, the Chinese Government decided to embark on a master plan for Taiwan. The Island will be divided into the following six regions: Northern Taiwan, Taichung, Kaohsiung-Tainan, Hsinchu-Miaoli, Chiayi-Yunlin, and Taitung-Hualien. Each area will be developed according to its own regional plan. First priority will be given to the Northern Taiwan region, with the intent being to make this study a model for the other areas. To facilitiate this planning, the Government has established the "Regional Construction Commission", its purpose being to coordinate planning as well as guiding and promoting the regional concept. First priority in the Northern region, will be given to a study of the development of the two new communities, Linkou Plateau and Neihu areas.

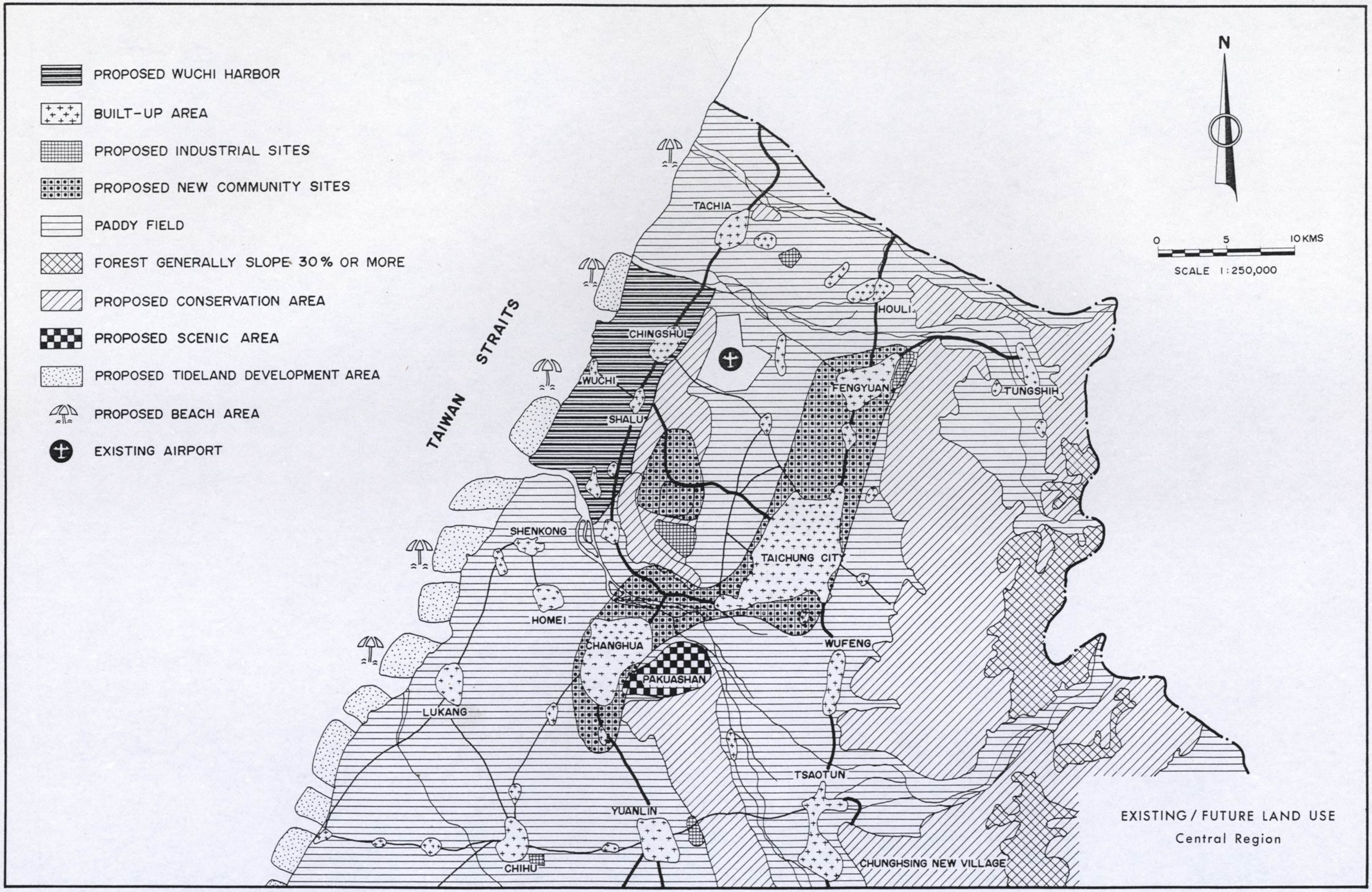


EXISTING LAND USE
Northern Region

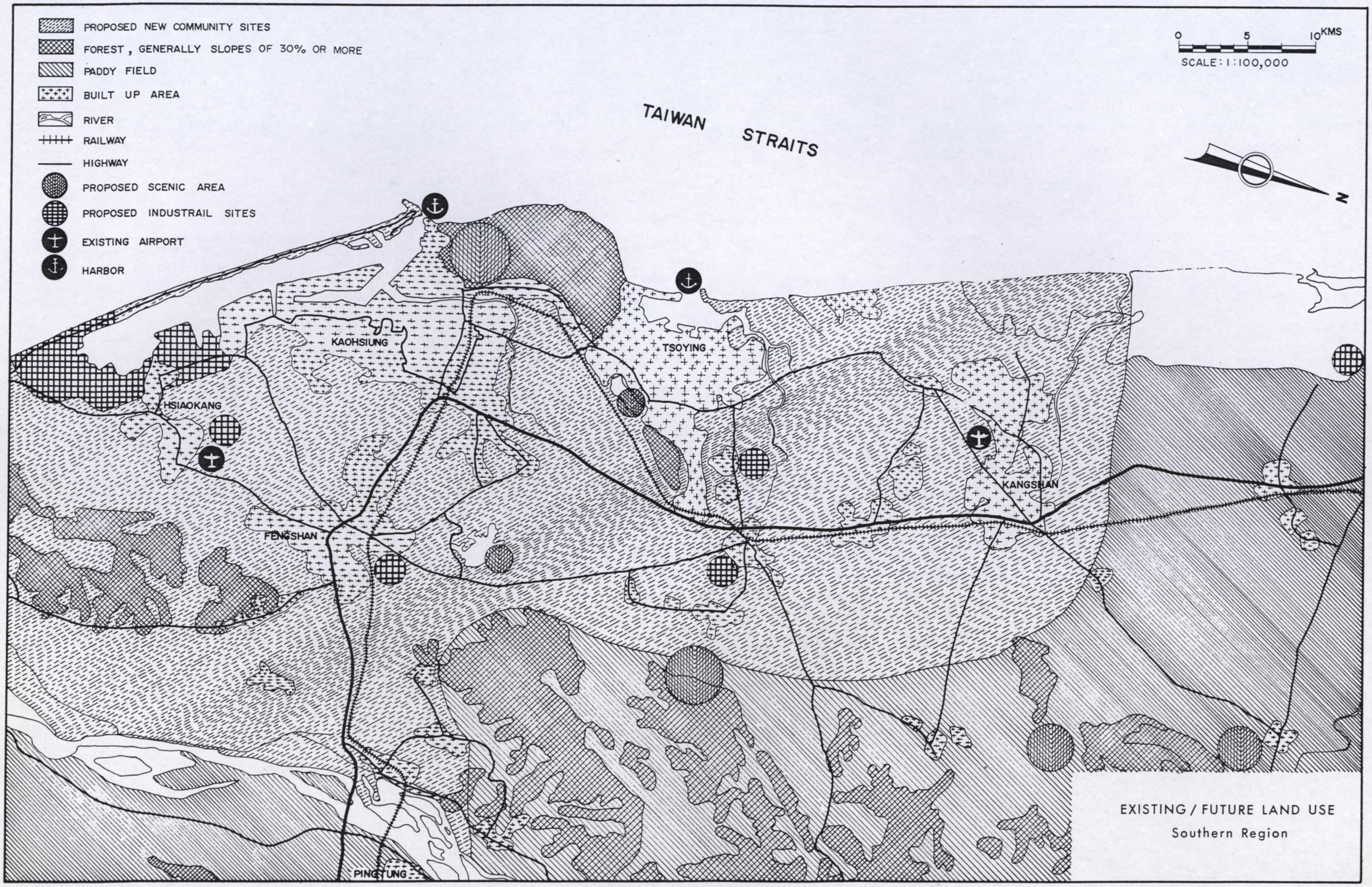
Exhibit V-2



EXISTING URBANIZED AREA
PROPOSED NEW COMMUNITY SITES
PROPOSED INDUSTRIAL SITES
AGRICULTURAL AREA
FOREST, GENERALLY SLOPES OF 30% OR MORE
RIVER
FLOOD PLAIN
RAILWAY
HIGHWAY
EXISTING AIRPORT
PROPOSED AIRPORT
HARBOR
0 5 10 KMS
SCALE : 1:100,000
N
TAIWAN STRAITS
TAMSHUI
KEELUNG
LINKOU
SHILIN
NEIHU
ERHCHUNG
NANKONG
TAIPEI
TAOYUAN
CHUNGLI
YANGMEI
FUTURE LAND USE
Northern Region



EXISTING / FUTURE LAND USE
Central Region


PROPOSED NEW COMMUNITY SITES
FOREST, GENERALLY SLOPES OF 30% OR MORE
PADDY FIELD
BUILT UP AREA
RIVER
RAILWAY
HIGHWAY
PROPOSED SCENIC AREA
PROPOSED INDUSTRAIL SITES
EXISTING AIRPORT
HARBOR
0 5 10 KMS
SCALE: 1:100,000
TAIWAN STRAITS
N
KAOHSIUNG
TSOYING
HSIAOKANG
KANGSHAN
FENGSHAN
PINGTUNG
EXISTING / FUTURE LAND USE
Southern Region

Proposed Freeway and Regional Land Use

Physical developments are lagging behind actual need in the three major urban areas. Immediate implementation of planning seems advisable to check excessive and unwanted growth. A major key to successful development of these three western regions will be the transportation system. Primary attention should be given to the highway system. The Fourth Four-Year Plan (1965-1968) for Economic Development of the Province of Taiwan called for expenditures of $4.5 billion for all forms of development. The importance of transportation was stated in this plan in the following words:

> "Sound transportation and communication systems are . . . basic requirements for economic development. They can lower the cost of distribution, facilitate market expansion, raise productivity, and accelerate the dissemination of technical know-how."

The Government is fully aware that these facilities are necessary if Taiwan is to attain the expected $1.4 billion investment from the manufacturing sector.

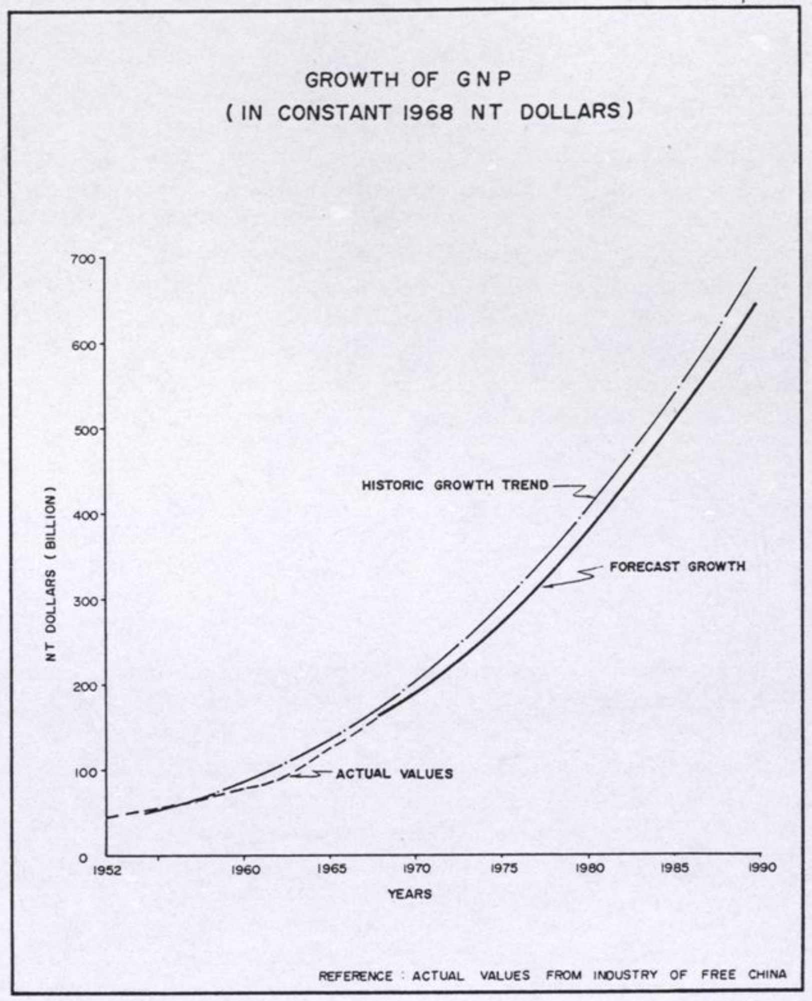
The three major regional planning areas have a combined population of more than ten million. All of the Island's factories and most of the agricultural development lie within these regions. Present land transportation systems consist of one railroad line and several roads of low standard. The roads are highly congested with cars, buses, trucks, and slow-moving vehicles such as motorcycles and small hauling machines. To connect the three major areas adequately, a high-speed freeway type facility is needed with interchanges strategically placed to encourage optimum development. Route Plans, through 27 show the proposed freeway and interchange locations.

