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FOR
INSTITUTE OF TRANSPORTATION
MINISTRY OF COMMUNICATIONS
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WEST TAIWAN HIGH SPEED RAIL FEASIBILITY STUDY

EXECUTIVE SUMMARY

MARCH 1990

AmDeC - CECI JOINT VENTURE

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EXECUTIVE SUMMARY

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1. INTRODUCTION

The West Taiwan High Speed Rail Feasibility Study examined existing conditions in the West Taiwan Corridor for all modes of transportation, projected future transport requirements, and evaluated the feasibility of implementing a high speed rail system. This study, commissioned by the Institute of Transportation, Ministry of Communications, started in mid-January 1989 and was completed in March 1990.

Primary aspects of the feasibility study include:

- Documentation of the present total travel demand in the West Taiwan Corridor.
- Projected passenger demand for a high speed rail system in year 2011.
- Investigation of upgrading the Taiwan Railway Administration's (TRA) narrow-gauge system using advanced technology.
- Analysis of station stops for a high speed rail system.
- Identification and evaluation of alignments for steel wheel-on-rail and maglev technologies and development of the capital cost for each alignment and technology.
- Evaluation of the alignments in terms of service to the Corridor and support of development plans.
- Evaluation of the high speed rail technologies to identify the most appropriate technology for application in the West Taiwan Corridor.

- Development of a preliminary environmental assessment to identify alignment and technology impacts and mitigation measures.

- Financial and economic analyses and evaluation.

- Development of an implementation plan including preliminary design and construction schedules.

The major findings of the feasibility study are summarized in this document and are presented in detail in the Final Report.

The study confirmed that the current transport facilities in the Corridor are approaching capacity and in some locations already exceed capacity. A principal finding of the study is that in the target year, 2011, a high speed rail system and two freeways will be required to meet the transport demand in the West Taiwan Corridor.

A high speed rail system in the West Taiwan Corridor would have a trip time from Taipei to Kaohsiung, with five intermediate stops of under two hours and by the year 2011, will carry approximately 180,000 passengers per day.

Most new railway systems are not financially viable. The study analysis shows that a new system in Taiwan would be no exception. To be viable, a capital grant is required. With the grant, the new railway will operate at a profit with no requirement for additional financial support from the government. The projected 4 to 1 ratio of annual revenue to operating costs will permit a relatively rapid repayment of construction loans from the surplus funds generated from the first year of revenue service in 2001.

The feasibility study examined the high speed rail technologies, steel wheel-on-rail and magnetic levitation (maglev), for application in Taiwan. Because the maglev technology has no system in revenue service, the finding of the study is that for implementation in the near term a steel wheel-on-rail technology proven in revenue service has the least risk and uncertainty.

The study conclusions are that a high speed rail system is feasible in the West Taiwan Corridor and will be required to meet the transportation needs of the future.

2. TRAVEL DEMAND / STATIONS

To develop travel demand projections for the West Taiwan Transportation Corridor, the first step was to collect the base year socio-economic data. For this study, current data was based on government statistics. This was then projected to the target year of 2011. Based on the available data, the year 2011 was selected as it was the furthest year for which socio-economic projections could be made with confidence.

The economy in the Republic of China is projected to continue its rapid growth for the near term. By 2011, household income is projected to double with car ownership increasing by a factor of four. Increased affluence and changes in social patterns will increase demand for transportation services.

The base year socio-economic data combined with the results of the study's March 1989 survey of travel behavior (origin-destination surveys, interactive interviews and screenline traffic counts) were input to a Transport Demand Model. This computer model tested combinations of: corridor alignments; vehicle technologies; number of stations and station locations; potential transfer stations; alternative operational concepts; and a range of fare structures. The model projected high speed rail ridership for the various combinations or scenarios. Twenty-three scenarios were tested in Phase I of the study and ten in Phase II to identify the optimum combination of factors.

The analysis identified an optimum scenario. For 2011, this scenario projected a ridership of 168,000 passenger trips per day with an additional induced demand (trips that would not have been made without high speed rail) of up to 11,000 trips per day. This average daily ridership combined with a "low staggered" fare generates revenue well in excess of operating costs.

Cities with station stops in the West Taiwan Transportation Corridor were selected based on modelling the transport demand for the urban areas in the Corridor. High speed rail extensions to Keelung and Pingtung were investigated but did not generate sufficient long distance passenger demand to support station stops. A three-station system, Taipei-Taichung-Kaohsiung, was examined. While the trip time was faster, the passenger demand was approximately 25% lower and a three-station system would be operationally uneconomical.

The study recommends the following major stations:

- Taipei Main Station
- Taoyuan / Chungli
- Hsinchu
- Taichung
- Chiayi
- Tainan
- Kaohsiung

Taipei Main Station and the Kaohsiung Station would be collocated with TRA stations while the other stations would be new. The new stations are recommended in lieu of joint use stations based on support of current and projected development patterns and avoidance of the high construction cost in urban areas as well as disruption to the population.

The high speed rail stations are projected to serve 60% of the population in the West Taiwan Transportation Corridor.

With an operational high speed rail system, TRA will continue to provide essential transport service in the West Taiwan Corridor. With over eighty stations between Taipei and Kaohsiung, TRA will serve the population which cannot conveniently access the high speed rail stations. TRA will also continue to provide freight movements in the Corridor and with the completion of the South Link will provide an around-the-island rail service.