GROWTH OF THE ECONOMY

Gross National Product (GNP)

As previously mentioned, the rate of economic growth in Taiwan has been rapid for many years, and most goals of the first four development plans (extending

Graph V-1



from 1953 through 1968) have been surpassed. During this period, the rate of real growth of GNP (i.e., growth of GNP in constant prices) accelerated from 7.3 percent per annum in the early years (1952-1960) to 10.2 percent per year over the 1961-1968 period. Real GNP, in 1968, was 10.3 percent above that of the preceding year, and equaled NT $166.2 billion (US $4.155 billion) in 1968 prices.

The Fifth Four-Year Development Plan, covering the period from 1969 through 1972, forecasts a slowing of the rate of GNP growth. On the basis of historic trends alone (as determined by regression analysis), the growth of GNP would average 8.2 percent per annum over the 1968-1972 period, and the average annual growth to 1990 would be 6.7 percent. The Fifth Development Plan, however, suggests that economic growth may decelerate over the Plan period because international conditions may be less conducive to expanding trade than in the recent past. Moreover, growth in GNP can be expected to slow because much of the investment over the Plan period will be required for infrastructure projects; most of these will result in minimal returns to the county before the end of the period. Thus, the Development Plan indicates that economic expansion over the 1968-1972 period may be held to an average annual rate of about 7.0 percent, rather than the 8.2 percent indicated by historic trends. Total expansion over the four years would then be approximately 31 percent rather than the historically indicated 37 percent.

The Development Plan indicates that the estimated seven percent per annum growth is the minimum to be expected over the Plan period, and that the Commission hopes the growth rate will be higher. The Plan's estimate of seven percent minimum as the rate of expansion was used in the Consultant's study as the probable average growth of the Taiwan economy over the 1968-1972 period, thereby introducing a degree of conservatism in the economic forecasts.

Graph V-1 shows two GNP projections to 1990. The upper curve describes the historic growth of GNP in Taiwan, and extends that trend to 1990. According to this curve, the average annual growth rate of the economy over the 1968-1990 period would be 6.7 percent.

The lower curve in the graph relates to an altered growth equation for GNP in which are incorporated the effects on the long-term trend of the forecast slowdown of GNP growth over the Fifth Plan period. This curve indicates that an average annual growth of 6.4 percent might be expected over the 1968-1990 period, and that 1990 GNP, in constant 1968 prices, would be approximately NT $644.8 billion. This projection is the basis for most of the economic forecasts presented in this study.

To maintain even the slower growth rates forecast for the Fifth Plan period, the Plan indicates that approximately NT $180 billion (US $4.5 billion) would be needed to be invested over the four years. This amount would represent an increase of about 67.5 percent over the total expended during the Fourth Plan period, and the annual average would rise from about NT $26.9 billion, over the Fourth Plan period, to NT $45.0 billion during the period of the Fifth Plan. Fixed capital formation, which ranged from about 14.1 to 16.6 percent of GNP over the 1958-1965 period, and climbed to 18.6 percent in 1966, 20.4 percent in 1967, and 21.8 percent in 1968, would represent approximately 22.8 percent of total GNP over the 1969-1972 period. If gross fixed capital formation should continue to expand beyond the Fifth Plan period at a rate which increased its share of GNP, then actual growth of GNP might be expected to exceed the forecasts of this study.

Population and GNP Per Capita

The forecasts of population growth take note of the apparent effectiveness of family planning in Taiwan. They also accept Government estimates of a continued slowing of population growth from actual rates of approximately 2.6 percent in 1967 and 2.35 percent in 1968, to forecasted rates of 2.03 percent in 1975 and 2.01 percent in 1976. The Consultant's study projected population growth beyond 1976 by modifying the actual and projected trend of 1966-1976 and reducing the annual growth rate by one-hundredth of one percent each year. Thus the 1977 growth rate was predicted to be 2.00 percent and the projected 1990 growth rate was diminished to 1.87 percent. By this method, the population of Taiwan has been projected to expand from about 13,644,000 at the end of 1968 to approximately 21,104,000 by the end of 1990.

With average growth rates of 6.4 percent and 2.0 percent for GNP and population respectively over the 1968-1990 period, GNP per capita can be expected to expand. The average annual rate of expansion should be 4.3 percent, rising from NT $12,180 (US $304) in 1968 to a 1990 value of NT $30,550 (US $766).

Structure of the Economy

The GNP shares of the major sectors of the economy are expected to continue to change as industry and services keep growing much more rapidly than agriculture. The relative importance of agricultural output has been diminishing rapidly for many years, even though real growth of agricultural output has been substantial. Over the 16-year period 1953-1968, annual agricultural gross product (in constant 1968 prices) climbed from NT $16.3 billion to NT $33.6 billion (an average annual growth of 4.9 percent), but the sector's share of the nation's total gross product declined from 33.3 percent at the beginning of the period to 20.2 percent in 1968. Over the same 16 years, the share of industry in total gross product rose from 19.4 percent in 1953 to 32.5 percent in 1968. The share of the services sector was 47.3 percent of GNP in both 1953 and 1968.

The Fifth Development Plan estimates that between 1968 and 1972 the share of GNP of the agricultural sector will continue its long decline, from its 1968 level of 20.2 percent to a 1972 level of only 18.3 percent. The Plan also predicts that the gross product of services will decline slightly as a portion of total gross product, falling from its beginning level of 47.3 percent to 46.6 percent in 1972. Thus industry, as the remaining major sector, would increase its share of the country's gross product from 32.5 percent to 35.1 percent during the Four-Year period.

Using Development Plan estimates of growth and changed gross product shares over the Plan period, the 1972 values of gross products (in constant 1968 prices) would be approximately as follows: agriculture, NT $40 billion; industry, NT $76.5 billion; and services, NT $101.5 billion. Within the industry sector, the gross product of manufacturing would be nearly NT $65 billion, the gross product of utilities would be nearly NT $5.5 billion, that of building construction would be more than NT $2 billion, and the gross product of mining would be slightly greater than NT $4 billion. The total value of agricultural production in 1972 would be NT $56 billion, while the value of production of mining would be about NT $4.6 billion, and of manufacturing would be nearly NT $130 billion. (See Table V-1, "Sector Distribution of GNP 1972 and 1990", and Table V-2, "Relation of Gross Product to Value of Production".)

The projections for gross products of the agricultural and industrial sectors to 1990 were made by incorporating the Development Plan forecasts for the 1969-1972 period into the trend analysis. On the basis of values for the years 1952-1972, trend equations were derived. These trend equations would give 1990 gross product values (in constant 1968 prices) of NT $85.2 billion for agriculture and NT $246.4 billion for industry. Such levels of value would mean that agricultural gross product, in real terms, would have expanded by an average rate of 4.3 percent per annum over the 1972-1990 period. At the same time, industrial gross product would have grown by an average of 6.7 percent per annum. Within the industrial sector, manufacturing is forecast to maintain an average annual growth rate of 6.7 percent over the 1972-1990 period. Other average rates of growth are forecast to be 8.65 percent per annum for utilities, 5.1 percent per annum for building construction, and 4.2 percent per annum for the gross value of mining products.

Because the gross product of the agricultural sector is projected to grow at a slower rate than GNP, the sector's share of total gross product is foreseen to continue to decline. From its actual level of 20.2 percent in 1968, and its forecast level of 18.3 percent in 1972, agriculture's share of gross product is expected to fall to only 13.2 percent in 1990. Actually a share decline of only that amount over an 18-year period would mean that the rate of diminution of share had slowed. This may be expected to happen since the major emphasis on future agricultural growth is apparently to be placed on the relatively high-value products of fish and livestock. The share of the industrial sector in total gross product in 1990 is foreseen to climb to 38.2 percent, while the share of the services sector would rise from 47.3 percent in 1968 to 48.6 percent in 1990.

Growth of Production Tonnages

The total value of production of the tonnage sectors (i.e., agriculture, mining, and manufacturing) is forecast to expand from the 1968 level of approximately NT $136.7 billion, to NT $190.5 billion in 1972, and to NT $546.1 billion in 1990. This growth would mean an average rate of 8.6 percent per annum over the Four-Year period 1968-1972, and an average annual growth of 6.0 percent thereafter to 1990. The average rate of growth for the entire 1968-1990 period would be 6.5 percent per annum.

Table V-3 shows the forecast of growth over the 1968-1990 period in value of production of the tonnage sectors Most of the commodity class growth rates for the 1968-1972 period were taken from the Development Plan. A number of these rates, however, were not indicated in the Plan for the entire class but were given for a single major product, or represented an average for a number of major products. Thus for the class "transport equipment" for example, no expansion rate was given in the Development Plan, but it was indicated that production of autos, buses and trucks would grow by 29 percent per annum, ship construction would expand by 35 percent per year, and the production of motorcycles would exhibit a growth of 7.8 percent per annum. From these various projections, the estimate of a Four-Year annual growth rate of 25 percent for the entire class of transport equipment was selected as conservative.

Other commodity groups for which no overall expansion rates were indicated by the Plan included basic metals, metal products, and both electric and non-electric machinery. Annual growth rates were forecast in the Development Plan, however, for such major items within these groups as steel products (15.6 percent), aluminum products (19.0 percent), electric motors (14.0 percent), refrigerators (19.0 percent), air conditioners (35.0 percent), and "general machinery" (9.5 percent).

Table V-4 shows how the values of Table V-3 were translated into tons. Excluded from the table of tonnage production, however, are crude oil, natural gas, and ships. These were excluded since the table's purpose is to indicate production tonnage which might possibly be carried by highway conveyance. Thus any product which likely would be carried by pipeline or by sea should be omitted.

Comparison of Tables V-3 and V-4 show that the expansion rate of each commodity class (excepting only "transport equipment") stays the same whether measured by value or by tonnage, but that the expansion rates of the major groupings (viz., agriculture, mining, and manufacturing) are not the same when measured in terms of values as they are when measured in terms of tons. In the case of each major grouping the expansion of value is greater than the tonnage expansion, despite an assumption of no inflation, because many higher-valued products are forecast to expand more rapidly than most of the lower-valued commodities. Also, of course, in the case of the mining sector, the most rapidly growing commodity class (viz., crude oil and natural gas), has been exluded from the tonnage table.

Similar changes in composition might be expected to occur within each commodity class. That is, in any given commodity class production of the higher-valued products might be expanded more rapidly than the lower-valued products. Therefore, it might also be expected that the average value of a ton of production within the class would rise, and the total value of the commodity class would expand at a faster rate than the tonnage production of the class. For purpose of this study, however, the changing composition of products within each commodity class was not taken into account since it was deemed that the lengthy procedure for accurately measuring this changing composition would not be warranted by the potential effect on the benefit/cost ratio of the freeway.

The growth of total tonnages of production may be over-estimated, however, to the extent that GNP is accurately forecast in this study while the ratio of the expansion of value of production to expansion of tonnages of production is understated. Since the forecast of GNP growth is thought to be conservative, it is unlikely that the forecast expansion of production tonnage is over-estimated to any significant degree.

The assumed constant relationship between tons and value in each commodity class was used in this study for projecting values to 1990. That is, most projections were made on the basis of tonnages (again incorporating values for the years 1969-1972 into the regression analyses to find trend equations based on both historic growth and Fifth Development Plan forecasts). The expansions derived for tons were then applied directly to 1972 total values of each commodity grouping to estimate the 1990 value of production of that grouping.

National Income and Per Capita Income

The evolution of Taiwan as an industrialized economy was considered in projecting the growth of national income. Regression analyses were then made to forecast the gradual divergence of national income from the level of GNP (resulting from a rising proportion of GNP representing gross capital formation and indirect taxes). National income represented about 84.8 percent of GNP in each of the years 1952 and 1953, declined to an average of 81.0 percent over the 1960-1962 period, averaged 81.0 percent again during 1966 and 1967, and fell to 80.0 percent in 1968. The straight line equation arrived at to describe this trend indicates that national income in 1990 might be expected to represent about 76.5 percent of GNP.

Accepting this relationship between national income and GNP in 1990, the level of the former (in constant 1968 prices) would be nearly NT $493 billion in 1990, and the average annual growth rate from 1968 to 1990 would be 6.1 percent. Per capita income is foreseen to rise at an average annual rate of 4.0 percent over the same period, rising from NT $9,740 (US $243) in 1968, to NT $23,360 (US $584) in 1990.

External Position

The forecast of imports used in this study is thought to be conservative, and together with the projection of exports (which may also be conservative) and the assumption of constant average value of tons within each commodity class, would result in a balance of trade surplus for Taiwan of about NT $2.34 billion (US $58 million) in 1990. Table V-5 shows the forecast exports and imports in terms of both tons and values. Exports are forecast to expand at an average annual rate of 5.3 percent in terms of tons while imports, inclusive of crude petroleum, are foreseen to grow at an average rate of 6.1 percent per year, but, exclusive of crude oil, are forecast to equal only the growth rate of domestic tonnages, i.e., an average increase of 4.8 percent per annum.

On the services account as well, Taiwan's external position is foreseen to improve, especially with regard to shipping and tourism. The Fifth Four-Year Development Plan places great emphasis on the expansion of the shipbuilding industry. It is forecast to grow at an average annual rate of 35 percent over the four years. This seems reasonable when compared with recent years since production increased by 61 percent in 1966, 161 percent in 1967, and 17.4 percent in 1968 when gross tonnage produced totaled 79,183. The Plan indicates that a total of 830,000 tons is to be added to the Chinese maritime fleet over the Plan period, and that by the end of 1972, new ships will comprise 60 percent of the total tonnage of the fleet.

With regard to tourism, it is one of the country's most rapidly growing industries. The number of visitors to Taiwan (excluding American servicemen) increased by more than fourfold in the five-year period 1963-1968, and more than doubled in the three-year span from 1965 to 1968, totaling 301,770 in the latter year.

The Taiwan Trade Monthly (April 1969) indicates that tourism officials foresee continued growth over the Fifth Plan period at an average rate of 20 percent per annum, to a 1972 level of 631,000 foreign visitors. It is forecast that this number of visitors will bring in about US $69.4 million in foreign exchange in 1972. This estimate may be quite conservative, however, since it is based on a 1968 earnings figure of approximately US $33.2 million, whereas one study indicated that 1968 earnings were at the much higher level of US $53 million (with an additional US $11 million being received from American servicemen).

According to the historic trend, the number of annual foreign visitors to Taiwan might be expected to pass the three million mark in 1990. Combining the two estimates of tourism earnings in 1968, the forecast of tenfold expansion of visitors over the 1968-1990 period might translate to gross earnings from tourism in the range of US $330-$530 million in 1990. The average annual growth rate of foreign visitors and gross earnings from tourism, over the forecast period would be approximately 11.1 percent per annum.

REGIONAL DISTRIBUTION OF PRODUCTION AND INCOME

The Regional Production Index

A locational index furnished the basis for estimating production among hsiens. Since statistical information regarding regional production in Taiwan was unavailable, an index of economic activity for the country as a whole was constructed. For this purpose statistics were gathered on a basis which could show relative economic activity for each hsien. Table V-6 shows a principal index of manufacturing which lists relative percentages and numbers of plants, capital invested, employment, and value added, according to distribution among the hsiens. Each column is a single index to relative location, and to the relative strength of economic acitivity between hsiens. When viewed in isolation, this affords only a fragmented view of manufacturing activity.

However, uniformity between the columns was less desired than the overall effect on their weighted average. Such a weighted average was obtained by giving every column equal weight in the total outcome. This was done by multiplying the figures in each column by 0.25 and summing the effect in the final column at the right. The data in the final column thereby approximate regional distribution of manufacturing output. This presumptive basis is used in this study to "locate" the origin of manufacturing and its relative volume by hsien. A similar index was prepared to locate consumption, and was used to determine the import matrix.

The manufacturing index shows the following regional distribution of manufacturing output:

North	: 60.5 percent	South :	17.5 percent
Central	: 20.5 percent	East :	1.5 percent

The regional production index was translated into regional percentages of the various industries by using a census of manufacturing facilities, by industry, in each hsien.

Table V-7 indicates the percentage of total output by hsien for each industry. The percentages were obtained by applying a 60 percent weight to the Production Index and a 40 percent weight to the percentage distribution of manufacturing plants for all industries.

Agricultural output by hsien was readily obtainable. The data showed total metric tons of production by the principal standard industrial classifications: forest, fishery, and livestock. Fruits and vegetables could not be separated nor fully accounted for, nor could total field crops be summed as these were composed of separate breakdowns by principal item only. As a counterpart for a field crop index, the total number of farm households, by hsien, was used. This compared favorably with the percentages of regional distribution of rice output, fruit and vegetable aggregates, and the population of farm households. The agricultural index showed these regional distributions of agricultural output:

REGIONAL DISTRIBUTIONS OF AGRICULTURAL OUTPUT

Area	Field Crops	Forest	Fisheries	Livestock
North	17.5%	32.0%	39.5%	42.2%
Central	47.3	36.6	7.3	30.3
South	27.2	18.4	44.9	23.1
East	8.0	13.0	8.3	4.4
Total	100.0%	100.0%	100.0%	100.0%

In company with the manufacturing index, a relatively complete production index could be formulated with the exception of mining output. No data on a regional basis could be obtained for mineral production. The only information available was the name of the mineral and its location by hsien in the original deposit, without reference to tonnages produced. Mineral outputs could be only crudely estimated, therefore, and only where a regional location had been given which was the case in connection with relatively few commodities.

Forecasts of Regional Economic Growth

Tables V-8 and V-9 show the results of applying the production matrix to the forecast national totals of tons and tonnage value. To distribute tonnage value, the matrix was altered to include oil, gas and ships. Each industry was forecast to grow at a uniform rate throughout the country, but the importance of some of the faster growing industries in areas such as Taipei and Kaohsiung hsiens affected overall growth so that it was forecast to be much more rapid than the country average.

The values of tonnage production, shown in Table V-9 were translated into gross products by using the established relationships between gross products and value of production shown in Table V-2. These are shown in Table V-10. Estimates were also made of base year regional gross products of services and growth to 1990 to arrive at the total regional gross products (shown in the last column of Table V-10). These estimates and projections are shown in Table V-11 and Table V-12. The percentage shares of national gross product of services shown in these tables were arrived at by estimating the approximate shares of each hsien's regional product that services represent in 1968 and would represent in 1990 (see footnotes on Tables V-11 and V-12). Basic to such estimates were evaluations of the importance of such services as government, transportation and communications, retailing, and tourism in the various hsiens. It will be shown later (Table V-31) that the distribution of light trucks in April 1969 was approximately the same as the estimated distribution of the gross product of services. Light trucks, being owned mainly by organizations and individuals providing services, constitute an acceptable index of services distribution. The distribution shown in Table V-11 for 1968, therefore, would seem to be substantiated.

Knowledge of population distribution was basic to forecasts of regional per capita gross product and income. This study's forecast of population distribution took into account the regional development plans for the Taipei, Taichung, and Kaohsiung areas, and the plans for a new port at Wuchi and an airport in Taoyuan hsien. Despite these aids to forecasting, however, population shifts over a 20-year period in an economy expanding as rapidly as the economy of Taiwan are difficult to measure. The forecasts shown in Table V-13 are intended to be only rough approximations of future regional population expansion. (See Exhibit V-5)

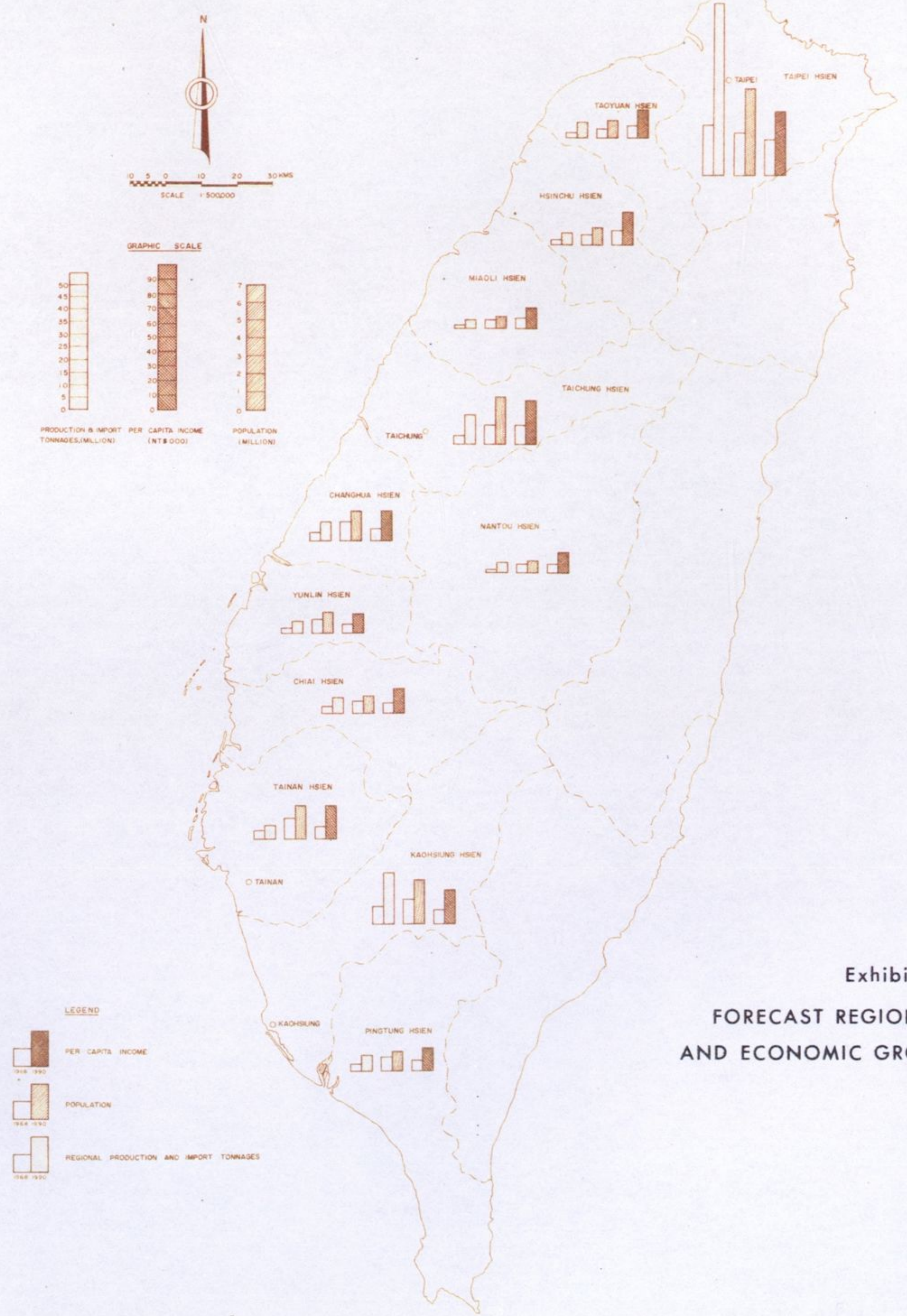


Exhibit V-5

FORECAST REGIONAL POPULATION AND ECONOMIC GROWTH 1968 TO 1990

Using the regional population forecast it was possible to measure the growth of per capita regional product which would obtain from the forecast regional products. Table V-14 indicates the estimated per capita regional products of each hsien in the base year and the projected per capita products for 1990. The high growth factor for Miaoli is due to an expected slow rate of population growth coupled with the forecast rapid growth of oil and natural gas production in the hsien.

Tables V-15 and V-16 show calculated 1968 regional incomes and per capita incomes, and the forecast regional and per capita figures for 1990. Table V-17 shows the total expansion of both regional and per capita incomes by hsien while Table V-18 shows how the distribution of national income is expected to change over the 1968-1990 period. The shift to larger portions of national income originating in Taipei, Taichung, and Kaohsiung hsiens is deemed likely in view of present regional development plans, the planned port at Wuchi (each of the three hsiens would then have a major port), the future importance of industrial parks in these areas, and the importance of imports and exports in general.

As mentioned above, the forecast distribution of gross product of services was used to distribute the forecast national total of light trucks. For the distribution of forecast auto registrations, per capita income was used, while to distribute forecast buses in Taiwan in 1990, regional income was used. The forecast of heavy truck registrations in 1990 was distributed by regional shares of national production and import tonnages. The forecast distribution of production tonnages was shown in Table V-8. Points of arrival (not final destinations) of import tonnages remain to be estimated.

Table V-19 gives the forecast distribution among points of entry of 1990 import tonnages. Admittedly, the estimates of tonnages arriving at the two international airports are arbitrary. The airport at Taipei is planned to be used solely for domestic traffic after the opening of the airport at Taoyuan hsien. No adequate method exists for measuring the impact of the so-called "jumbo" jets" on future movements of cargo, and "authorities" on the matter have shown a wide disparity of views.

The Japanese study, which analyzed the possibility of a third major port at Wuchi, indicated that such a port had it been open in 1967, would have handled nearly 18 percent of total revenue tons at all ports in that year. Furthermore, the study indicated that once a port at Wuchi was opened, its effect would be primarily on shipments that would otherwise pass through Keelung. The share of total imports that would enter at Wuchi in 1990 has been taken as 15 percent. Eighteen percent was viewed as too high, since greater shares of production would be in the northern and southern regions in 1990 than in 1967. It was estimated that, in the absence of a port at Wuchi, 90 percent of the imports that would logically have been handled there would be handled at Keelung while only ten percent would have been handled at Kaohsiung.

The potential import tons at Keelung and Kaohsiung (i.e., before diversion to Wuchi) were calculated by maintaining the 1968 shares of total imports to 1990. Thus Taipei and Taoyuan would, in the absence of a port at Wuchi, be expected to receive 48.5 percent of total import tons, or 7,568,000 tons. From this total the tons expected to arrive at the Taoyuan airport and the tons foreseen to be diverted to Wuchi were deducted to obtain the forecast number of tons to enter at Keelung.

After the regional distribution of 1990 import tonnages was derived, these tons were added region-by-region to the forecast production tonnages. Table V-20 shows the hsien totals of production and import tonnages in 1968 and 1990, and indicates the total expansion over the period. Not surprisingly (in view of the planned new port), the forecast expansion for Taichung hsien is by far the highest.

Table V-21 gives the regional percentage shares of national production and import tonnages in 1968 and 1990. Taichung hsien shows the greatest increase in share, although Taipei hsien nearly matches the increase.

PLANS FOR IMPROVING THE TRANSPORTATION SYSTEM

Many improvements to the transportation system are envisioned to implement the Fifth Four-Year Economic Plan (1969-1972). The Government realizes that the transportation facilities are inadequate to meet the demand, and that they must be greatly expanded. Management must also become more competent and operating efficiency improved.

The Government proposes to call for improvements in all phases of transportation. These projects are expected to be financed partly by such international lending agencies as the Asian Development Bank or the World Bank.