3. ALIGNMENTS

In Phase I of the study, three alignments were developed using 1:25,000 scale maps. These alignments were designated the Mountain, Central and Coastal routes (see Figure 3-1). The Coastal alignment was dropped after Phase I due to significantly lower ridership (up to 30% less than the other alignments), lack of support of development plans and constructibility concerns. The Mountain alignment, modified to avoid fault lines north of Taichung, is recommended as the preferred alignment. This alignment (Figure 3-2) has a slightly lower cost, no

Figure 3 – 1

PHASE I HSR ALIGNMENTS

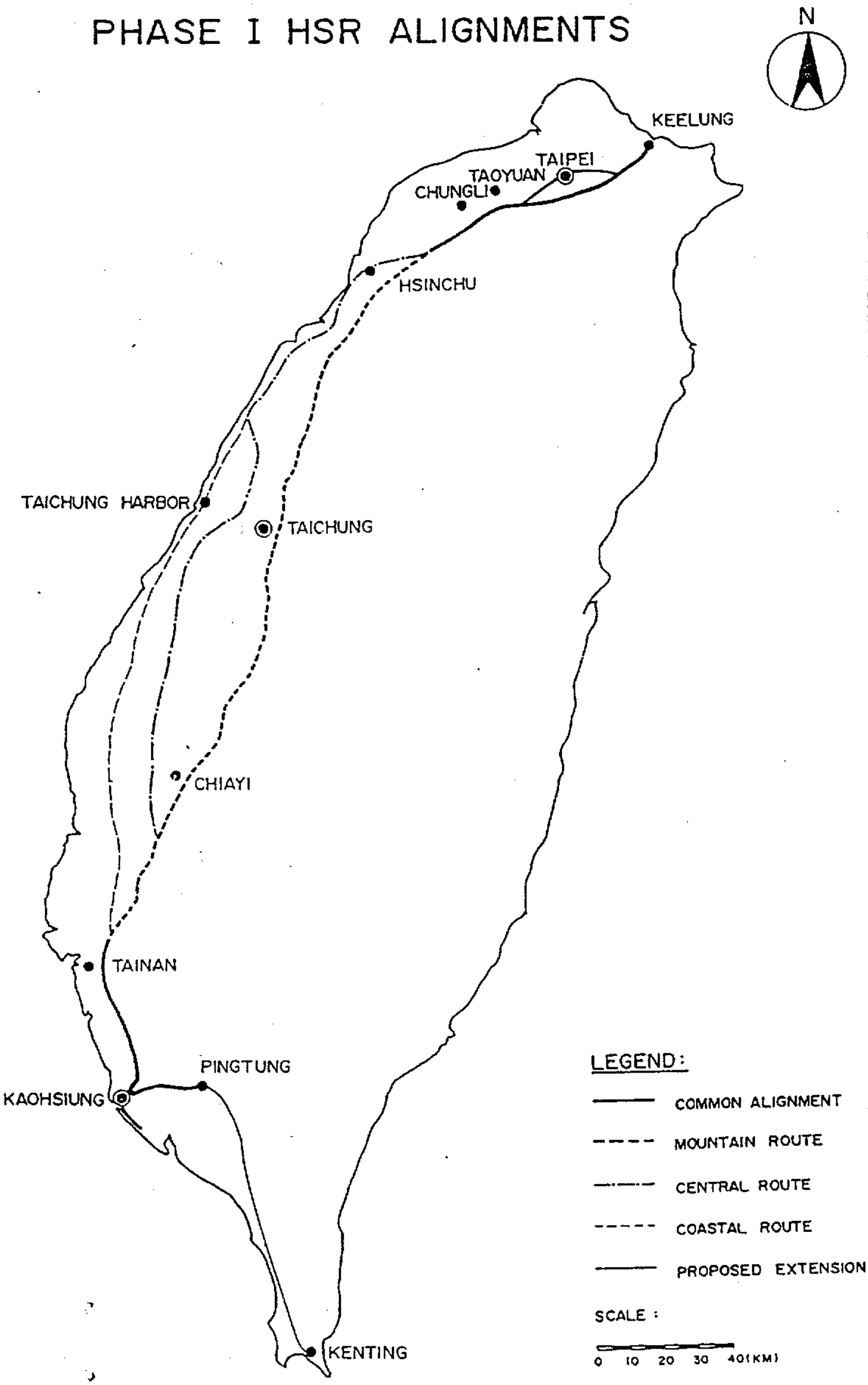
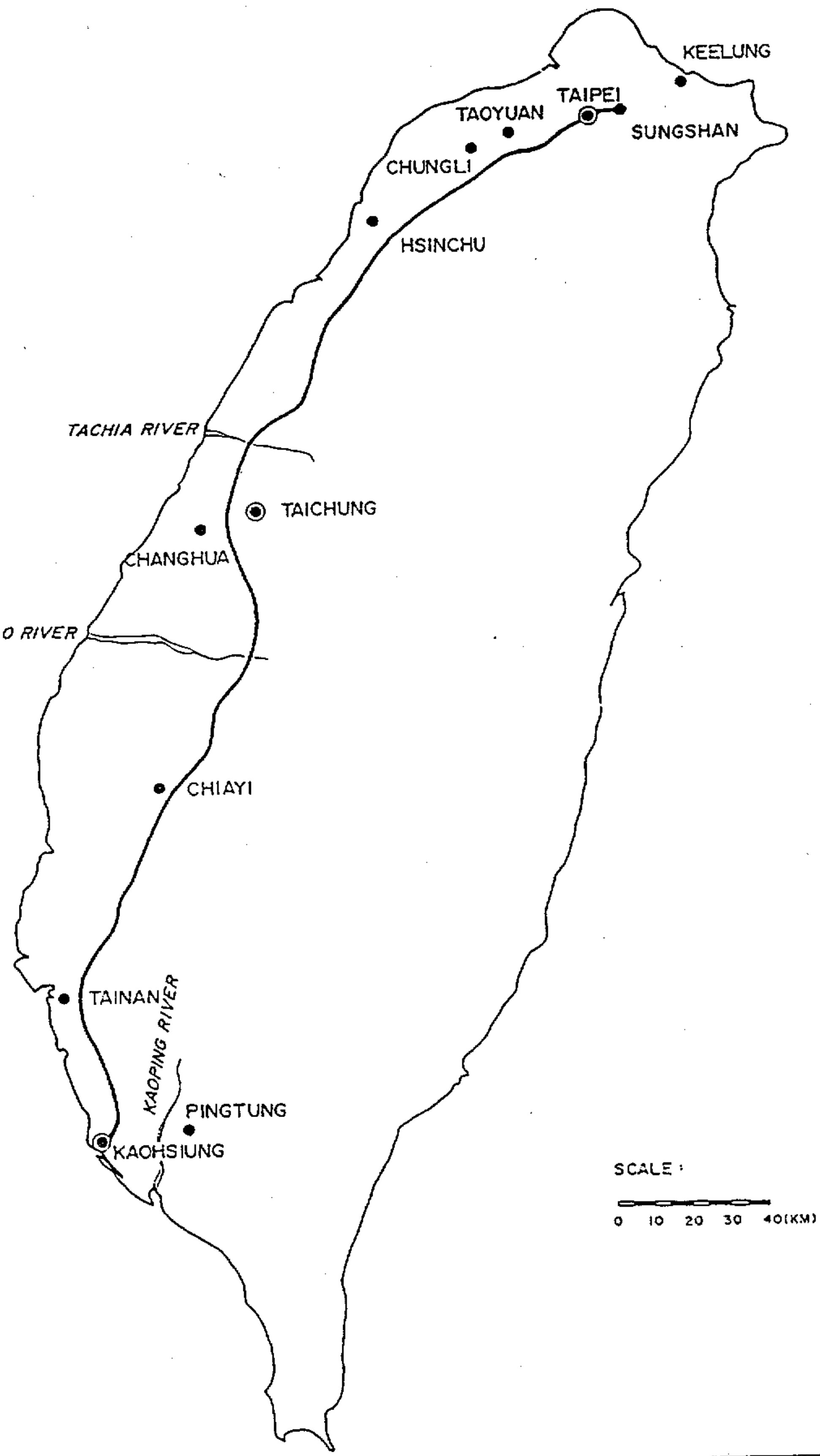