Highways

The Taiwan Highway Bureau, in its Fifth Four-Year Highway Construction Plan, outlines 13 improvement and construction projects related to the highway system. These are in addition to construction of the North-South Freeway. Among the most important improvements under this plan are the following:

- Improvement of the existing North-South Arterial Highway System. This calls for continuing work to increase capacity and average speeds on existing highways. Bridges will be widened, surfaces repaired, slow moving traffic lanes provided, and traffic safety devices installed.

- Improvements to the Eastern Arterial Highway System. An all-weather facility will result from improvements to the Taipei-Suao-Hualien Highway.

- Improvements to the East-West Cross Island Highway. This facility will be improved to meet the demands of a rapidly growing tourism industry.

- Construction of the Southern Cross Island Highway. This 182-kilometer project will complete the connection between the east and west coasts.

- Improvement of rural highways planned to handle the development of regional areas.

In addition to the Taiwan Highway Bureau's construction plan, a general upgrading of the Bureau's capabilities is under way. Plans are being implemented to train THB personnel in special fields of highway work. Key people will be sent to Japan and the United States for training in data processing techniques, transportation analyses, and new construction methods.

Railways

According to recent budgets for future investments in rolling stock, track facilities, and signal and other equipment, the Taiwan Railway Administration proposes to spend US $128 million for improvements during the period 1969-1972. Of this total, US $68.5 million will be sought from foreign sources. This money is proposed to be used to purchase equipment not made locally.

Long-range forecasts of the Taiwan Railway Administration extend to 1978. The West Line passenger and freight demand during this period is expected to rise as shown below.

TRA LONG-RANGE FORECASTS 1968-1978

Year	Passengers (million passenger-km.)	Freight (million ton-km.)
1968	5038.2	2434.0
1972	6428.7	2652.4
1978	8660.1	3136.0

These volumes reflect annual rates of growth in passenger-kilometers of about seven percent up to 1972, and about five percent thereafter. For freight the growth rates are about three percent annually. Based on similar demand forecasts and the TRA's operating record of accommodation of such traffic, the Taiwan Railway Administration has obtained financial assistance in the past from the World Bank (IBRD). The first loan in 1966 provided funds for investments in rolling stock, and a second loan in 1969 partially financed the procurement of signalization and maintenance equipment. A third loan has recently been negotiated for purchase of rolling stock and a broader range of track facilities. The rolling stock includes 18 diesel-electric locomotives, 268 passenger cars, and 600 freight cars. Workshop equipment, track-strengthening devices, and 64 automatic warning devices for level crossings, together with consulting services on electrification and traffic costing, are also included in the loan.

Additional costs for planned Taiwan Railway Administration improvements include double-tracking, more commuter cars, and freight handling equipment. For the same four-year period, TRA will construct a new marshalling yard at a total cost of US $10 million, and expend a total local currency equivalent to US $80 million (about US $20 million yearly) on total improvements complementary to the foreign loan of US $45 million.

Ultimate electrification will depend mainly on the future availability of electric power as an alternative to coal and imported diesel fuel. Offsetting the potential economic gains expected from local power supply will be the high first costs of importing major items of new equipment, and of the electrification system itself. Two recent studies indicate the need for electrification. The World Bank loan provides funds for further study. A later chapter in this report includes the Consultant's estimates of the cost of such electrification in developing a "future railway model."

Elevation of the railroad within the City of Taipei has been approved by the Government, and approximately US $33 million will be spent on this project. The

Panoramic view of Kaohsiung Harbor

Government has asked for engineering proposals, and work is expected to begin early in 1970. The project will take four years to complete.

Air Transportation

Approximately US $45 million is earmarked for improvements in civil aviation. These improvements will consist of purchasing new aircraft and navigation systems, and constructing an international airport at Taoyuan.

Some existing airports will be expanded to accommodate air traffic growth in the immediate future. Sungshan International Airport in Taipei will be expanded to handle air traffic for the next five years until the opening of the new airport in Taoyuan. Expansion will include extending the runway to 10,000 feet, enlarging aprons, and adding to cargo and passenger facilities. Kaohsiung's Hsiaokang Airport is similarly being expanded to handle international service. The runway will be extended to 9,500 feet. Cargo and passenger facilities will also be expanded. The Government has decided to build a new airport next to the existing military airport at Taoyuan. This facility will become the new international airport after Sungshan International Airport in Taipei has reached its ultimate capacity.

The potentials of international cargo and passenger service to Taiwan are extremely attractive to competing international air carriers. Two more foreign carriers were recently awarded routes to Taiwan. China Airlines, flag carrier for Taiwan, was also awarded flights to the United State's West Coast, and service will soon begin.

Harbors

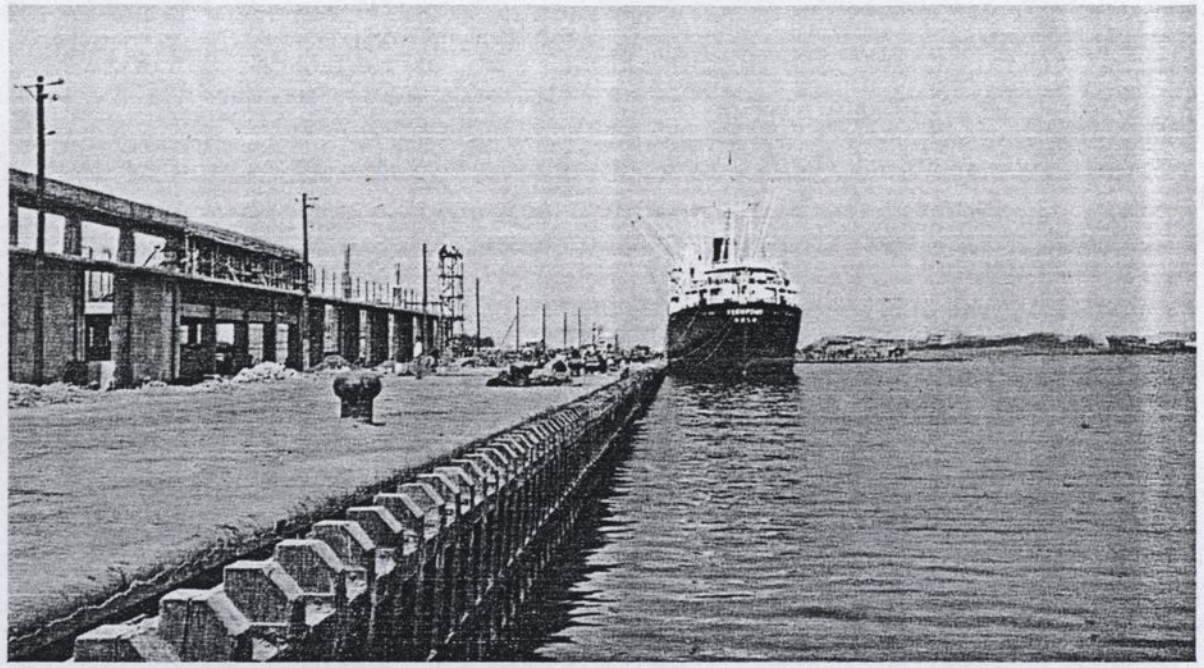
Under the Fifth Four-Year Economic Development Plan, US $95.2 million is budgeted for improvement of harbor facilities. Included in the plan is construction of a wharf for shipments of explosives and completion of a new passenger center at Keelung harbor. Part of the money is slated for continuing construction at Kaohsiung, which includes a new entrance to the harbor. Both Keelung and Kaoshiung harbors will receive facilities for handling containerized freight. The remaining funds will be used in developing a third major port.

After extensive studies the Government has decided to build this third major port at Wuchi in the central part of the Island. The alternative site, Tamshui, is to be expanded later to increase harbor capabilities in the Northern Region. The rapidly rising level of import/export business at the northern and southern ports will require that the harbor at Wuchi be completed soon. This harbor will induce economic growth in the central part of Taiwan. It will encourage further dispersion of industry and thus relieve industrial congestion in and around Taipei.

Shipping

Shipping will benefit from planned improvements in containerization and from the greater capacity of ships. The Government, working with private firms, has established the Planning Committee on Container Transport to study conversion to containerization. Its function is to foster efficient implementation of containerization in Taiwan. Private corporations are being established to set up operating bases at the ports. Granting shipping companies special loans for building container ships, rather than conventional type ships, is an interesting governmental device to further the implementation of containerization. The government and foreign investors are hopeful that Taiwan can be developed into a major distribution terminal for container shipments to and from Southeast Asia.

Shipping will experience additional growth through increased tonnages of import/export goods, especially as the Republic of China adds super tankers to its maritime fleet. The Chinese Petroleum Corporation (CPC), a state-owned enterprise, predicts the demand for petroleum will double in the next four years. Presently CPC operates one 100,000-ton tanker. Two more super tankers will be delivered in 1970 and 1971. Facilities for unloading these large ships have been constructed offshore at Kaohsiung harbor. Another improvement is the addition of a second export processing zone which will increase export tonnage, and hence the growth of shipping. Located at Nantzu near Kaohsiung, the new zone is expected to draw some 200 foreign manufacturing plants and to account for export goods worth US $120 million a year.


Newly-built deep water wharves in the new commercial harbor - Port of Kaohsiung

Bus Service

The Taiwan Highway Bureau plans to increase bus service and equipment during the period corresponding with the Fifth Four-Year Plan (1968-1972). Thirty new air-conditioned buses were proposed to be added in 1969, some of which would replace obsolete buses. Tentative plans call for a yearly new bus increment of 150 units, beginning in 1970, for a total of 450 by the end of 1972. Bus service will increase to meet the rapidly growing tourist industry. Private bus service will also increase with the addition of six new companies. In Taipei alone, four new bus companies started in the summer of 1969.

Vehicle Production

Vehicle production is expected to grow by 29 percent per annum during the Fifth Four-Year Economic Plan. The Government predicts that foreign-made vehicles will not have to be imported after 1969. However, demand for foreign-made vehicles is expected to continue. The Government recently approved importation of 4,000 foreign vehicles. The official government procurement agency, Central Trust of China (CTC), plans to permit importation of 3,000 vehicles annually. The Yue Loung Company, the largest Chinese auto maker, has plans to increase capacity to 100,000 units annually in the mid-1970's.

Overall Transportation Amelioration Study

The Government has been contemplating an overall transportation study to evaluate all forms of transportation throughout the Island. Inability to obtain specialists and funds has delayed the start of such a study to identify the requirements of each transport sector and to enable planning to be coordinated among regions.

Overall transportation planning is still in the early stages. Each transportation agency prepares its own plans, paralleling the government's Four-Year Plan, and submits its report to the Central Government. The following table covers the proposed investment program for the years 1969-1972. It should be noted that the highway investments exclude expenditures for a north-south freeway. It is assumed that the investment program will be adjusted when cost estimates become available from this feasibility report.

PLANNED INVESTMENTS IN TRANSPORTATION
FOUR-YEAR PLAN, 1969-1972

Type of Transportation	Investments (Millions)	Relative Proportion
Railways	NT$ 5,121	25%
Highways	3,271	16
Harbors	3,809	18
Shipping	6,659	32
Civil Aviation	1,820	9
Total Transport Investments	NT$ 20,680	100%
Total National Fixed Investment	NT$156,460	

FORECAST GROWTH OF TRANSPORTATION DEMAND AND VEHICLE REGISTRATIONS

Traffic Expansion to 1990

This study arrived at forecasts of traffic volumes in 1990 by using historic trends of traffic growth, vehicle registrations and production growth; by making use of the Fifth Development Plan projections of traffic and GNP growth; and by analyzing correlations between GNP and traffic growth as well as between per capita income and both auto and total vehicle ownership.

Tables V-22 and V-23 show the forecast highway traffic growth in terms of total expansion and in terms of average compound rate per annum. Table V-24 indicates the forecast growth rate of railroad traffic. All of these tables apply to the "without freeway" condition, and thus exclude any traffic conversion effect which the freeway might have. When the effects of the freeway are taken into account, the expansion factors for ton-kilometers are as shown in Table V-25. No change in the passenger-kilometers growth factors should be occasioned by construction of the freeway if the railway is improved as scheduled in a later chapter of this report.

Historic Trends

The period 1954-1968 was used to determine historic trends of passenger-kilometers and ton-kilometers. Table V-26 shows that the average annual compound growth rate of highway ton-kilometers (available data pertains only to trucking companies), over the 1953-1968 period, was 16.3 percent. During the same period, highway bus passenger-kilometers expanded by an average rate of 9.8 percent per annum. In both cases, the rate of highway traffic growth considerably exceeded that for the railway. Tables V-27 and V-28 show how the split between railway and highway has changed over the 1952-1968 period for both passenger- and ton-kilometers.