Figure 3-2

RECOMMENDED HSR ALIGNMENT



major constructibility concerns and is favored from environmental and support of development plan viewpoints.

With regard to the alignments, the study team only made limited field reconnaissance of the routes. The final alignment, subject to socio-economic, environmental and construction considerations, could vary from that shown by several kilometers or more in some locations. The final alignment will require further study, coordination with communities along the route and in-depth analysis during the planning and preliminary engineering phases.

The Mountain alignment is recommended for the high speed rail system in the West Taiwan Corridor.

4. HIGH SPEED RAIL TECHNOLOGY

One of the initial study requirements was to examine the potential of applying advanced technology to the existing TRA system to significantly reduce the trip time between Taipei and Kaohsiung.

The technology options available for narrow-gauge railways were investigated to include increasing the power-to-weight ratio and using tilt-trains on the existing alignment with speed limited to the current maximum of 120 kph. These technology applications provided minimal trip time improvement and were not cost effective. Increasing TRA's maximum allowable speed to 160 kph again provided minimal time savings with significantly increased cost. At 160 kph, there would be extensive requirements for curve straightening with associated land take and infrastructure improvements. Beyond 160 kph, the technology has not been developed for narrow-gauge railways, and no development is underway. The maximum trip time saving achievable with a large-scale upgrade of TRA (at considerable cost) was under forty minutes for the Taipei-Kaohsiung route. It was concluded that available narrow-gauge technology would not provide the desired trip time saving on the TRA system between Taipei and Kaohsiung.

Dual-gauging the TRA West Line for operation of a mix of narrow and standard-gauge trains was examined and was not feasible from engineering and train operations viewpoints. Limited sections of TRA track on the approaches to

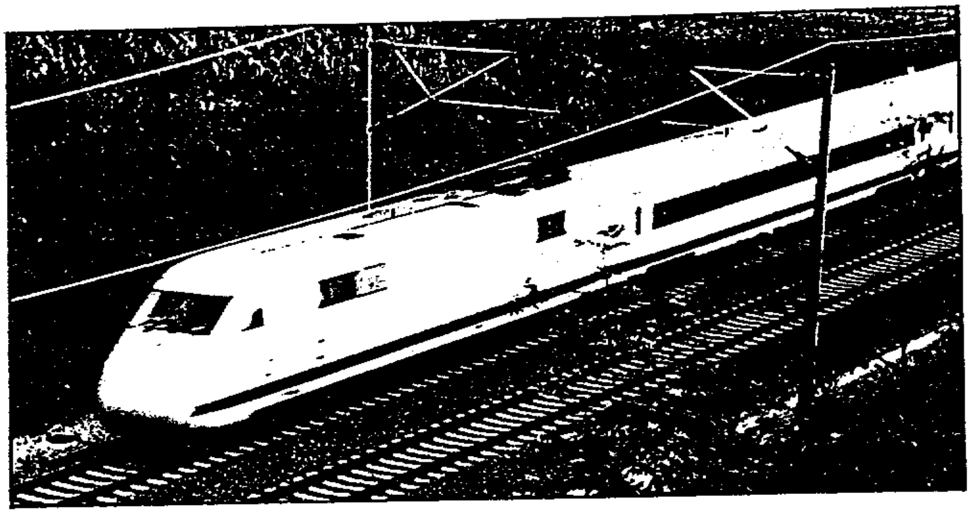
Taipei Main Station and Kaohsiung Station are recommended for dual-gauging. This will provide TRA and high speed rail transfer stations and reduce costs, particularly in Taipei where high speed rail will use existing and proposed TRUPO tunnels.

The use of the TRA right-of-way for a standard-gauge high speed passenger system would require such extensive curve straightening that the resulting alignment essentially would be totally new. The impact of this alternative is the same as a new alignment for high speed rail.

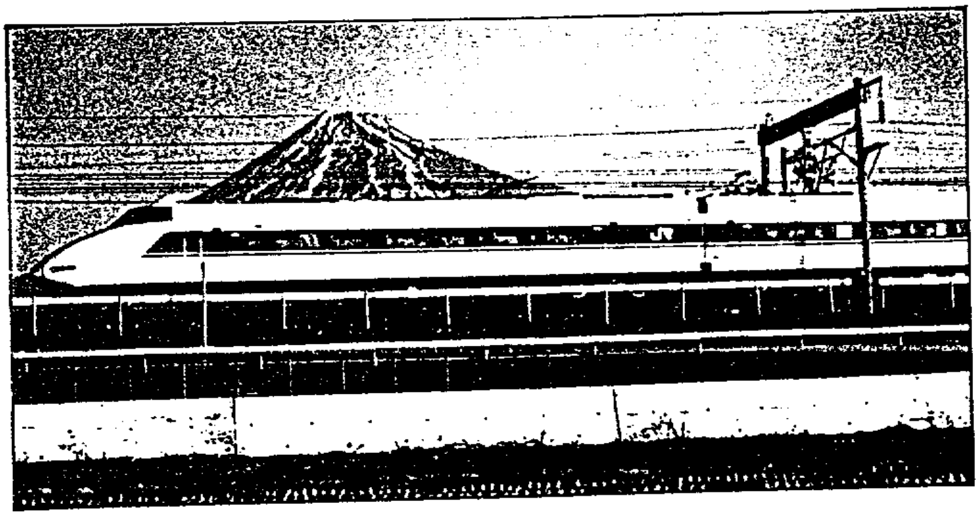
The study performed an in-depth analysis of the standard-gauge steel wheel-on-rail and magnetic levitation (maglev) high speed rail technologies. Steel wheel-on-rail systems examined included the Japanese Shinkansen series 100, the French TGV-A (Train a Grande Vitesse - Atlantique), the West German ICE (Intercity Express) and the Italian ETR 500. (See photographs next page.) The design speeds of the steel wheel-on-rail systems are in the 250 to 300 kph range which is applicable for the West Taiwan Corridor requirements. The Japanese Shinkansen system has been operational since 1964 with an unblemished safety record while the French TGV has eight years of revenue service. Both systems are technically mature. The ICE is in vehicle production and will be operational on West Germany's new high speed rail system within the next year. The Italian ETR 500 is in prototype production and the schedule for implementation is in the mid-1990s.

While four steel wheel-on-rail technologies were examined, other advanced steel wheel-on-rail systems could be candidates for application in Taiwan. If this type of system is selected, vehicle performance specifications should be tendered to the international market to obtain the best possible terms and conditions.