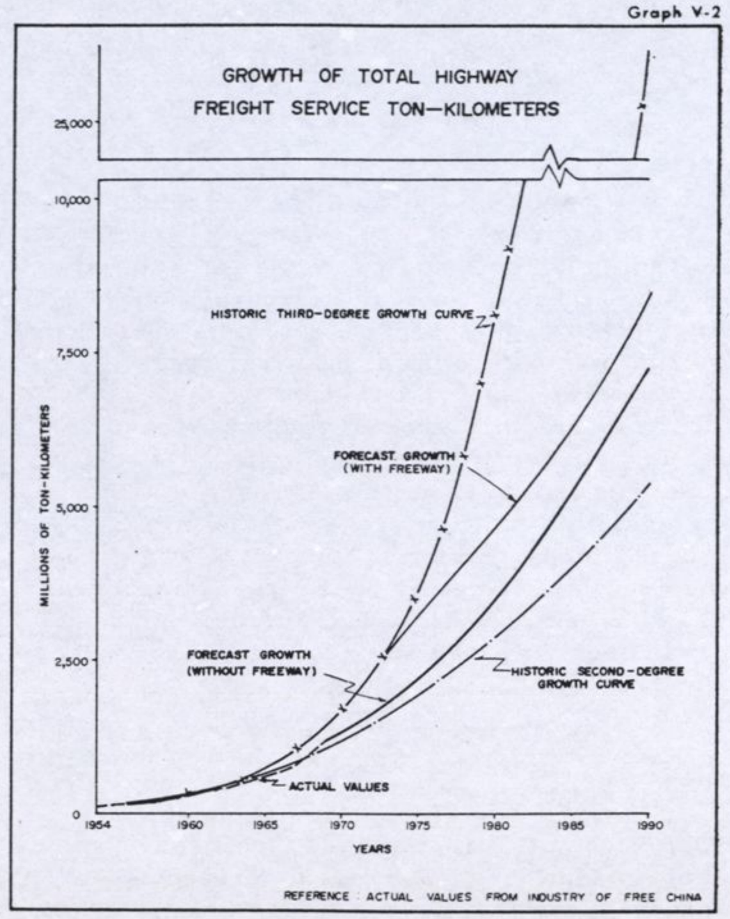
Graphs V-2 to V-9 indicate historic trends (as determined by regression analyses) extended to 1990. They show the growth of highway ton-kilometers, highway tons, West Line Railway ton-kilometers, tonnages, highway passenger-kilometers (buses only), highway passengers, and West Line Railway passenger-kilometers and passengers. In the case of highway ton-kilometers, two historic trend lines are shown. As with the other cases, a second-degree curve was first used to attempt to depict past growth, but since there was sharp divergence from the second-degree trend line in 1968, a third-degree curve is also shown as the curve of best fit. Data available through April 1969 indicated that the divergence from the second-degree trend was further corroborated by a similar divergence in the trend of heavy truck registrations. (See Graph V-15.) It appears to be the greater availability of trucks, in fact, that is responsible for the sharply accelerating rise in highway ton-kilometers.

Graphs V-2 to V-9 also indicate the forecasts of expansion of each of these traffic measurements for the "without freeway" condition. In the case of highway ton-kilometers, the alteration from the second-degree trend line was accomplished in several steps. Even though the third-degree trend line was the curve of best fit, it gave an unrealistic value when extended to 1990, and therefore was not used. Only one-step alterations from the historic second-degree trend lines were required to arrive at the forecasts for growth of the other seven traffic measurements.

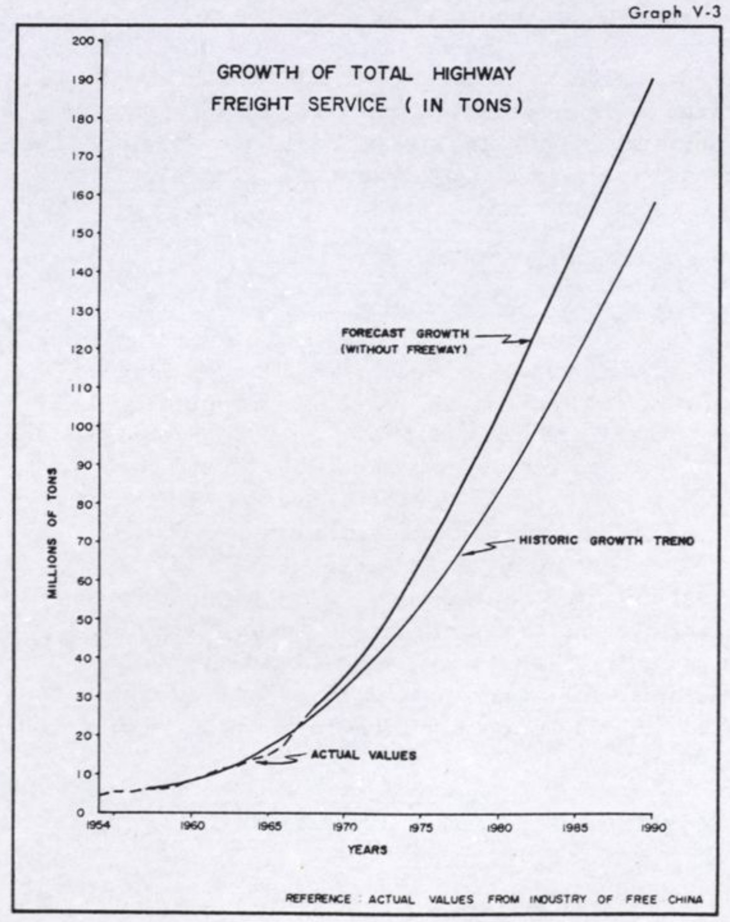
Alteration of the Trend of Highway Ton-Kilometers

The first step in altering the trend line for ton-kilometers was to estimate the 1969 ton-kilometer total by using published data for the first four months. The ton-kilometer total for the January-April 1969 period was slightly in excess of 392 million. Assuming this figure to equal one-third of the total for the year, the 1969 total would be more than 1,177 million, or slightly more than 19 percent above the 1968 total. Over the years 1959 through 1968, however, the January-April totals represented, on the average, only about 31.4 percent of the yearly values. If this relationship held true in 1969 the total for the year would have been about 1,251 million ton-kilometers, which would represent a 26.5 percent rise from 1968. This study averaged this and the 1,177 million figure giving 1,214 million highway ton-kilometers for 1969.