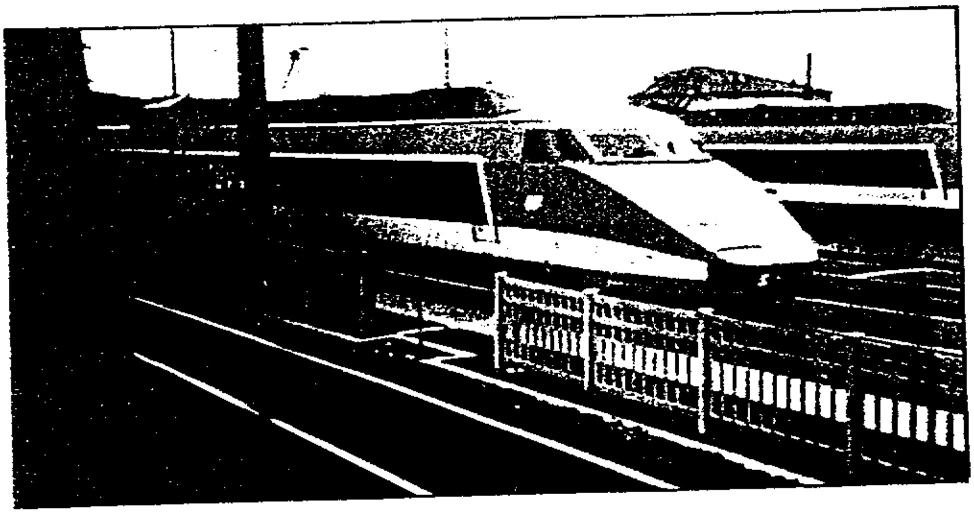
Magnetic levitation has been under development in a number of countries, with the Federal Republic of Germany and Japan at the forefront of this technology. West Germany has developed the TRANSRAPID maglev with the latest in a series of vehicles being the TR07 Europa designed for speeds up to 500 kph. The system has undergone extensive testing on a 31 kilometer guideway facility and in December 1989 attained a speed of 435 kph. TRANSRAPID has no system in revenue service although there are several locations in the United States of America and elsewhere where application of this technology is under consider-



WEST GERMANY: INTERCITY EXPRESS (ICE)



JAPAN: SHINKANSEN - SERIES 100



FRANCE: TGV (TRAIN A GRANDE VITESSE)

ation. In December 1989, the government of the Federal Republic of Germany approved construction, pending finalization of the financial package, of a maglev line between the Cologne/Bonn Airport and the Dusseldorf Airport.

The Japanese maglev, the MLU 002, has been tested on a 7 kilometer guideway facility but also has no system in revenue service or plans for a revenue service system at this time. A 40 kilometer double-guideway will be constructed to test their next generation of vehicle, the MLU 00X1. The Japanese maglev is not projected to be ready for commercial application until after the mid-1990s.

With no maglev system tested in daily revenue service, there is risk and uncertainty with regard to the application of the system in Taiwan. If a high speed rail system in the West Taiwan Transportation Corridor is not implemented until a maglev system is fully tested in revenue service and considered mature, the potential use of this technology should be reevaluated. However, the near-term implementation of a high speed rail system should utilize the proven steel wheel-on-rail technology.

5. CAPITAL COST AND OPERATIONS AND MAINTENANCE COSTS

The capital cost of a high speed rail system was estimated based on the conditions in Taiwan. These conditions include local construction costs, the potential of earthquakes and typhoons, heavy rains, numerous fault lines and generally poor soil conditions. All of these conditions increase the cost of construction.

Measures to minimize the impact of a high speed railway on the population in the West Taiwan Corridor include: the use of elevated structures to reduce severance and disruption of drainage and irrigation systems; tunneling in densely populated areas; and noise barriers at special locations and in the populated areas. These measures also increase capital cost.

The capital cost for steel wheel-on-rail on the Mountain alignment using Taipei Main Station, was estimated as NT$ 279 billion in 1989 NT$.

In Taipei, it is recommended that the high speed rail system use the TRA tracks and platforms in Taipei Main Station. Access to the station will be via the existing and proposed TRUPO tunnels on dual-gauge track shared by TRA and high speed rail. For the capital cost estimate, the TRUPO tunnels were considered a sunk cost, and costs for high speed rail in the tunnels included the dual-gauge track and systemwide (signals, communications and electrification) requirements.

Operations and maintenance (O&M) costs were estimated at NT$ 6 billion per year in 1989 NT$. This amount provides for personnel salaries, administration, the operation of trains, stations, and maintenance facilities as well as the maintenance of vehicles, track, structures and facilities.

For the steel wheel-on-rail option, the ratio of annual revenue to O&M costs in year 2011 is four to one. Once the system starts operations, it will be self-sustaining and require no government subsidies subsequent to the initial capital grant.

6. PRELIMINARY ENVIRONMENTAL ASSESSMENT

Any new transport system in the West Taiwan Corridor will impact the environment. Railways with their narrow right-of-way and electrification have less impact than other systems, such as freeways and highways, in terms of land take and pollution.

The environmental impacts of high speed rail systems were analyzed for the alignments and technologies. Considerations included:

- Noise and vibration
- Visual impact
- Land take
- Severance
- Safety
- Electromagnetic interference
- Energy consumption
- Construction impacts
- Mitigation measures

With regard to the high speed rail technologies, steel wheel-on-rail and maglev, there was very little difference between the systems in terms of impact. Both systems will generate noise at about the same level at their respective top speeds. The noise levels of the systems will be lower at the low-speed approaches to stations. On balance, there is no basis to favor one system over the other on environmental grounds.

Both alignments will have impacts with regard to noise, visual intrusion, land take and severance. These impacts can be mitigated to a large degree by noise barriers, landscaping, use of elevated structures and the selection of the alignment. The stations in Taipei City and Kaohsiung are underground which essentially eliminates impact in these cities. Other stations in the West Taiwan Corridor have been located to serve the major population centers while minimizing the impact on the developed urban areas.