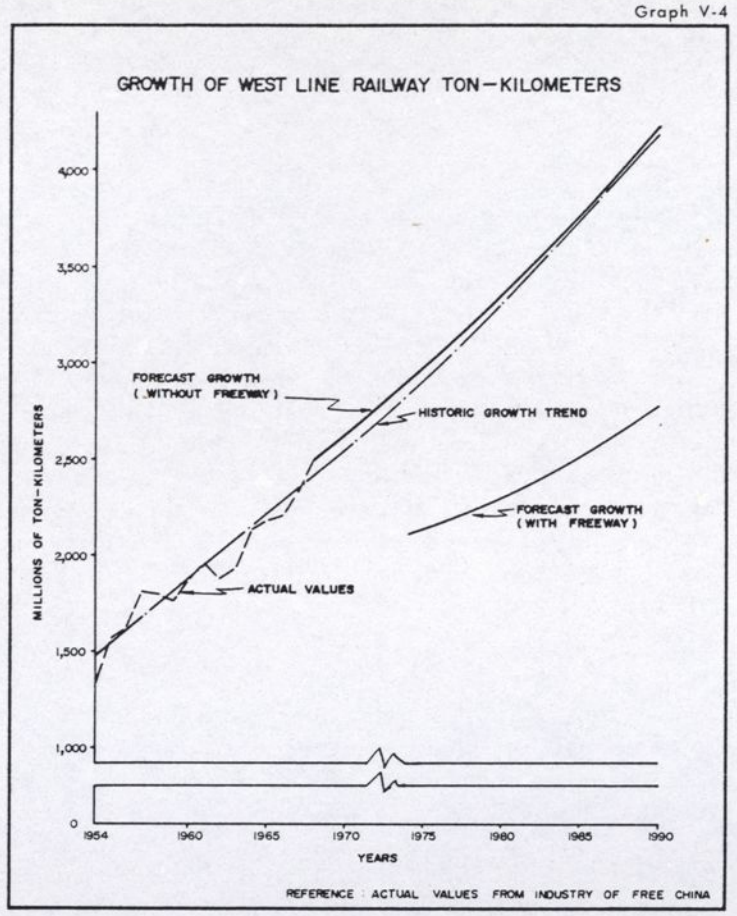
Graph V-2



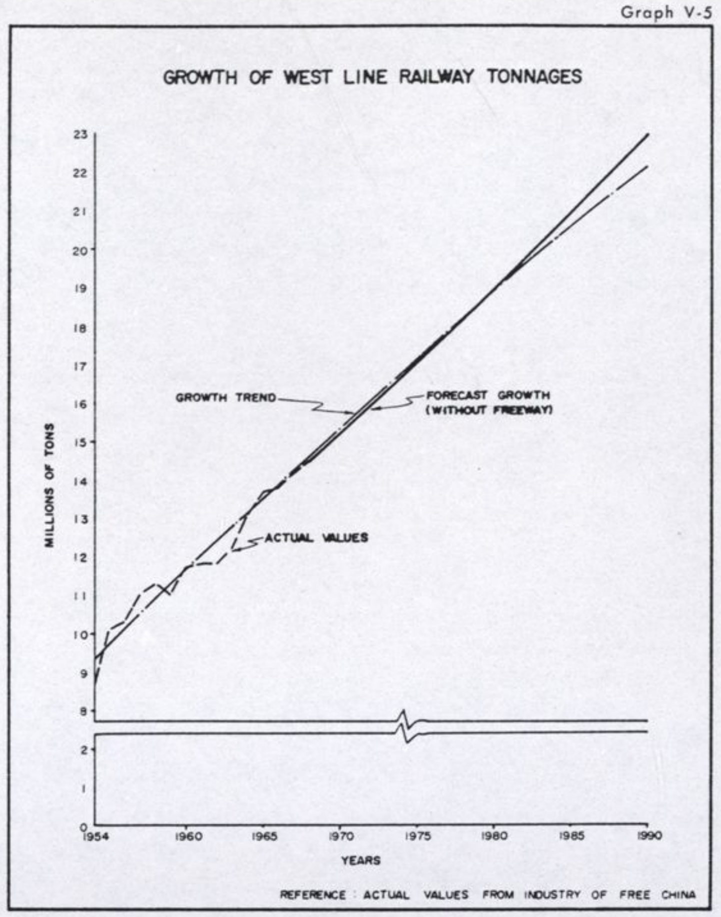
Graph V-3



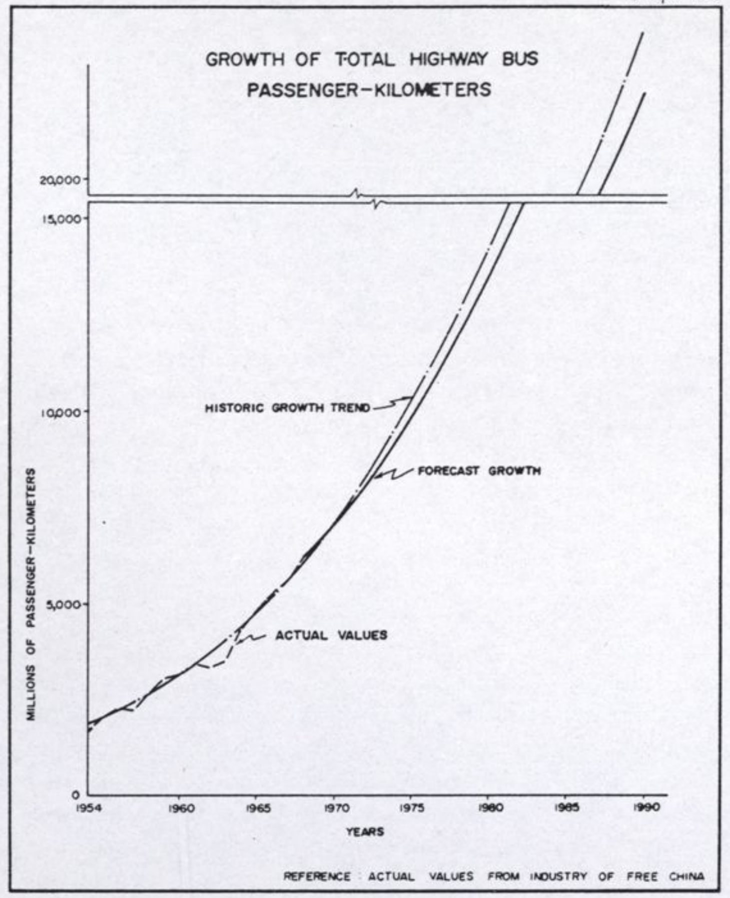
Graph V-4



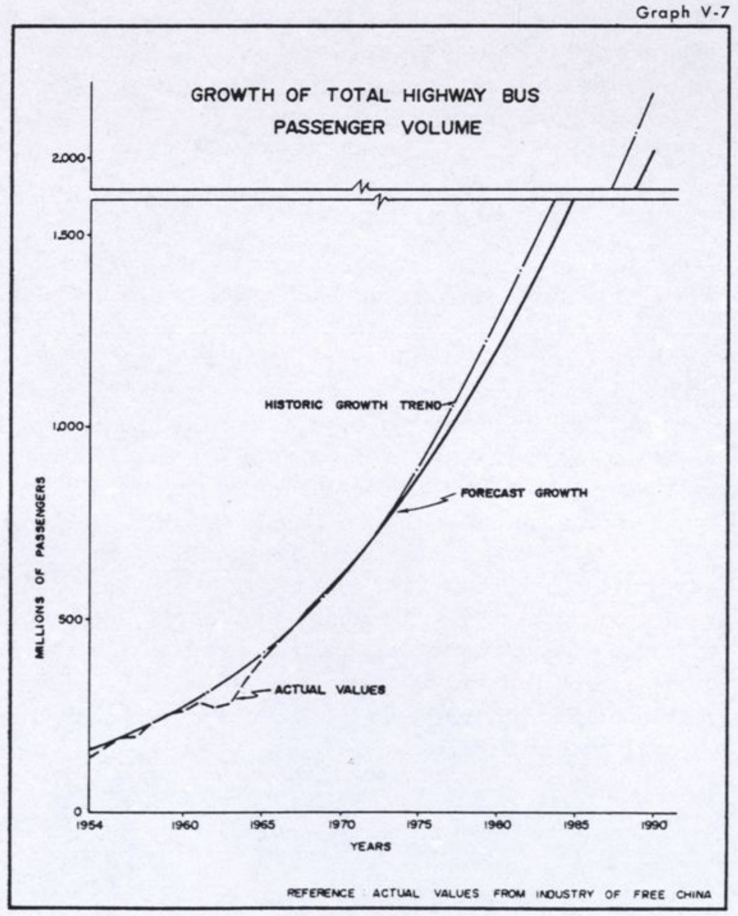
Graph V-5



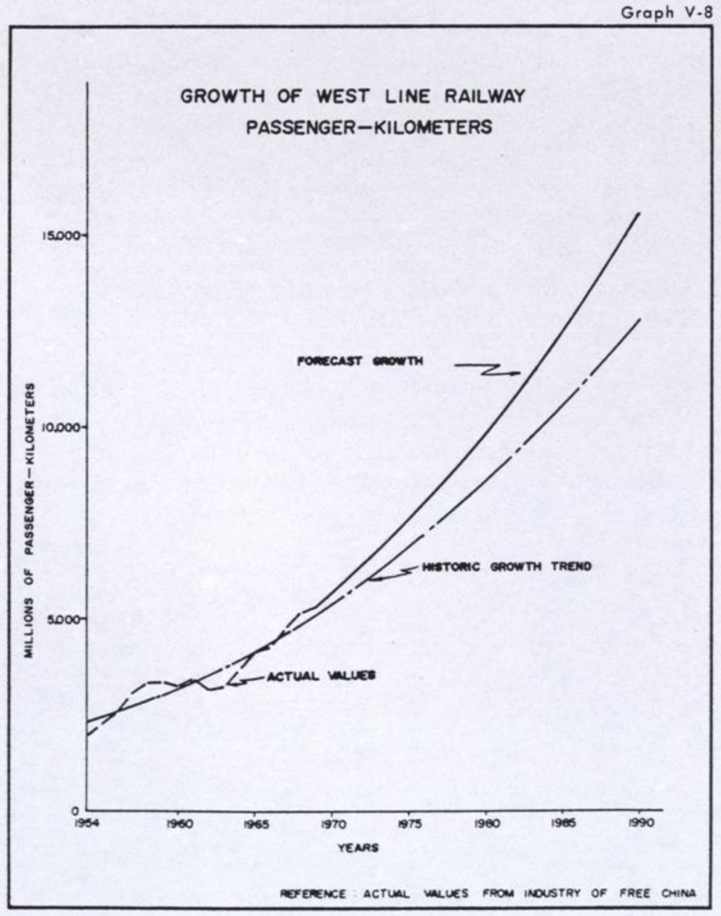
Graph V-6



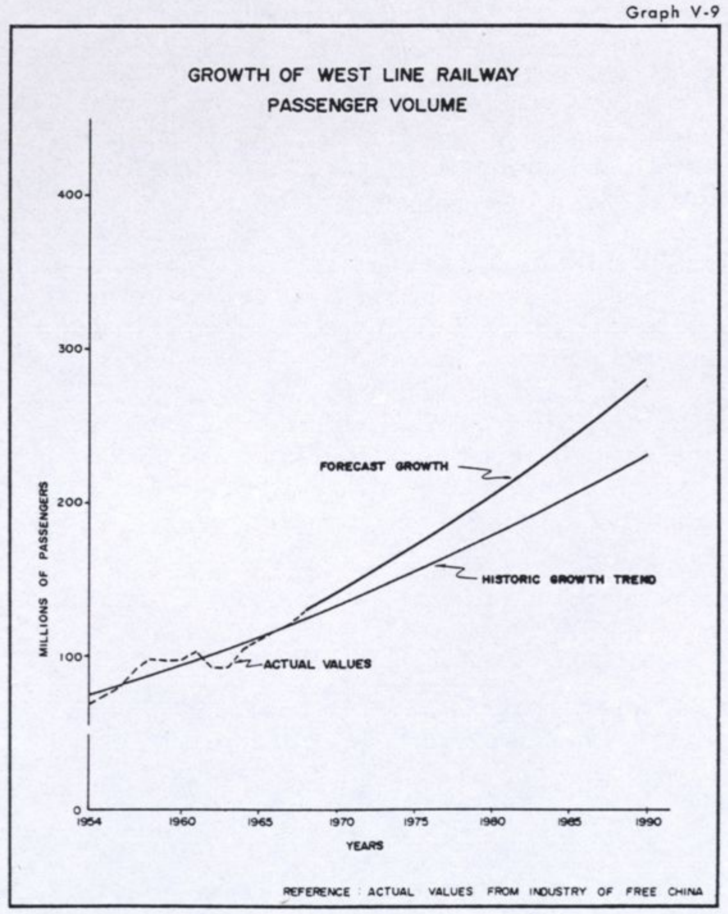
Graph V-7



Graph V-8



Graph V-9



With this value for 1969, a percent-of-trend analysis was made to determine the extent of divergence from the second-degree trend line. Since the line was established by using the 1968 value, inter alia, the 1968 and 1969 divergence from the previous years' trends would be somewhat understated. The percent-of-trend analysis indicated that, whereas the values for 1963 through 1967 ranged from only 95.3 percent (1967) of the trend estimate to 99.2 percent (1966), the value for 1968 was more than 106 percent of trend, and the estimated value of 1969 was approximately 116 percent of the trend estimate.

A conservative estimate was applied to this continuance of divergence from past trend. While actual ton-kilometers in 1970 and thereafter might deviate from the trend line estimates by a greater amount than the 1969 total is expected to, estimates for ton-kilometers over the years 1970-1972 were arrived at by keeping these values at 116 percent of the trend line values. Thus, although the increase in 1968 was about 26 percent above 1967 and the estimated 1969 rise would be 23 percent, the rise in 1970 (by not increasing the percent of trend) would drop to around 12 percent.

These estimated values for 1970 through 1972 were not used. In order to insure that the values were not overstated, the Development Plan's forecast of a slowdown in economic growth over the Fifth Plan period was taken into account.

The ton-kilometer growth during 1970-1972 was altered so that the ratio of the final growth estimate to the estimate obtained from the percent-of-trend analysis was equal to the ratio of the Development Plan's forecast of GNP expansion in the 1970-1972 period to the GNP growth which might be expected from the historic trend, or, stated as a formula:

$$\frac{\text{final estimate of 1970-1972 ton-kilometers growth}}{\text{growth indicated by altered historic trend}} = \frac{\text{final estimate of GNP growth}}{\text{growth indicated by historic trend}}$$

The final forecast ton-kilometer figure for 1970 obtained in this manner was 1,347 million. This would mean an increase of almost 11 percent in that year. Subsequent rises in 1971 and 1972 would be by less than ten percent and less than nine percent, respectively.

After these calculations had been made, a new trend line was obtained by using the values, actual and projected, for the 1958-1972 period. The trend equation derived by regression analysis is:

$$Y_E = 632 + 101.44x + 6.34x^2$$

where $\underline{x}$ equals the number of years after 1965 (i.e., after the mid-year of the 1958-1972 period), and Y_E equals millions of highway ton-kilometers in the $\underline{x}$ year.

This equation gives a value of 7,131 million highway ton-kilometers in 1990, an expansion of approximately 7.21 times the 1968 value. The average annual compound growth rate over the 1968-1990 period would be 9.4 percent. The figure of 7,131 million was not the final forecast for the "without freeway" condition, however. The last step, which increased the 7,131 million figure to 7,243 million and increased the expansion factor from 7.2 to 7.3 (as shown in Table V-22), requires a separate discussion of the proposed port at Wuchi.

The Effects that a Port at Wuchi Would Have on Rail-Highway Competition

To assess the effects that a port at Wuchi might have on the inland transport pattern, it is a prerequisite that the patterns of exports and imports be known. The Japanese port study (which assesses the relative merits of developing Wuchi or Tamshui as the third major port) indicated that, had a major port at Wuchi been open in 1967, it would have handled about 2.8 million revenue tons of cargo. This amount would have represented approximately 17.8 percent of the revenue tons which were handled in 1967, and it would have equalled nearly one-half of the revenue tons handled at the port at Keelung.

If this relationship were to hold true to 1990, i.e., if Wuchi continued to handle about 17.8 percent of all sea-going cargoes, and if this were true not only for total cargoes but for both exports and imports (coastal shipping will be ignored here, and the advantage to the highways may therefore be somewhat understated), then Wuchi would handle about 1.7 million metric tons of exports and 2.34 million metric tons of imports in 1990. As will be discussed later in Chapter VI under Freeway-Railway Competition, all of these tons ought to be shipped to and from Keelung and Kaohsiung by rail, since their inland origin or destination is too distant for trucks to be competitive with rail.

With a third major port at Wuchi on the central west coast, however, the situation would change markedly. As the rail-highway competition discussion shows, the present average distance at which trucking becomes competitive with rail transport is 90 kilometers. Thus, any of the export or import tonnages which would be handled at Wuchi and which would require only 90 kilometers (or less) of inland transportation, would be carried by truck rather than rail. Exhibit VI-4 shows the area in which exports and imports going through Wuchi would be handled by truck; that is, all exports and imports that would travel to or from any point within the 70 air-kilometer (approximately comparable to 90 land-kilometers) semi-circle around Wuchi might be expected to be shipped overland by truck.

Thus all export and import tonnages from or to the hsiens of Miaoli, Taichung, Chang Hua, Nantou and Yunlin would have been shipped by rail under the "without freeway" condition if there were no port in central Taiwan. With a port at Wuchi, however, all of these tonnages (with or without a freeway) would be shipped by truck. In 1990 these tonnages should total approximately 2.9 million. In addition there should be a small amount of exports originating from, and imports destined to, the hsiens of Hsinchu that would be within 90 kilometers of Wuchi, and would therefore be transported by truck. The total forecast export and import tonnages to be handled at Wuchi and to be transported overland by truck in 1990 is nearly three million.

Tons were translated into ton-kilometers by using the reported (trucking service) average distance of shipment over the 1964-1968 period. This average distance was 37.6 kilometers. The Wuchi export and import tonnage that should be shipped by truck in 1990 multiplied by this distance equals approximately 112.3 million ton-kilometers. Using the reported average distance of shipments produced a conservative estimate of the growth of highway cargo traffic. The road survey in April 1969 indicated that the average distance of heavy truck shipments was 67.24 kilometers. If this figure had been used to determine the effect of the proposed Wuchi seaport on growth of highway cargoes, the increase in 1990 ton-kilometers would have been 200.9 million.

When the 112.3 million ton-kilometers for Wuchi cargoes in 1990 are added to the previously estimated total of 7,131 million for the year, the final forecast of the 1990 "without freeway" highway ton-kilometers became 7,243 million. This represented a projected expansion of 1969 ton-kilometers by 7.324 times over the 22-year period. The average annual compound rate of growth would be 9.5 percent.

Alteration of Other Historic Trends of Cargo Traffic

The forecast of "without freeway" highway tonnages to be transported in 1990 is tied directly to the ton-kilometer forecast. In other words, since the distance at which trucks become competitive with rail (presently averaging 90 kilometers) is not expected to change under the "without freeway" condition to 1990, the average distance of a shipment (as reported by trucking companies) is not predicted to change. It follows that highway tons under these conditions would then grow at approximately the same rate as ton-kilometers. This is only an approximation since the average distance used was for the entire 1964-1968 period, rather than for 1968 alone. Thus highway tonnages are expected to expand from a 1968 level of 27.3 million to a 1990 level of 190.6 million, a total expansion of around 7.0 times, and an average annual rate of growth of about 9.25 percent.

As indicated earlier, the Development Plan's forecast of reduced economic growth over the Fifth Plan period was used to adjust downward the forecast of growth of highway ton-kilometers. The same is not true, however, for the forecast of West Line Railway ton-kilometers. Rather, use of the Development Plan's projection to 1972 of West Line ton-kilometers resulted in an upward adjustment of rail cargo growth.

As shown in Graph V-4, the historic trend of West Line ton-kilometers would indicate a level of nearly 2,700 million in 1972 and a level of approximately 4,186 million in 1990. This means that the average annual growth rate over the entire 1968-1990 period would be around 2.4 percent.

The Development Plan, however, foresees a West Line ton-kilometer level of 2,778 million in 1972, or 78 million more than indicated by the historic trend. Despite the fact that this growth acceleration might seem to be contradicted by the Plan's forecast of an economic slowdown over the same period, the Plan's forecast of rail ton-kilometers was accepted as reasonable because: (1) TRA's acquisition of the Metal & Mining Corporation Railway in August 1967 should mean that subsequent TRA traffic totals will be slightly higher than those indicated by the historic trend (thus the 1968 figure was higher than the trend estimate); and (2) an acceleration of railway investment and completion of double-tracking along the entire West Line route should stimulate growth somewhat beyond what has occurred historically.

After it was determined that the Plan forecast of West Line ton-kilometers over the 1969-1972 period was realistic, these figures were incorporated in a trend analysis which resulted in the equation:

$$Y_E = 2,052 + 72x + 1x^2$$

where $\underline{x}$ is the number of years after 1963, the mid-year of the surveyed period, and Y_E is the number of West Line ton-kilometers in millions.