Both alignments serve development plans equally well. The conclusion of the environmental assessment is that there are equal environmental impacts using either vehicle technology and that from an environmental viewpoint the Mountain alignment is slightly favored over the Central alignment.

7. FINANCIAL / ECONOMIC EVALUATION

The benefits of a high speed rail system to Taiwan include: significant reduction in travel time compared to other surface modes; a reduction of traffic on the freeway(s) and provincial highways; the transfer of a significant number of bus passengers to high speed rail, thereby reducing the number of buses on the road (in 2011, an estimated 2,400 bus trips per day will be eliminated); and provision in the West Taiwan Corridor of an alternative means of reliable transportation which is fast, comfortable, efficient and non-polluting.

The financial and economic analysis was performed for the two technologies, steel wheel-on-rail and maglev, on the Mountain and Central alignments for a total of four options. These options were evaluated using a comprehensive evaluation methodology which incorporated the relevant factors identified during the course of the study. To these quantifiable factors, "risk and uncertainty" was added to consider the potential inaccuracies of long range projections and to measure the difference in maturity of the steel wheel-on-rail and maglev technologies. The evaluation results were that the steel wheel-on-rail technology on the Mountain alignment is preferred over the other options by a wide margin.

Steel wheel-on-rail on the Mountain alignment (Option 1) was then reevaluated and refined with regard to: capital cost; scheduling of expenditures; the addition of a modest amount of non-operating revenue; recalculation of residual value; and modification of the depreciation schedule. With these refinements, Option 1 was renamed Revised Option 1 - the preferred technology and alignment.

The financial and economic indicators for Revised Option 1 are:

- Financial Internal Rate of Return: 5.0%
- Economic Internal Rate of Return: 7.8%
- Net Present Value, 2001: NT$ -5.0 billion
- Required Capital Grant: NT$ 117 billion

The financial results are not surprising as very few new rail systems are financially viable. In this instance, the capital grant will provide a high speed rail system which, when revenue service starts in 2001, will start to repay the design and construction loans as well as cover all O&M costs.

The proposed funding structure for Revised Option 1 in 1989 NT$ would comprise:

- A government capital grant of NT$ 117 billion or 42% of the capital cost.

- A government equity investment of NT$ 18 billion or 6.4% of the capital cost.

- A private sector equity investment of NT$ 5 billion or 1.8% of the capital cost. This investment could come from developers and construction interests and possibly from local governments where stations will be located.

- Supplier credits, government-to-government soft loans as well as loans from international lending agencies to fund equipment and other costs of NT$ 63 billion or 22.6% of the capital cost.

- Loans in the amount of NT$ 76 billion or 27.2% of the capital cost. The source of these funds could be bank loans or public bond issues.

With the capital grant and equity from the government, there would be no further requirement for government funds. The balance of the required financing would be provided by the private sector and other sources. Under this funding structure, the payback year for all financing (excluding the capital grant) is projected as 2014. Other funding scenarios are possible which could reduce the capital grant and extend the payback year.

The capital investment requirements are significant. However, from the start of revenue service the high speed rail system will be a self-supporting entity. In the initial year of revenue service, 2001, annual revenue based on a low staggered fare is projected to be NT$ 16.5 billion (1989 NT$) with administration and O&M costs estimated at NT$ 4.4 billion (1989 NT$). This ratio of revenue to cost is 3.7 and by 2011, with increased ridership, the annual revenue is projected to be NT$ 26.8 billion with operations and maintenance costs of NT$ 6.1 billion or a 4 to 1 ratio.

These ratios demonstrate a viable railway from the initial year of operation.

8. IMPLEMENTATION

The initial milestone is the government's decision to implement a high speed rail system. The next step is to establish the organization for the management, ownership and operation of the system.

The study analyzed five scenarios presenting potential arrangements and relationships for management, ownership and operation of the high speed rail system. The most feasible of the scenarios is Central Government management and ownership. The institutional arrangement would include the establishment of a Central Railway Authority or similar agency under the Ministry of Communications.

The Central Railway Authority (CRA) would manage and operate the high speed rail system and the Taiwan Railway Administration. With both railway systems under one agency, coordination and control of day-to-day operations would be facilitated. Administrative functions common to both systems could be combined under the CRA for cost effectiveness.

For high speed rail, the initial requirement for the CRA would be to organize and implement the planning, design and construction. For this phase, estimated to last ten years, it is recommended that the services of a General Consultant (GC) be retained. The GC under the authority of the CRA would direct and coordinate the activities and architectural/engineering disciplines required for a project of this size and complexity. The GC would be responsible to insure the government's requirements are satisfied and the project is completed on time, within budget and to the specified quality standards.

The initial years of the ten-year design and construction program will concentrate on planning, design and, most important, acquisition of property for the right-of-way, stations and other facilities. A design schedule is shown in Table 8-1.

Construction elements of long duration, such as tunnels, will start as early as possible in the program with the heavy construction concentrated primarily in the middle years. Station construction, installation of systemwide facilities, construction of yards and maintenance facilities will start about the mid-point of the construction phase and continue almost to the end of the project period. A construction schedule is shown in Table 8-2.