The value this equation gives for 1990 is 4,725 million, or 539 million more than were indicated by the historic trend. The total expansion from 2,500 million in 1968 would be 1.890 times, or an average growth of about 2.9 percent per annum.

Just as with highway ton-kilometers, however, the growth forecast is not complete until the proposed Wuchi port has been taken into account. The cargo which would be diverted from rail to highway as a result of the port under the "without freeway" condition was calculated at 2,987,600 tons. When this total is multiplied by 164 kilometers, which is the average distance of a rail shipment for the period 1964-1968, the total reduction of ton-kilometers is 490 million. The final "without freeway" forecast of West Line Railway ton-kilometers becomes 4,235 million, or about 1.69 times the 1968 total. The average annual growth rate over 1968-1990 would be 2.4 percent.

The forecast of tonnage by rail to 1990 was accomplished in the same fashion as the forecast of highway tonnage. That is, the average distance per shipment was assumed to be maintained at the 1964-1968 average (always for the "without freeway" condition only). Thus, tonnages of West Line cargoes are foreseen to expand by approximately the same amount as rail ton-kilometers. Specifically, West Line tons are expected to grow from a 1968 level of 14.5 million to a level of 23.0 million in 1990. This would be a total expansion of 1.59 times, and an average growth rate of 2.1 percent per annum.

Forecast of Total Land Freight Service Traffic to 1990

This study forecasts that total land freight service in 1990 for the "without freeway" condition, would transport approximately 214.3 million tons, giving a figure of 11,562 million ton-kilometers. Of these totals, trucks would account for 62.6 percent of ton-kilometers (compared with nearly 26.9 percent in 1968 as shown in Table V-27) and 88.8 percent of total tons.

The West Line Railway would account for most of the remainder of tons and ton-kilometers, although the forecast of East Line cargoes (again taking into account projections of the Fifth Development Plan) indicates that the East Line might be expected to have about 1.1 million tons in 1990 (compared with 584,000 in 1968), and account for 84 million ton-kilometers. It seems doubtful, however, that the East Line will still handle cargo in 1990, since the entire railway length is an uneconomic (for freight shipment) distance of only around 176 kilometers, and, moreover, the railway is narrow gauge. The railway's present usefulness stems from the absence of any adequate highway. There is only a single-lane, unpaved highway which can be used only in the dry season. This condition will surely change prior to 1990. Nonetheless, no attempt was made to adjust highway ton-kilometers for the expected takeover of East Coast cargo transportation; such an adjustment of national highway ton-kilometers for highway traffic growth on the East Coast would have unduly affected the forecast for West Coast traffic growth.

The future of the railways not controlled by TRA was also investigated, viz., the railways owned by the Taiwan Sugar Corporation and the Taiwan Forestry Administration. As with the East Line Railway, the usefulness of these lines for hauling cargo is expected to decline in the future, and in fact, has already been waning. Trend analyses indicate that traffic on these lines should decline to zero prior to 1990. Judging by the length of the rail lines, they seem uneconomical and therefore their decline is likely. No cargo shipments were forecast for these lines in 1990.

Alteration of the Historic Trends for Passenger Traffic

As with highway ton-kilometers, highway passenger-kilometers were altered to take into account the expected slowdown in economic growth over the Fifth Plan period. This was done, as in the previous case, by making the ratio of the final estimate of 1969-1972 passenger-kilometer growth to the growth indicated by the historic trend equal to the ratio of the Plan's GNP growth estimate for 1969-1972 to the GNP trend line figure for the period.

The historic trend of highway bus passenger-kilometers indicates a level of 8,324 million in 1972 and a 1990 level of 23,822 million. The growth rate over 1968-1972 would average 7.6 percent per annum (compared to an average growth of 9.8 percent per annum over the 1954-1968 period), and the growth rate for the entire 1968-1990 period would average 6.3 percent per annum.

When a new trend line was derived, using the downward adjusted figures for the years 1969-1972 (8,006 million in 1972), the 1990 figure was reduced to 22,237 million, or 1,585 million below the historic trend value. The total 1968-1990 expansion would be by 3.58 times, or an average annual compound growth of about 6.0 percent. (See Tables V-22 and V-23.)

Highway bus passengers were projected by using the ratio of passengers to passenger-kilometers in 1990 provided by extension of historic trends. Thus the historic trend of highway bus passengers indicates a total of 2,172.7 million in 1990, or one passenger per every 11.0 passenger-kilometers. If this ratio were maintained with the revised passenger-kilometer forecast, the 1990 passenger total would be 2,022 million.

The forecasts of railway passenger-kilometers were made by incorporating Development Plan estimates (both for the West and East Lines) for the years 1969-1972 into trend analyses. As in the case of rail ton-kilometers, the Development Plan adjusts the historic trend for the West Line upward (rather than downward as highway passenger-kilometers were adjusted). As previously noted in the discussion of railway ton-kilometers, however, some upward adjustment seems reasonable in view of the railway's recently accelerated investment.

The upward adjustment of the 1969-1972 passenger-kilometer figures for the West Line Railway and the subsequent derivation of a new trend line by using 1954-1972 values, resulted in a forecast for 1990 of 15,530 million passenger-kilometers, or approximately 2,533 million more than indicated by the historic trend. The 1968 total is trebled, and the average annual compound rise is 5.1 percent. (See Table V-24.)

The Development Plan does adjust the East Line rate of growth downward for the 1969-1972 period, and the new trend line, obtained from using Plan values through 1972, indicates a passenger-kilometer total of 664 million in 1990 (as compared to 769 million indicated by the historic trend). The average growth rate over the 1968-1990 period would be about 5.5 percent per annum.

If the forecasts of railway passenger-kilometers were translated into passengers (using the same method as was used for buses, i.e., finding the passenger to passenger-kilometer ratio indicated for 1990 by the historic trends and applying that ratio to the revised passenger-kilometer forecasts), the 1990 West Line passengers would number 280.0 million and the East Line passenger total would be 18.9 million.

Forecast of Land Passenger Service to 1990

The combined railway and highway bus passenger services transported nearly 679 million passengers in 1968, and reached a level of 11,722 million passenger-kilometers. These totals are forecast to increase to 2,321 million passengers in 1990, and 38,431 million passenger-kilometers. The total expansion and average annual growth rate of passengers would be 3.42 times and 5.8 percent, while the expansion and average rate of growth of passenger-kilometers would be 3.28 and 5.6 percent.

Distribution of Ton-Kilometer and Passenger-Kilometer Growth Among Regions

The figures above the columns marked "heavy trucks" and "bus" in Table V-22, represent the expansion factors derived for the growth of national highway ton-kilometers and passenger-kilometers; and for the purpose of projecting future traffic, these factors have been equated to the growth of heavy truck and highway bus traffic.

In order to distribute this growth and the West Line Railway passenger and cargo growth (see Table V-24) by region, the cargo traffic growth was related to regional production and import tonnages, while the expansion of passenger traffic was related to regional income. Both the growth of regional production and import tonnages and the regional distribution of rising income were discussed in the preceding chapter (see Tables V-17 and V-20).

Production and import tonnages was forecast to expand 2.794 times over the 1968-1990 period; therefore total growth would be 1.794 times, or 179.4 percent. The growth of highway ton-kilometers would be 6.324 (after reduction of the expansion factor by 1.000), or 632.4 percent. The ratio of highway ton-kilometer growth to the rise of production and import tonnages would then be approximately 3.525.

This ratio was used to determine the regional distribution of highway ton-kilometer growth. Thus in Taipei hsien, for example, the forecast growth of production and import tonnages over 1968-1990 was about 201.5 percent. This figure, multiplied by the above ratio (viz., 3.525), equals 710.4, which represents the forecast growth of highway ton-kilometers in Taipei hsien. A similar procedure was used to obtain all the regional growth factors for highway ton-kilometers.

A similar procedure was also used to obtain regional growth values of railway ton-kilometers as well as highway and railway passenger-kilometers. The ratio of West Line Railway ton-kilometer growth to expansion of production and import tonnages was 0.387, and the ratios of highway and railway passenger-kilometer growth to the growth of national income were estimated at 0.953 and 0.739, respectively.

The Effects of Conversion of Traffic to the Freeway

Only the "without freeway" condition has been considered to this point, and all of the expansion factors shown in Tables V-22 to V-24 consider only that the highways and the railway will continue to be improved at approximately the same rate as has been true historically. Some allowance was made, however, for accelerating investment in the rail system, and this is reflected in the rail expansion factors.

Under the "with freeway" condition, only the ton-kilometer expansion factors for highway and railway would be changed. See Chapter VI for discussion of freeway-railway rivalry. The 1990 ton-kilometers which would be converted from railway to highway with the freeway are forecast to be around 1,253 million, and would increase highway ton-kilometers from the forecast "without freeway" level of 7,243 million to a level of 8,496 million. The highway ton-kilometers expansion factor would then become 8.59 and the average annual compound growth to 1990 would be 10.3 percent

The reduction by 1,253 million of West Line Railway ton-kilometers would lower the forecast 1990 level from 4,235 million under the "without freeway" condition to 2,982 million. The average annual growth rate from 1968 would be only 0.8 percent, and the expansion to 1990 would be 1.193, i.e. the 1990 total would be only about 19.3 percent above the total realized in 1968.

Correlation Analysis to Project Automobile and Light Truck Traffic

For the projections of auto and total vehicle registration, and subsequently for the forecasts of auto and light truck traffic growth, correlation analyses were done relating per capita income to auto registration and total vehicle registration per thousand population. The data used consisted of International Road Federation statistics on motor vehicle registrations in 27 countries and U. N. statistics on per capita income in these same countries.

The relations of total vehicle registration, auto registration, and truck and bus registration to per capita income for these 27 nations are shown in Graphs V-10 and V-12.

The correlation equation obtained for total vehicle registration is:

$$Y_E = -1.026 + 0.058x + 0.000077x^2$$

where Y_E is the number of vehicles per thousand population; and <u>x</u> is the per capita income expressed in U.S. dollars.

The equation has a standard error of 25.5 vehicles per thousand people.

The forecast of per capita income in Taiwan in 1990 is US $584 and the correlation equation gives a value of 59.2 vehicles per thousand, or a total registration (with a 1990 population about 21.1 million) of about 1.25 million.

Table V-29 indicates how regional forecasts of growth of vehicle registrations were accomplished. Actually the values shown differ somewhat from the final forecasts which were arrived at by totaling the various vehicle types in each region, after they were considered separately--see Table V-34. Using the regional per capita income forecasts previously discussed, a Y_E value was obtained for each hsien. These values were then multiplied by the forecast 1990 population for each region to arrive at vehicle totals for the several regions.

Because of the high standard error (viz. 25.5 as previously mentioned) it was deemed prudent for this forecast that the final projection should be the equation value less one standard error. Thus the figure of vehicles per thousand was reduced from 59.2 to 33.7 which reduced the forecast of total vehicle registration from 1.25 million to 711,200. According to the statistical method used, there should be an 86 percent chance that any country with the per capita income forecasts for Taiwan in 1990 would have a vehicle registration ratio at or above 33.7 per thousand population.

To distribute total vehicles by region, it was not possible to reduce all the regional Y_E values by one standard error, since one of them was smaller than, and others were only slightly higher than, the standard error. Therefore, the regional percentages of the country total were found from the original correlation equation values, and these percentages were then applied to the reduced country total in order to distribute these vehicles.

The end-of-April 1969 vehicle registration was used to measure growth to 1990. As the table indicates, total expansion for the nation was foreseen to be approximately 10.2 times, or at an average compound rate of 11.7 percent per annum. The regional expansions varied from around 6.5 to 15.7 times, and annual growth rates from 9.3 percent to 14.0 percent. The national expansion factor was used as the forecast of total vehicles; the regional expansion factors, however, do not represent the final forecast, but are shown to corroborate regional factors arrived at by another method.

An automobile registration forecast was derived by a method similar to that just described for total vehicles, as shown in Table V-30. The growth factors correspond to the automobile traffic expansion factors in Table V-22.

To forecast total number of light trucks in 1990, it was necessary to first project the 1990 numbers of heavy trucks and buses so that these totals, together with the forecast number of autos, might be subtracted from the forecast of total registered vehicles.

The 1968 highway ton-kilometer and passenger-kilometer totals were achieved with approximately the average number of registered trucks and buses, respectively, in that year. The expansion factors for ton- and passenger-kilometers, therefore, were multiplied by the 1968 average number of heavy trucks (13,551) and buses (5,975) to arrive at the 1990 forecasts of 99,240 heavy trucks and 21,410 buses. It was realized that this method of forecasting heavy trucks and bus registration contained an element of imprecision since it did not allow for the fact that a significant number of trucks were used for construction, or other urban use, and a sizeable number of buses also are used solely in urban areas and thus do not account for any portion of highway-kilometers. Moreover, to the extent that the average size of a heavy truck might increase in the future over the 4.3 metric ton average of 1969, fewer heavy trucks would be required to handle a given level of ton-kilometers. Nevertheless, the trend analysis of registrations, which will be discussed later in this chapter, indicates that there is presently a backlog of unmet demand for these vehicles for both urban and highway purposes; thus it was concluded that the 1990 totals indicated above were realistic.

When the forecast totals of autos, heavy trucks and buses were deducted from the forecast of total registered vehicles in 1990, the remainder was 113,550 vehicles. After checking this number with past growth and the extended historic trend, this was taken as the forecast of registered light trucks in 1990.