One of the final activities in the design and construction period will be the testing of vehicles and systems to insure they function as required and operate in a fail-safe manner.

The final step prior to revenue service will be inspection and acceptance of the system by the Government of the Republic of China.

9. CONCLUSIONS

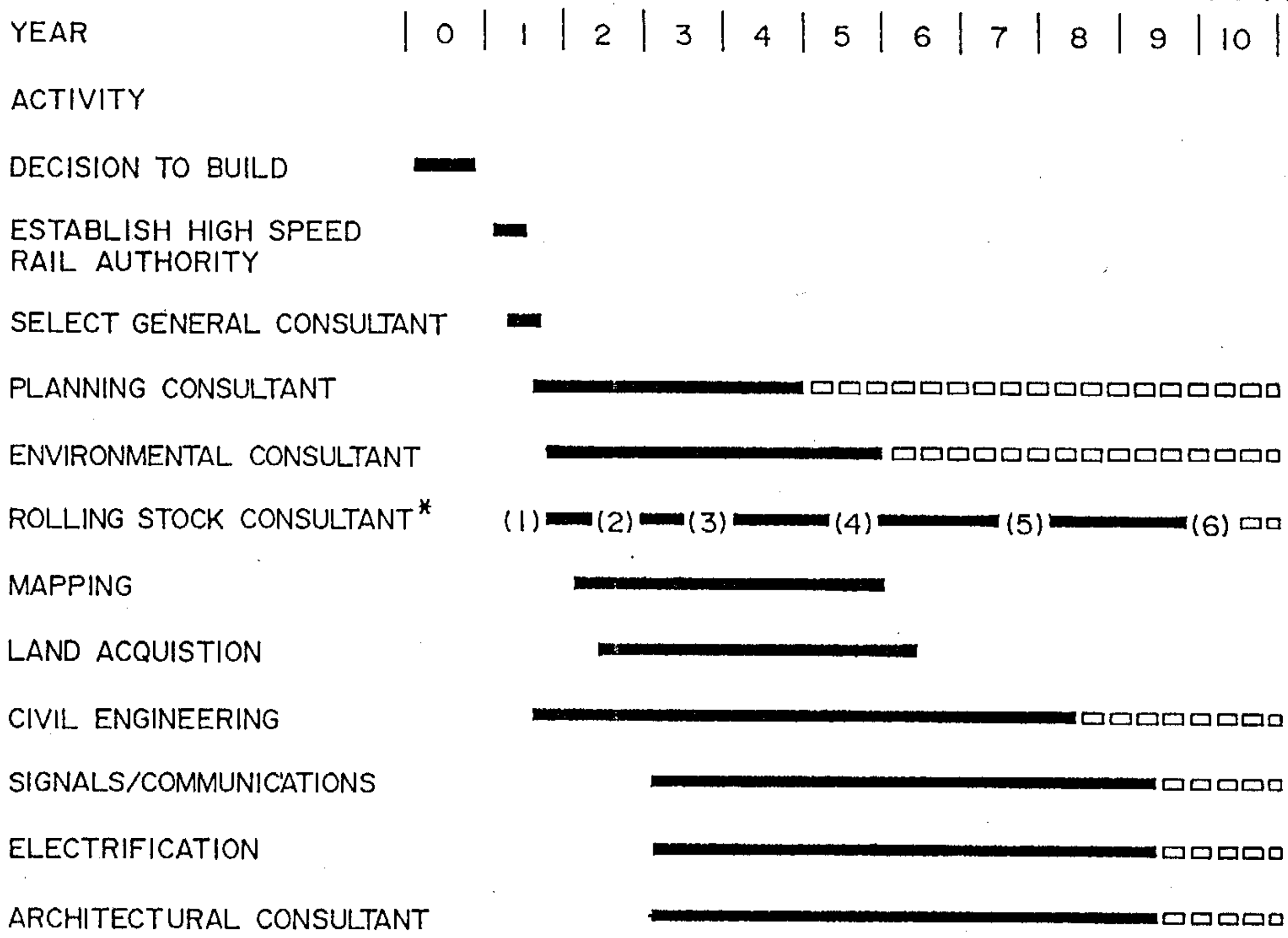
The objective of the West Taiwan High Speed Rail Feasibility Study was to analyze the requirements and potential for a high speed rail system.

The steel wheel-on-rail high speed rail technology is a mature system proven in revenue service.

The Mountain alignment is favored based on cost and environmental considerations. Between Taipei and Kaohsiung, five intermediate stations were selected.