To distribute the 1990 total of light trucks by region and to obtain the expansion factors for light truck traffic, two separate theorectical distributions of end-of-April 1969 light trucks were measured against actual distribution. Light trucks were distributed by the regional percentage shares of national income and the percentage shares of national gross product of services, the latter on the theory that the preponderance of light trucks were used by organizations or individuals providing some sort of service.

The distribution obtained by using percentage shares of national income showed wide variance from the actual end-of-April 1969 distribution and was discarded. As Table V-31 shows, the results obtained by using regional gross products of services as an index were much more satisfactory. Hence, the 1990 forecast of light truck registrations was distributed according to the forecast regional gross products of services. The regional expansions of light truck registrations, shown in the last column of Table V-31, are identical to the Table V-22 expansion factors for light truck traffic.

Forecast of Vehicle Registration

The forecasting of vehicle registrations was discussed previously. The national totals of autos, heavy trucks, light trucks, and buses have been forecast for the "without freeway" condition (only the total of heavy trucks is forecast to change for the "with freeway" condition), and the projected 1990 numbers of autos and light trucks have been distributed by region. Three steps remain: (1) heavy trucks and buses must be distributed by region; (2) the forecasts must be checked by analyzing the trends of registration of each vehicle type; and (3) by looking at future vehicle requirements and projected domestic production, it must be determined whether import requirements might be so large as to prevent the forecast totals from being attained.

Tables V-32 and V-33 show the distribution of the forecast heavy trucks and buses by region. The procedure used was similar to that used for distributing light trucks, except that heavy trucks were distributed on the basis of percentage shares of national production and import tons, and the forecast total of buses was distributed on the basis of regional incomes. The high positive deviations of actual heavy trucks registrations from the theorectical in Taipei and Kaohsuing hsiens may well mean that production in those hsiens has been understated to some extent. Conversely, production in the hsiens of Pingtung, Yunlin and Changhua may be overstated.

Table V-34 presents a summary of the final "without freeway" vehicle registration forecasts. By referring back to Table V-29, it can be seen how closely the two forecasts, arrived at by different methods, agree. The final forecast foresees an expansion by 9.3 times of registered vehicles in Taipei, whereas the correlation analysis indicated an expansion by 9.7 times. In no region do the twin expansion factors differ by as much as 2.0, and only in Miaoli, Yunlin, Chiayi and other hsiens do the two forecasts of expansion differ by more than 1.0.

Historic Trends of Vehicle Registrations

Table V-35 indicates past growth in number of vehicle registrations and the rates of growth projected to 1990. As would be expected from the preceding discussion of registration forecasts, only private automobiles, among all vehicle types, are foreseen to increase their percentage share of total registrations. Their share of the total was 33.4 percent at the end of 1955 and declined to 23.5 percent by April 1969. The forecast anticipates private autos representing about 59.6 percent of total registrations in 1990. Vehicles owned by transport service companies--viz., taxis, heavy trucks and buses--are expected to experience declines in their percentage shares of total registrations.

Graphs V-35 to V-17 show both the extended historic trends of registration of the various vehicle types in Taiwan, and the forecast levels of registrations. The second-degree historic trend lines understate the recent growth rates of all vehicle types except buses, since they give too much emphasis to past years of low domestic production and import restrictions, and place too little weight on the recent period of accelerated production and liberalized imports. Thus the graphs show also third-degree trend lines as the curves of best fit. These give unrealistic values when extended over the future 20-year period, however, and are shown only to indicate the extent to which the Consultant's projections fall below these values.

The quadratic curves, which were estimated to show growth from present registered vehicle levels to the forecast levels, are conservative since they show rapid deceleration of present growth rates. These curves were later used to find interim year values for user savings; and had these curves been less conservatively estimated, user savings in early years (which are heavily weighted when discounting is done) would have been higher than those shown in the discussion of freeway benefits. Table V-36 shows the expected numbers of registrations, as estimated from the growth curves, for all years to 1990. These totals are for the "without freeway" condition and do not include the additional heavy trucks which would be required for hauling cargoes diverted from rail to freeway.

Vehicle Requirements and Domestic Production

This analysis would be incomplete if it were shown only that the vehicle registration forecasts were realistic in terms of demand, and no effort was made to forecast sources of supply--and in particular, to project the import requirements. To complete the analysis, the vehicle requirements were projected taking into account increasing registrations and the number of vehicles to be replaced each year, i.e., vehicles which would be fully depreciated. In order to estimate the latter, eight years was taken to be the useful life of all vehicles with the exception of taxis which have an average useful life of only about six years.

After projecting vehicle requirements, domestic production of each vehicle type was forecast by using past production figures and Development Plan estimates of production over the 1969-1972 period. Actually, the trends of production may greatly understate future production capability; the largest Chinese motor vehicle manufacturer, Yue Loong Motor Co., is expanding capacity in 1969 from 8,000 to 20,000 units per year and has plans to increase capacity to 100,000 units per year by the mid-1970's.

Tables V-37 to V-40 show the forecast vehicle requirements for all years to 1990; Table V-41 indicates the projected growth of production over the 1969-1990 period while Table V-42 compares the levels of requirements and production. The same forecasts and comparisons are shown graphically in Graphs V-18 to V-23. Graphs V-22 and V-23 compare light and heavy vehicle requirements with light and heavy vehicle production. These latter comparisons were included to indicate the increased portions of light and heavy vehicle requirements which might be met by domestic production if, rather than attempt to export surplus production of autos and buses, growing production were directed to expanding the manufacture of light and heavy trucks.

Effects of Converted Traffic on Heavy Truck Registration

To this point in the discussion of vehicle registration only the "without freeway" condition has been considered. As mentioned earlier (and as will be discussed in detail in Chapter VI), the conversion of traffic from rail to the highways under the "with freeway" condition, is foreseen to have little effect on traffic other than heavy truck volumes. Thus traffic conversion would also effect only the number of heavy trucks registered.

The number of heavy truck registrations was expanded by calculating the number that would be required to haul the tons diverted from the railway. This number would be 17,170 in 1990 (measured in terms of 1969 truck equivalents), and would bring the forecast level of all heavy trucks to 116,410 in 1990. Total vehicle registrations in that year could then be expected to be 728,370.

Containerization Under the "Without Freeway" Condition

Without a freeway, and without substantial new investment for railway container cars and facilities, containerization could not be developed to its full potential in Taiwan. Present highways are not adequate to permit efficient movement of trailers as large as even medium-sized containers, and certainly it would be very difficult to move the larger containers over most of the country's present highways.

If one mode (i.e., railway or highways) were to improve its container-handling capability substantially, while the other made only gradual progress, the rapidly improving facility would achieve a significant temporary advantage--at least until the opening of a port at Wuchi. In such a case the forecast of the near-term split of freight service cargoes between railway and highways would likely be inaccurate.

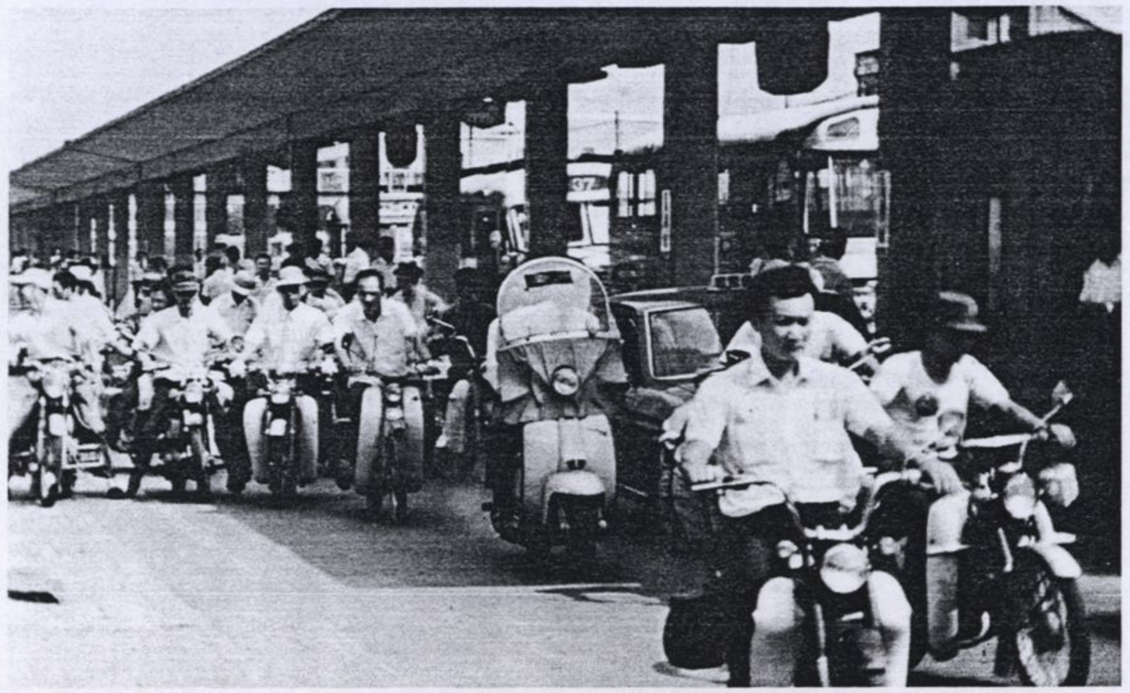
The basic assumption in making the forecast, as stated earlier, was that future investments in the railway and highways would continue at approximately the same rates of past investment, although some acceleration of the rate of investment was allowed for in the case of the railway. A corollary to this basic assumption was that container-handling capability would advance only gradually for both modes, and that therefore containerization would not cause any change in the break-even competitive distance for highway and railway which would remain at about the present distance of 90 kilometers.

Moreover, even if the railroad were to substantially improve its capability to handle containers, its advantage would be largely dissipated, even without the freeway, once the planned port at Wuchi was opened. This would be true since containerization would be used mainly for foreign trade cargoes (since the great advantage of containerization is in saving harbor handling and time), and trucks could be expected to handle most port traffic since most would travel to the larger cities, all of which would be fairly close to a port, and to nearby industrial parks.

Slow-Moving Vehicles

To complete this review of highway traffic and vehicle registrations, some thought must be given to the future of slow-moving vehicles, which presently far outnumber the number of fast-moving motor vehicles.

Slow-moving road traffic in Taiwan includes three-wheeled vehicles (both motorized and manually driven), motorcycles, bicycles, hand-carts, and ox-carts. Of these, only motorcycles have been increasing in number recently. Table V-43 indicates how the numbers of these various vehicle types have varied over the past several years.



Slow Moving Traffic

Of the various types of vehicles, carts (both hand-drawn and ox-drawn) and manually-driven, three-wheeled vehicles are declining in number. There may also be fewer motorized three-wheeled vehicles, and the number of registered bicycles has varied only slightly since 1965.

The number of motorcycles, on the other hand, has been growing quite rapidly. In 1968 the number of motorcycles of 50 cc and over grew by 70.2 percent. If the increase in number of all motorcycles over the last eight months of 1969 continued at the January-April rate, motorcycle registrations at the end of 1969 would have been more than 637,000, and the rate of increase over 1968 would have been nearly 32 percent.

In order to forecast the number of motorcycle registrations in 1990, this study made two assumptions: (1) there will be approximately four million family units in Taiwan in 1990 for a total of approximately 21.1 million persons and an average family size of about 5.3; and (?) with a forecast per capita income of US $584 in 1990, the average family unit would have a total income of around US $3,000 and could afford at least one motorized vehicle.

With these assumptions, the minimum number of privately-owned vehicles in Taiwan in 1990 would be four million (i.e., equal in number to total family units). If most of the forecast number of light trucks were privately-owned, the number of private autos (the forecast is for 424,000) and light trucks (113,550 are forecast) would be about one-half million. The remaining minimum of 3.5 million would be motorcycles.

The forecast of 3.5 million motorcycles in 1990 would mean that the number of registered motorcycles would grow by about 5.5 times over 21 years, or at a rate of approximately 8.5 percent per annum. This rate of increase would be higher than that forecast for buses, but lower than the forecast rates for other vehicles.

Coastal Shipping and Domestic Air Traffic

As previously discussed, coastal shipping and domestic air traffic have been of only minor importance in Taiwan compared to highway and railway traffic. In 1968, while trucks and railways were hauling about 53 million tons, coastal shipping carried only about 329,000 tons, and domestic air service accounted for only around 7,000 tons of cargo.

The situation with regard to passenger traffic has been quite similar. In 1968, when railways and buses accounted for nearly 1.1 billion passengers and 14.4 billion passenger-kilometers, coastal shipping transported only 172,000 passengers over approximately 17.8 million passenger-kilometers, and domestic air traffic transported 555,000 passengers over a total of 101.4 million passenger-kilometers. Thus number of coastal sea and domestic air passengers and passenger-kilometers represented only about 0.07 percent and 0.82 percent, respectively, of the national domestic passenger service totals.

In the future, coastal shipping and domestic air transport are expected to remain insignificant insofar as cargo movement is concerned. Coastal shipping cargoes are forecast (from the historic trend) to rise by only 2.5 percent per year, while air cargoes, even though they are forecast to rise by more than ten times over the 1968-1990 period, are expected to remain insignificant at a level of 71,000 tons.

With passengers, however, domestic air travel may become of some importance. It is estimated that growth of domestic air passenger traffic will maintain an average rate of increase of 16 percent per annum to 1990 (compared with 17 percent per annum over the 1965-1968 period). If this forecast proves to be correct, domestic air passengers will total approximately 14.3 million in 1990, while air passenger-kilometers will rise to about 2.6 billion. Domestic air service will then account for about 0.6 percent of the national total of domestic passengers, and 6.3 percent of total passenger-kilometers.