Table 8 - 1

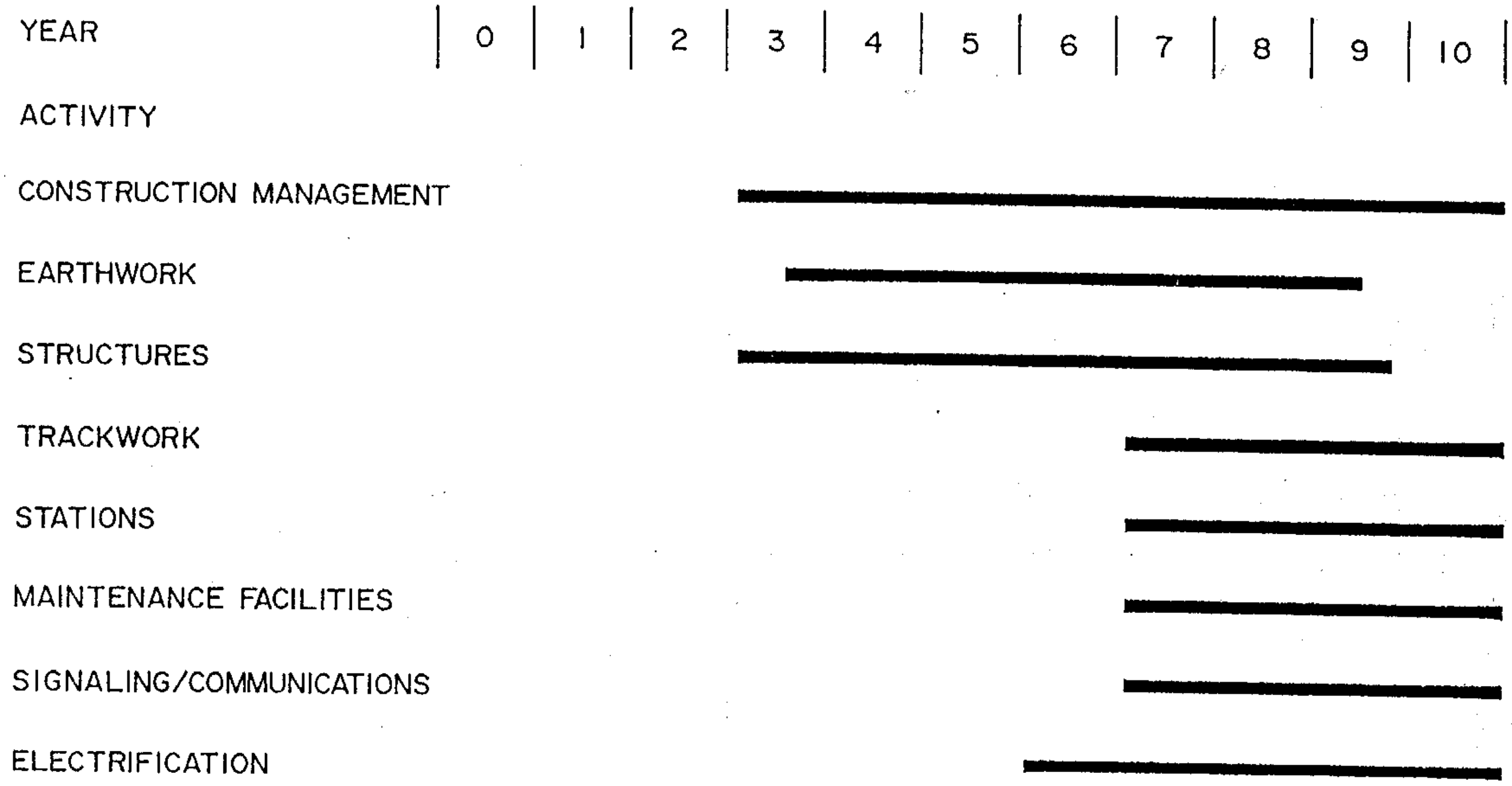
DESIGN SCHEDULE WEST TAIWAN HIGH SPEED RAIL SYSTEM



*NOTES: ROLLING STOCK: 1) PREPARE PERFORMANCE SPECIFICATIONS; 2) SELECT MANUFACTURER; 3) DESIGN MODIFICATIONS; 4) BUILD PROTOTYPE; 5) MANUFACTURE VEHICLES; 6) TEST VEHICLES / SYSTEMS: ▭▭▭ REDUCED STAFFING: ▬▬ FULL STAFF

Table 8 - 2

CONSTRUCTION SCHEDULE
WEST TAIWAN HIGH SPEED RAIL SYSTEM



The capital cost of the system is estimated at NT$ 279 billion (1989 NT$) based on using the Mountain alignment and Taipei Main Station. In the design phase, the capital cost will be adjusted based on detailed information.

Any new transport system in the West Taiwan Corridor will have negative environmental impacts. Of the potential transportation systems, high speed rail properly designed with mitigating measures for noise, visual impact, severance and land take will be the least intrusive of the potential systems.

The financial and economic considerations have been evaluated with the conclusion that under the optimum scenario, a capital grant of NT$ 117 billion would be required. This capital grant would insure that the high speed rail system would be able to repay the balance of the capital cost as well as maintain an excellent ratio of revenue to operating expenses.

A comprehensive evaluation was conducted to evaluate all the factors studied: ridership, capital cost, operations and maintenance costs, vehicle technology, alignments, and environmental impacts. The result of the evaluation was the selection of a steel wheel-on-rail system on the Mountain alignment over the other alternatives by a considerable margin.

An implementation plan was developed to include proposed institutional arrangements for ownership and management of the high speed rail system. It is proposed that the Central Government own and operate the high speed rail system and TRA. The plan sets forth an arrangement to finance the implementation of the system. An organization to manage the design and construction is proposed and preliminary schedules for design and construction were developed.

The findings of the study is that the Republic of China should implement a high speed rail system between Taipei and Kaohsiung.